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GEOLOGICAL SURVEY OF GEORGIA

DEPARTMENT OF FORESTRY AND GEOLOGICAL DEVELOPMENT

RICHARD W. SMITH, State Geologist

BULLETIN NO. 46

KYANITE AND VERMICULITE DEPOSITS OF GEORGIA

By

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With Contributions by W. D. Johnston, Jr., Geoffrey W. Crickmay, B. W. Gandrud and Richard W. Smith

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Prepared in Cooperation with the U. S. Geological Survey and the U. S. Bureau of Mines

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Georgia Department of Forestry and Geological Development

IN THE YEAR 1934

HIS EXCELLENCY, EUGENE TALMADGE, Governor of Georgia,
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LETTER OF TRANSMITTAL

GEOLOGICAL SURVEY OF GEORGIA,
DEPARTMENT OF FORESTRY AND GEOLOGICAL DEVELOPMENT,
ATLANTA, DECEMBER 28, 1934.

To His Excellency, EUGENE TALMADGE, Governor and Chairman of the Georgia Commission of Forestry and Geological Development.

SIR: I have the honor to transmit herewith for publication a report on the Kyanite and Vermiculite Deposits of Georgia by Louis M. Prindle, W. D. Johnston, Jr., G. W. Crickmay, B. W. Gandrud, and Richard W. Smith. This report is the result of field work conducted in the summer of 1934 by the United States Geological Survey, in cooperation with the Geological Survey of Georgia and the United States Bureau of Mines, under funds granted by the Public Works Administration.

The romance of research and applied science that lies behind the recent commercial uses of kyanite and vermiculite is little known to the general public. Years of quiet experimentation have developed important uses for these minerals which have long been known to occur in Georgia although the extent of the deposits was not known. This investigation was undertaken, at the request of the State Geologist, to determine if possible the extent and commercial possibilities of these minerals in Georgia. It resulted in the discovery of important deposits of kyanite, described herein, which should prove a source of income to Georgia for years to come. Sufficient funds were not available to make an extensive search for vermiculite. The deposits described are of doubtful importance, but the descriptions of the mode of occurrence will aid in the search for better deposits.

Very respectfully yours,

RICHARD W. SMITH,
State Geologist.

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KYANITE AND VERMICULITE DEPOSITS OF GEORGIA

by Louis M. Prindle[1]

INTRODUCTION

Man has always striven to make the materials of the earth increasingly useful. Among these materials, rocks, minerals, and metals have played a fundamental part. The story of man's work with minerals, from the fashioning of the first arrowhead to the modern production from mine, quarry, factory, and studio, forms a moving picture that shows vividly the continuity of progress in improving the conditions of existence and teaches that such progress will proceed unceasingly toward a still brighter future.

With this story as a background and a broader appreciation of the materials of the world he lives in, man is studying more carefully the nature of minerals and their possible uses in industry. He is becoming mineral-minded.

Minerals that were formerly of interest mainly for their beauty or their composition and distribution in the rocks gradually came under the scrutiny of research and were found to be useful for many purposes. The development of higher-temperature furnaces has demanded fire brick that could withstand the higher temperatures. New kinds of porcelain were found necessary to enable spark plugs to survive the furious attacks of electric discharge to which they are exposed. The ceramic arts are thus demanding for their uses special qualities that certain minerals possess. Some of these minerals, among them kyanite [sometimes spelled *cyanite*], are found in Georgia, and vermiculite, useful for insulation, decorative paints, etc., also occurs there.

Through the efforts of the State Geologist and the cooperation of the United States Geological Survey a field party consisting of the writer, assisted by Mr. C. F. Greene, of Georgia, studied the deposits of kyanite and vermiculite in north Georgia in the summer of 1934 under an allotment of Public Works funds. In 3 months of field work it was found that many localities could not be visited and that only cursory studies could be made of others.

The outstanding fact that emerged from the season's work is the presence in north Georgia of a belt of kyanite schist 30 miles long that contains large reserves of kyanite. This report describes these deposits and also the deposits of vermiculite.

The deposit of kyanite at Graves Mountain, in eastern Georgia, was visited by W. D. Johnston, Jr., of the United States Geological Survey, and his results are included.

[1]Associate Geologist, U. S. Geological Survey.

The wide distribution of kyanite in Georgia is emphasized by the occurrence of kyanite in Upson, Talbot, and Fulton counties, visited and described for this report by Geoffrey W. Crickmay, Assistant State Geologist of Georgia.

Several hundred pounds of material, including kyanite schist, crystals of kyanite, and massive kyanite, was shipped to the Southern Experiment Station of the United States Bureau of Mines at Tuscaloosa. A preliminary statement of the results of studies of this material is included.

The index map (fig. 1) shows the distribution of the areas, parts of which were studied. The sketch map of Habersham and Rabun counties (pl. 1) is based largely on the maps of these counties published in the county soil reports of the United States Department of Agriculture. The maps of the Dahlonega, Ellijay, and Tate quadrangles published by the United States Geological Survey served as a base for the work farther west (pl. 7, fig. 2). There were also available the maps of the Nantahala and Cherokee National Forests by the United States Forest Service. The results shown on the sketch maps are only approximately correct, and much geologic field work is necessary before the many geologic problems arising in this region can be satisfactorily solved. There has been no opportunity for petrographic studies. Attention was directed primarily to the occurrence of kyanite and its relation to the economic development of the region.

Acknowledgment is gratefully extended to the kindly people who live among the beautiful hills of north Georgia, for their constant readiness to further the work in any possible way.

ALUMINOUS MINERALS

Aluminum is the most common metal in the earth's crust but is found only in combinations in different minerals, such as the feldspars, micas, and clays, and as the oxide in corundum.

Kyanite, sillimanite, andalusite, and corundum have been called "the four faithful companions." They have characteristics in common; all are compounds of aluminum, all but corundum have the same composition, all are useful for similar purposes, and in many places all four occur together.

Kyanite occurs usually in long-bladed or platy crystals and crystal aggregates. The color varies from white and light gray to blue, grayish blue, and greenish blue. Many of the crystals are blue in the center and white along the edges. The cleavage is perfect in one direction and less perfect at right angles to this. In the third direction the mineral has a parting. The most characteristic feature aside from its appearance is its hardness, which is 4.5 parallel to the length of the crystals and 7 perpendicular to the length. This means that a knife-blade will easily scratch kyanite parallel to the long way of the crystal but not across the crystal. As its specific gravity is about 3.6 it is considerably heavier than quartz (about 2.65). It crystallizes in the tri-

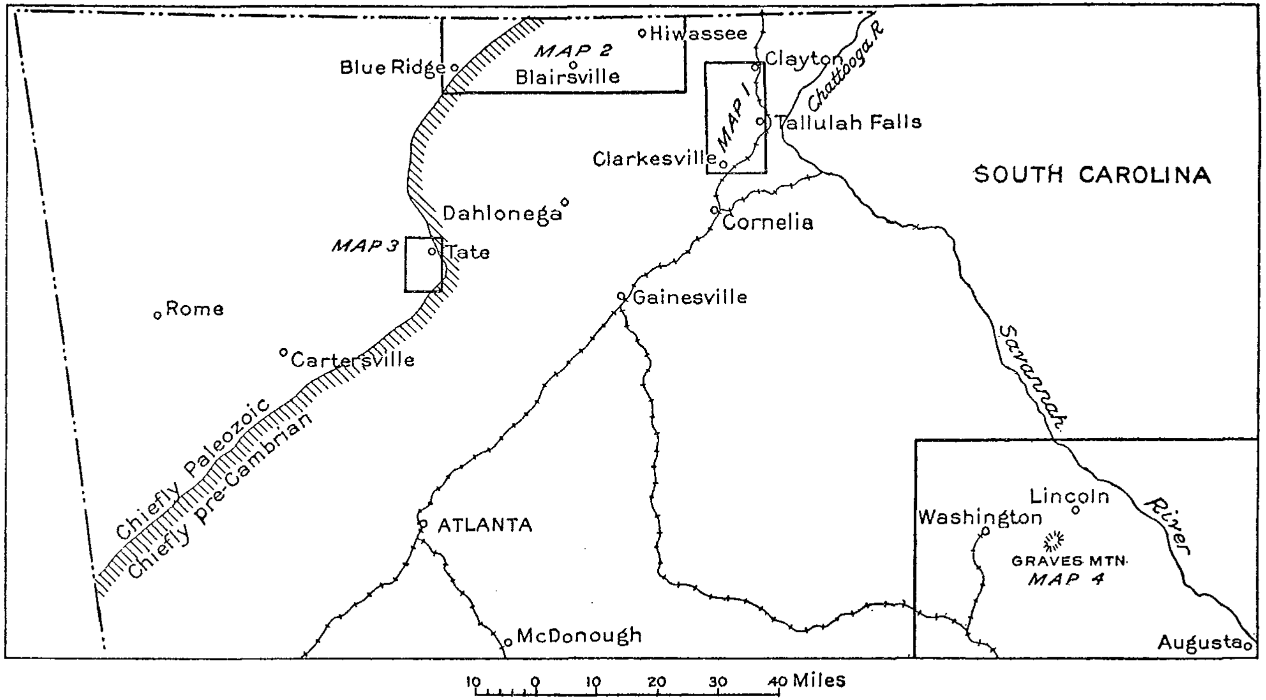


Fig. 1.—Index map showing location of areas shown on plates I and VII [map 2], and text figures 3 and 4.

clinic system. The characteristic appearance of kyanite in several of its occurrences is shown in plates II, III, and VI.

Sillimanite, which, according to Dana,[1] crystallizes in the orthorhombic system, occurs commonly in long, slender crystals not distinctly terminated, often in close parallel groups, passing into fibrous and columnar massive forms, locally radiating. It has a very perfect cleavage, and uneven fracture, and a vitreous luster. Its hardness is between 6 and 7, and its specific gravity 3.23. Its color is brown, grayish brown, grayish white, or greenish, and it is transparent or translucent. Some compact varieties were used for making utensils and implements by prehistoric man in western Europe. In the region examined it accompanies the kyanite in some occurrences (see pl. IX) but is nowhere abundant.

Andalusite, as described by Dana, is also orthorhombic. It usually occurs in coarse, nearly square prismatic forms but may be massive, imperfectly columnar, radiated, or granular. It has cleavage more or less perfect in three directions and an uneven fracture. It is brittle and has a vitreous luster, often weak. Its hardness is 7.5, and its specific gravity 3.16 to 3.20. Its color is whitish, reddish, violet, grayish, greenish, or brownish, and it is usually subtranslucent.

Corundum, of which the ruby and the sapphire are the most beautiful expression, found its earliest use as gems. Ranking next to diamond in hardness, corundum in the less pure form of emery was found to be so useful for abrasive purposes that deposits in different parts of the world were rapidly developed. Valuable deposits were discovered in North Carolina[2] and Georgia.[3] Corundum has been found at many localities in Georgia, and the mine on Laurel Creek, about 11 miles east of Clayton, in northeastern Georgia, was once one of the great corundum mines of the country. The mineral has not been mined in the United States since 1918, so far as Government records show. As a small tonnage of imported corundum, chiefly from South Africa, is used each year, there has been some interest in the development of domestic deposits. Such an enterprise must face competition from artificial abrasives, in the development of which much progress has been made in recent years.[4]

Kyanite, sillimanite, and andalusite have the same chemical composition (Al_2O_3 63.2 per cent, SiO_2 36.8 per cent) and undergo similar transformations when subject to high temperatures.[5]

[1]Dana, E. S., A system of mineralogy, 6th ed., New York, 1914.

[2]Pratt, J. H., and Lewis, J. V., Corundum and the peridotites of western North Carolina: North Carolina Geol. Survey, vol. 1, 1905.

[3]King, F. P., A preliminary report on the corundum deposits of Georgia: Georgia Geol. Survey Bull. 2, 1894. Pratt, J. H., Corundum and its occurrence and distribution in the United States: U. S. Geol. Survey Bull. 269, 1906.

[4]Bowles, Oliver, and Davis, A. E., Abrasive materials: U. S. Bur. Mines, Minerals Yearbook, pp. 901–903, 1934.

[5]Bowen, N. L., and Greig, J. W., The system Al_2O_3 SiO_2: Am. Ceramic Soc. Jour., vol. 7, pp. 238–254, 1924. Greig, J. W., Formation of mullite from cyanite, andalusite, and sillimanite: Idem, vol. 8, pp. 465–484, 1925.

Corundum has the composition Al_2O_3 and would be suitable for the manufacture of heat-resisting products and metallic aluminum if found sufficiently pure in commercial quantities. In its more abundant form, emery, it contains too much iron for such use.

INDUSTRIAL USE OF KYANITE, SILLIMANITE, AND ANDALUSITE

Until a few years ago kyanite had no commercial value and was of scientific interest chiefly because it is the only common mineral that is much softer in one of its crystallographic directions than in others. Now it gives promise of considerable industrial use if cheap methods of concentrating it from its enclosing rock can be devised and if suitable means of utilizing its heat-resisting properties can be worked out.

According to Smith[1] it was noted in 1908 that most porcelains when examined under the microscope show interlocking needlelike crystals that resemble the natural mineral sillimanite. Later these crystals were found to differ slightly from sillimanite and were named "mullite."

About 1917 ceramists of the National Bureau of Standards were given the problem of developing a better spark-plug core. Cores that would better resist sudden changes in temperature and high heats were necessary for airplane motors for war use. They decided to experiment with sillimanite, but, because of the scarcity of the natural minerals of this group, synthetic sillimanite was prepared by calcining clay and artificial alumina. This synthetic sillimanite was deliberately incorporated into a porcelain body in a quantity larger than it would have been possible to develop from the clay contained in the body. It was used as a substitute for other ingredients, especially quartz or potter's flint. The addition of the sillimanite calcine and the firing to a temperature high enough to develop mullite in the clay resulted in a body with a mechanical strength two to four times as great as normal porcelain. It also improved heat-shock resistance and made a much better spark-plug core. Other studies showed sillimanite to be constant in volume and to possess characteristics that would be beneficial if it were used as an ingredient in refractories subject to high-heat duty. Fire brick made from sillimanite bonded with clay outlasted all other types. The high heat to which they were subjected seemed to increase the network of mullite crystals and therefore their strength.

The successful use of synthetic sillimanite caused manufacturers to search for the natural mineral in commercial quantities. Obviously a suitable natural mineral would be less expensive and more stable than the artificial substitute. The officials of one company manufacturing spark plugs searched through the mineralogic literature, following up every possible lead with systematic prospecting, and finally located a large deposit of andalusite high in the mountains of California near the

[1]Smith, R. W., Kyanite, vermiculite, and olivine in Georgia: Georgia Dept. Forestry and Geol. Devel., Information Circ. 3, 1934.

Nevada line. This is probably the only deposit of andalusite in commercial quantities thus far discovered. Natural sillimanite is even more scarce. Only a few small outcrops have so far been found in the United States, chiefly in South Dakota. Large but rather inaccessible deposits have been found in India. Sillimanite and andalusite possess an advantage in having no appreciable change in volume when they are converted to mullite on heating to about cone 12 to 13 (1,310° to 1,350° C., 2,390° to 2,465° F.). This makes it possible to use them without previous calcination and has the tendency to form a better bond of interlocking mullite crystals in the finished product.

Kyanite, when calcined to about cone 12 or 13, expands considerably, principally in the long direction of the crystals, and the original specific gravity (3.6) drops to that of a mixture of mullite and glass (3.1). The calcined material is friable and more difficult to bond than raw andalusite. For these reasons kyanite is not as satisfactory for some purposes as andalusite. Experiments show that it can be used satisfactorily, however, in the manufacture of refractories for uses requiring extremely high heat resistance and low coefficient of expansion. Material now being shipped from Georgia, as shown below, is finding use in this way.

KYANITE

GENERAL OCCURRENCE IN GEORGIA

The kyanite deposits of Georgia have been described by Smith as follows:[1]

"The kyanite deposits of Georgia are of two types—(1) loose [separate] crystals embedded in micaceous kyanite-staurolite-garnet schists and (2) crystal aggregates associated with quartz in small and very irregular veins. The last type at first sight would appear to be the best source of supply. Large boulders or donnicks of kyanite with more or less quartz are found on the surface at places through the Piedmont Plateau and the mountains of Georgia, but so far prospecting has failed to disclose a sizable vein at any of these places. It seems likely that these donnicks may be a surface accumulation from small veins or miniature lens-shaped masses not over a foot in thickness and with a horizontal extent of not more than a few feet. The larger surface accumulation of kyanite donnicks may prove to be marketable, but it now appears doubtful if a vein large enough to mine will be found. Deposits of this type have been noted near Woodland, in Talbot County; northwest of Carrollton, in Carroll County; in the northwestern part of Habersham County; in the Gumlog district of Union County; in Fannin County north of Hemp, on Hothouse Creek, and near Sugar Creek; in the Boardtown district of Gilmer County; near Refuge Church, in Pickens County; and west of the Louisville & Nashville R. R. between Keithsburg and Ball Ground, in Cherokee County."

Each of these types may be regarded as having two subtypes, dependent on the processes of weathering and transportation. If weathering alone has been the active agent, residual deposits have been produced; but if transportation has also come into play, placer deposits have been formed.

Residual and placer deposits are now being actively worked on a small scale, as described on pages 11 and 15. These sources, however,

[1] Smith, R. W., op. cit.

are subject to early depletion if worked on a larger and more intensive scale. The kyanite deposits in the micaceous schists above mentioned constitute the principal resource upon which any enduring or long-lived kyanite industry in Georgia must be based. The present investigation was therefore directed chiefly to the mapping and study of these schists, to determine, so far as practicable, both their distribution and their relative richness in kyanite. In the time available it was possible for the writer to examine only three general areas,—(1), Habersham and Rabun Counties, (2) Towns, Union, and Fannin Counties, and (3) Pickens and Cherokee Counties. The contributions by W. D. Johnston, Jr., and G. W. Crickmay serve to round out the report by providing information about additional areas. Samples were collected of several representative deposits for beneficiation tests by the United States Bureau of Mines, the preliminary results of which are given on pages 40-41.

KYANITE DEPOSITS OF HABERSHAM AND RABUN COUNTIES

RELIEF AND DRAINAGE OF AREA

Two types of country predominate in the area included in Habersham and Rabun Counties—an upland region and a highland region. The upland is part of Piedmont Georgia, with an average altitude above sea level of about 1,400 feet. The surface is undulating, with a rather level sky line, and the valleys are narrow and inconspicuously sunk beneath the general level. This is the type of country in the vicinity of Clarkesville.

From this upland surface near Clarkesville can be seen a magnificent panorama toward the north and west, where the highlands of the Blue Ridge present to the beholder their long array of peaks, "balds," "knobs," ridges, gaps, and forest-covered slopes. Oakey Mountain and Stony Mountain, with the accompanying ridges, form the southern limit of the highlands and mark the boundary also between the two counties. The area south of the county line shown on the map (pl. I) is mostly upland; that to the north of it is mostly highland.

The rainfall is heavier than in most other areas of the United States, averaging in Rabun County 69.65 inches a year. There are consequently numerous small streams whose waters find their way ultimately into the Gulf of Mexico by way of the Mississippi or more directly to the Atlantic Ocean by way of Savannah River, which forms the boundary between Georgia and South Carolina. Savannah River to the east and Chattahoochee River to the west dominate the drainage, but both lie outside the area covered in this report. The principal streams of the area are Tallulah River, flowing toward the Savannah, and Soque River, flowing toward the Chattahoochee.

The most impressive drainage feature in the region is the gorge of Tallulah River. This river has been regulated by dams for the production of electric power until large portions of the valley have been transformed to Lake Rabun, Burton Lake, and other smaller lakes.

The smaller tributaries of both the Tallulah and Soque rivers have played an important part in the transportation of kyanite and its concentration in placer deposits.

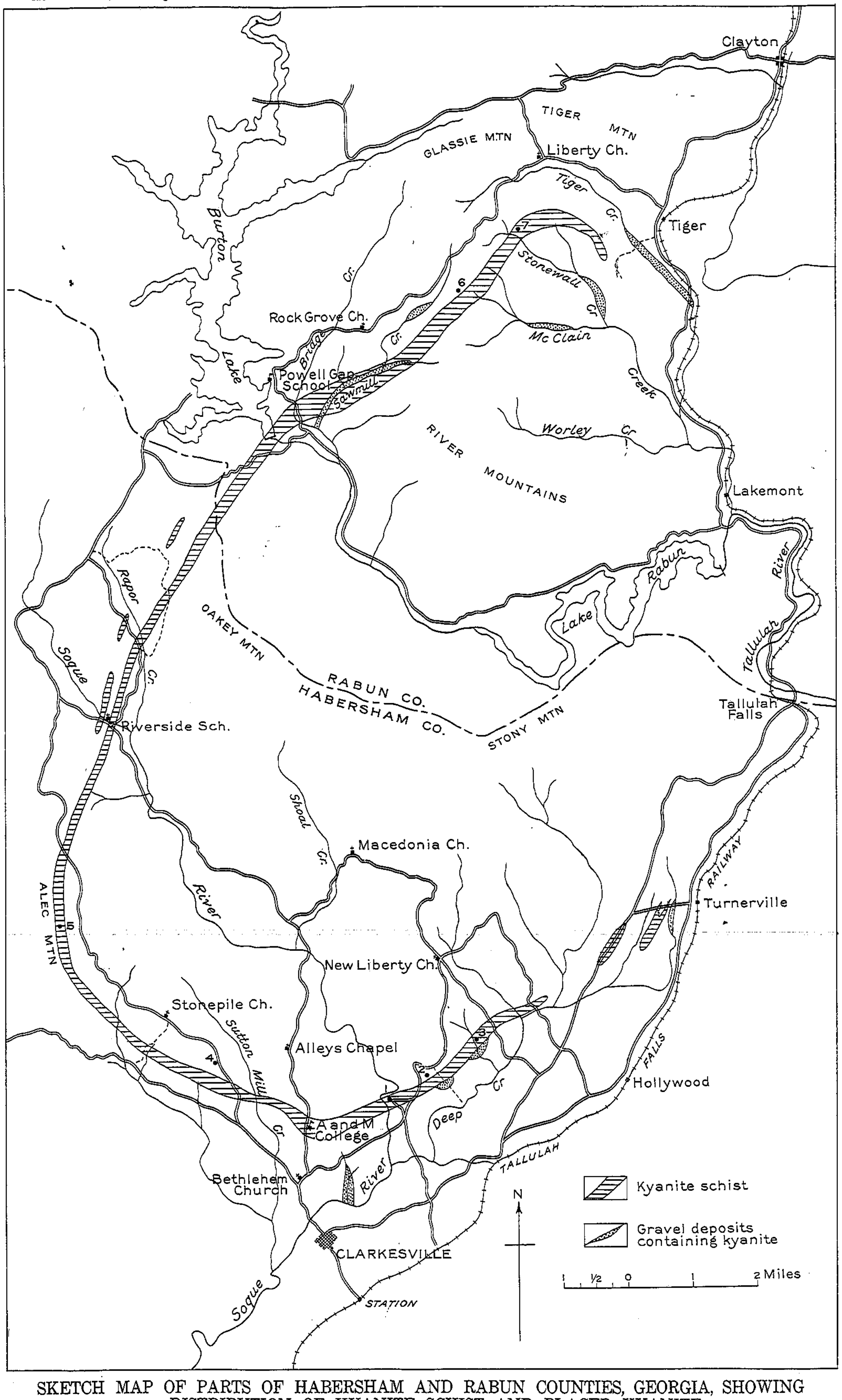
The region is served by a paved highway that extends northward from Cornelia through Clarkesville and Clayton, roughly paralleling the Tallulah Falls Railroad. Secondary roads maintained by the counties and, in the Nantahala National Forest, by the Forestry Service, give access to the kyanite deposits described below.

GENERAL GEOLOGY

If a knife is left out-of-doors and thus exposed to the effects of air and moisture, it becomes coated with oxide of iron—that is, it becomes rusty. If rocks are thus exposed a million years or so they too become rusty and decay deeply to a mass of soft material far different in appearance and character from the original rock. The iron and manganese commonly present in the rocks yield on weathering various shades of red, yellow, and black, and finally there is formed a thick mantle, much of it a vivid red due to the iron oxides present. This mantle of decomposed rock becomes conspicuous in the landscape and rests like a mask upon the fresh rock that lies far beneath the present surface.

Such is the character of much of the upland area, in which fresh rock is rare except where streams have cut deeply into it or near the ridge lines where beds of greater resistance have withstood the processes of weathering. The streams too become colored with the fine products of weathering, and during every rain each rivulet carries quantities to the larger streams. Rock decay is less evident in the highland areas, where fresh rocks and clear-water streams prevail. The presence of this product of rock decay renders it difficult to map geologic formations except where there are conspicuous and persistent differences in the original rocks.

The mud, sand, and gravel derived from the waste of the land are transported by water and ultimately reach the ocean, where they undergo a sorting action that results in beds of clean gravel, sand, or mud. All these materials after consolidation become the conglomerates, sandstones, and shales of the sedimentary rocks. The igneous rocks have had a different history. When molten lava pours out from a volcano, it forms, on cooling, volcanic rocks of various kinds. When the molten material deep within the earth migrates and penetrates other rocks and finally cools slowly, minerals have a chance to exert a force of crystallization, and a rock is formed like granite, for example, composed of quartz, feldspar, and mica, each mineral taking its place in an orderly sequence of crystallization. But both sedimentary and igneous rocks are subject to changes resulting from changing conditions—changes different from those above referred to in the weathering of rocks, changes that have taken place deep in the interior of the earth, changes that have produced new kinds of rocks from both the sedimentary and igneous rocks. They become metamorphosed.



SKETCH MAP OF PARTS OF HABERSHAM AND RABUN COUNTIES, GEORGIA, SHOWING DISTRIBUTION OF KYANITE SCHIST AND PLACER KYANITE.

The following numbers refer to some of the localities described in the text. No. 1, Sleepy Hollow; No. 2, The Kollock Home; No. 3, J. M. Inglis' Home; No. 4, The Addison Home; No. 5, The mine at Alec Mountain; No. 6, The Loven Home; No. 7, The Keson Home.

The great mass of the rocks in north Georgia are gneisses and schists of metamorphic origin. Intrusive masses of comparatively fresh granite and coarse-grained rocks composed of quartz, feldspar, and mica, classed as pegmatites, are also present. The intrusive masses of peridotite and pyroxenite are well known for the corundum associated with them.

The gneisses and schists have much in common. There is a parallel arrangement of the minerals in both, but the gneisses have in general a banded structure, whereas the schists, with a larger proportion of mica, present a wavy appearance.

The parallel arrangement of the minerals is the result of the mountain-making forces. The rocks became folded, and the folds became closely appressed, overturned, and thrust one upon the other. Older rocks were thrust westward, in places for miles, over younger rocks throughout the length of the Appalachian Mountains. The rocks became broken, crushed, and sheared. New structural features and new minerals replaced those characteristic of the original sedimentary and igneous rocks, and the gneisses and schists bear within themselves the evidences of these various changes. Their age has been regarded as pre-Cambrian.

BELT OF KYANITE SCHIST

The belt of kyanite schist approximately outlined on the map (pl. I) is the dominant feature of this report.

When the work started it was supposed that there were two beds of kyanite schist about 6 miles apart, one trending northeast toward Turnerville, and the other at Alec Mountain trending also northeast toward the highlands west of Oakey Mountain. On following the eastern belt to the southwest, however, it was found to swerve round toward the west in the vicinity of the institution locally known as the "Ninth District A. and M. College," then to the northwest, and finally to be continuous with that of Alec Mountain. In plan, then, this bed of kyanite schist forms an unsymmetrical, U-shaped body with a western limb somewhat longer than the eastern limb and a total length of about 30 miles. The underlying gneisses follow a similar course, paralleling the strike of the schists and dipping toward the outside of the U. Toward the north a similar situation prevails. The schist bends round toward the east and finally narrows and seems to end. The general structure appears to be that of a broad dome in this sequence of gneisses and schists. The width of outcrop of the schist ranges from over 100 feet to a quarter of a mile or more, depending on the attitude of the beds, the dip ranging from nearly horizontal to vertical. Where the strike changes at the A. and M. College the schists are intensely crumpled.

On the northeast side of the dome the schist seemed to diminish and was not found between Turnerville and Tallulah Falls. It was reported north of Tallulah Falls, however, and a small band of kyanite schist half a mile long was found in the area near Camp Creek, about 5 miles southeast of Lakemont, extending toward Chattooga River. This locality is beyond the limit of the area mapped.

Kyanite is produced from two localities in this belt in the vicinity of Clarkesville. On Alec Mountain near the Piedmont Orchards, 6 miles northwest of Clarkesville, kyanite is recovered from the decomposed surface portion of mica schist similar to the schist shown in pl. II. A mile northeast of Clarkesville kyanite is recovered from stream gravel. This is the only placer mine of kyanite known to the writer. About half a mile north of the placer mine is a belt of mica schist similar to that of Alec Mountain and striking northeast parallel with it.

BEDROCK DEPOSITS

The principal kyanite deposits of the area are the relatively low grade kyanite mica schists that occupy the belt just described. No sharp boundary can be distinguished between the kyanite schists and the adjoining rocks. The largest crystals occur in the middle part of the belt. In places there are subordinate beds of schist with kyanite separated from the main bed by micaceous quartzites. One of these west of Riverside School is shown on the map. The thickness of the kyanite-bearing schists, so far as observed, ranges from 30 to 60 feet. The crystals are not uniformly distributed through the entire thickness. Beds a few inches thick and crowded with crystals alternate with beds of equal thickness where the crystals are more sparsely distributed, but in general the proportion of kyanite appears to be fairly persistent throughout.

RESIDUAL DEPOSITS

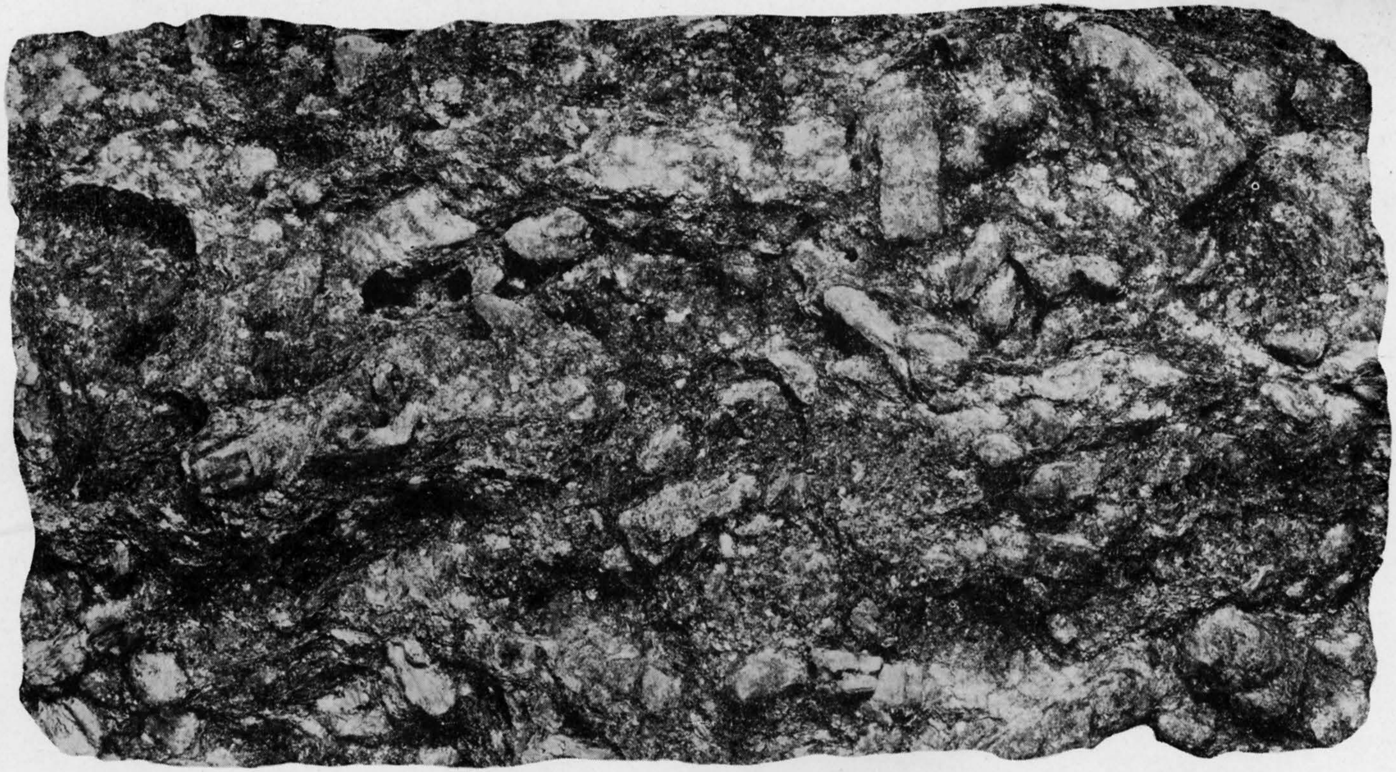
The residual deposits accompany the bedrock deposits and afford a means of tracing the main belt across country. The loose crystals strewn thickly over the surface of the ground glisten in the sunlight along the roads and in the fields and lie heaped in the hollows of the mountain trails.

The schist became disintegrated during the long process of weathering, and the minerals composing it became detached and subject to removal by transportation agencies. Water began to carry the lighter material away, and kyanite, being of higher specific gravity, tended to lag behind. Through this process of selective removal, similar to that employed in the placer mine, there was formed this accumulation of loose crystals so conspicuous throughout the belt of kyanite schist.

PLACER DEPOSITS

The persistent streams, acting over long periods of time, have carried away much of the residual kyanite and deposited it in placers.

The history of the drainage of this upland region is complicated. Long ago the streams followed very different courses, as is shown by the fact that water-worn gravel is found in places on the upland surface high above the level of the present streams, abandoned there by some preexisting drainage system that had little relation to the present drainage. It is shown also by other gravel deposits more closely related to the present streams but still about 30 feet vertically above them. Some of the gravel contains quartz boulders as much as 2 feet in diam-



KYANITE SCHIST FROM RIDGE SOUTH OF TIGER CREEK. RABUN COUNTY, SHOWING DISTRIBUTION OF THE CRYSTALS IN THE SCHIST. NATURAL SIZE.

eter and a large proportion of cobbles. All these indicate much activity in those streams. Kyanite is present not only in the gravel of the present streams, but in that about 30 feet above the present streams and in the still higher gravel whose drainage relationships are shrouded in obscurity. The kyanite crystals in this natural process of transportation become freed to a large extent from remnants of quartz and mica that may still have been adhering to them, and when they have undergone repeated scrubbings of this sort they are not only cleaned but somewhat rounded. The locations of the placer deposits identified by the writer are shown on plate I. It is likely that others will be disclosed by more careful search.

EASTERN PORTION OF KYANITE BELT

EXPOSURES AT A. AND M. COLLEGE

Crystals of kyanite are strewn along the highway opposite the A. and M. College for a quarter of a mile and are also thickly distributed over the college yard and the adjacent lands. The schist crops out also at the college and again along the road east through the corn fields of the college farm. These outcrops show the kyanite in the bedrock and can be followed over the fields and through the woods to Soque River.

A few hundred feet west of the A. and M. College along the road, near a schoolhouse, there is a fine exposure of schist containing kyanite, and the school yard is strewn thickly with the crystals. The schist is closely crumpled but a short distance farther west begins to show a definite trend toward the northwest. The width of the belt is about 300 feet. Near the base of the slope in the rear of the schoolhouse the gneisses below the schist strike N. 50° W., paralleling the strike of the schist, and dip 35° SW.

PLACER ON W. E. BLACK PROPERTY

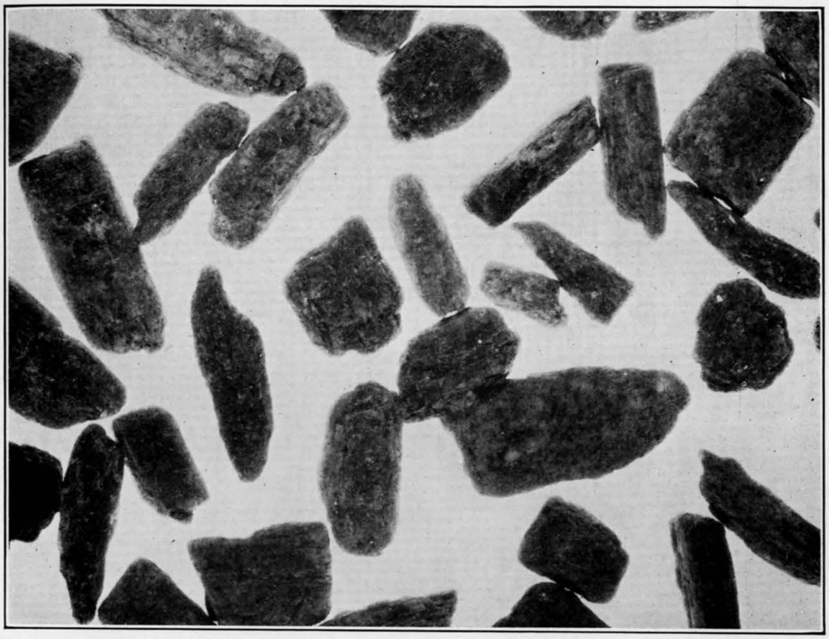
A small stream about a mile long heads in the area half a mile east of the A. and M. College, flows south, and enters Soque River a mile above the bridge at Clarkesville. The valley, about half a mile above the mouth, is limited on the west by the rather steep slope of a ridge less than 50 feet high. This ridge extends southward, tonguelike, from the main upland surface toward the valley floor of Soque River. East of the small stream is a flat about 200 feet wide beyond which the ground gradually begins to rise. The stream is small but beneath it and overlying the decomposed bedrock is a bed of gravel 2 feet or more thick, thinning in some places and thickening in others, overlain by 2 to 3 feet of overburden. The gravel bed is about 300 feet or more wide and thins gradually toward the east. It is at least a quarter of a mile long and may extend much farther unless cut away by Soque River. The gravel is composed mostly of vein quartz of which the largest fragments are boulders as much as 1 foot in diameter. It was apparently deposited under more active drainage conditions than now prevail. This gravel is so rich in kyanite crystals that it is reported to carry in places as much as 40 pounds to the cubic foot. Such places, where exposed, seem to bristle with kyanite crystals.

The difference in specific gravity between the kyanite (generally about 3.67) and quartz (maximum 2.66) renders it easy to separate by the ordinary processes of placer mining combined with screening. The overburden, 2 to 3 feet thick, composed largely of humus, is stripped, the gravel is wheeled to the sluice boxes, the cobbles are thrown aside, and the fine gravel and kyanite crystals are scraped back and forth with hoes in the water running through the wide sluice boxes until the clay, sand, and fine gravel are washed away. The concentrates are then screened, and the kyanite crystals are recovered in three grades as coarse, medium, and fine. The coarsest and medium sizes are shown on a natural scale in plate III. The crystals are comparatively free from adhering quartz and mica, because the material has undergone a preliminary cleaning process by nature during the time it was being carried from its source in the bedrock to its present position. In the summer of 1934 about 1½ to 2 tons of crystals a day were produced and about a dozen men were employed. As soon as a carload of crystals accumulated it was transported by trucks about 2 miles to the railroad at Clarkesville. It is estimated that several thousand tons of kyanite is available in this deposit. The land is the property of W. E. Black, whose house is on the low ridge directly west of the valley, and the placer is leased by Philip S. Hoyt, of Franklin, N. C.

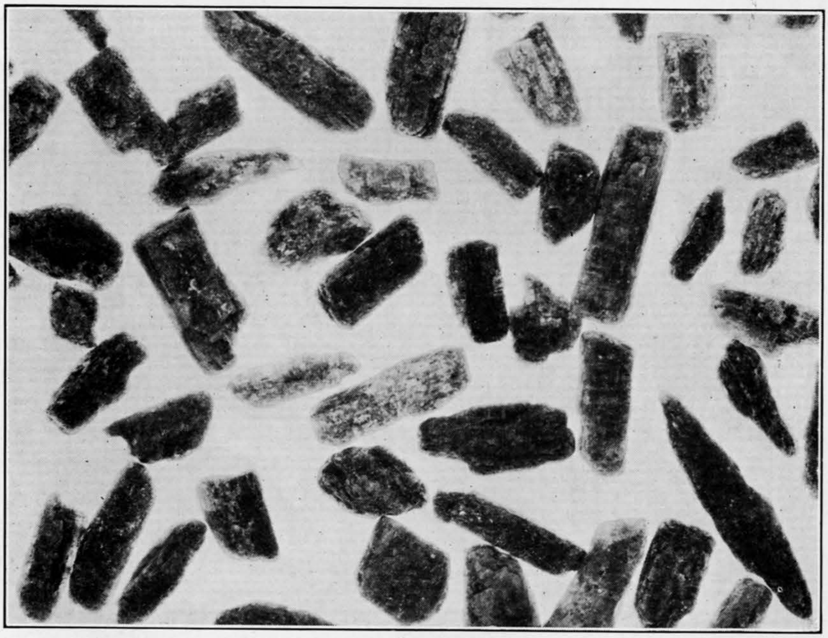
That this deposit was formed under conditions differing from those of the present is shown by the fact that the low ridge west of the stream is also strewn with kyanite crystals. Both ridge and valley deposits are evidently the residuals from a larger gravel deposit formerly present. The nearest bedrock source is the kyanite schist half a mile to the north.

It is difficult to visualize the changes in drainage conditions without taking into account the elevations and subsidences to which the land has been subject. Increased altitude increases the fall to sea level, and streams become more active. The sequence of events that led to the formation of the present kyanite placer may have been somewhat as follows: There was a washing out of the kyanite crystals from the kyanite schist to the north; an accumulation of these crystals and associated gravel in an ancient drainage system far different from the present; an elevation of the land that gave opportunity for renewed activity of streams and made it possible for the streams to carve new valleys in the preexisting surface; a reconcentration of gravel and kyanite in these new valleys; and finally, with the end of great stream activity, the development of the present streams. The flow of the present stream in this valley is probably a mere trickle compared with the flood capacity of the stream that handled the heavy gravel.

This kyanite placer illustrates, at a very accessible locality and in a very impressive way, processes that have been in progress at many localities throughout the region.



A. KYANITE CRYSTALS FROM THE KYANITE PLACER NEAR CLARKESVILLE; LARGEST SIZE SHIPPED. NATURAL SIZE.



B. THE INTERMEDIATE SIZE SHIPPED FROM THE PLACER MINE, CLARKESVILLE. NATURAL SIZE.

KOLLOCK AND HEYWARD PLACES

Along the strike of the kyanite schist northeastward from the A. and M. College, exposures are found in the woods near the west side of Soque River on property of the Kollock family. Crossing the river to the east side, the schist continues northeast across part of the Kollock property and part of the Heyward property.

Soque River makes an abrupt bend in this part of its course and is limited on its left by a steep cliff about 1,000 feet long and 100 feet high. The bedrock for 70 feet above the level of the river is composed of gneisses, which appear to be mostly of sedimentary origin. The uppermost 30 feet of the cliff is made up of kyanite schist with some interlayered pegmatite, biotite quartzite, and a thin, closely folded bed of vitreous quartzite. Nearly 25 feet of this part of the section contains kyanite. To the west, toward Soque River, in the vicinity of Sleepy Hollow (no. 1, pl. I), the surface of the ground slopes to the north and south and is strewn with an abundance of residual kyanite crystals over a width of 300 to 400 feet. Many of the crystals are of finger length, and there are scattered pieces of massive kyanite. A terrace deposit of gravel occurs on the west side of Soque River, S. 82° W. from Sleepy Hollow. This deposit, situated about 400 feet back from the stream, and about 20 feet above it, is about 15 feet thick. It is composed largely of well-rounded quartz cobbles with a few boulders nearly 2 feet in diameter. The gravel also contains some kyanite that appears to have been derived from the marginal part of the kyanite schist.

WOODLANDS LOCALITY

Three miles northeast of Clarkesville the schist, 300 to 400 feet or more wide, crosses a part of the property of W. A. Nicholson and the Kollock property south of the residence at Woodlands (no. 2, pl. I). Several large pieces of the massive kyanite a foot or more in diameter have been found in this vicinity.

An instructive section is shown where the kyanite schist crosses the farm road that extends from the main road south to Deep Creek east of Woodlands. In addition to the residual crystals, kyanite is also present in water-worn gravel at a level about 80 feet above Deep Creek. One gravel deposit, about 15 feet thick, occupies an oval area approximately 100 feet long.

The schist belt crosses the farm road 200 feet farther south, and the fine-textured alluvial beds extending from the higher level toward Deep Creek contain thin layers of gravel with kyanite. One such bed is 4 inches thick under 1 foot of overburden. These thin gravel beds are about 400 feet wide and fringe the southeast side of the belt of kyanite schist for an unknown distance. The part that was observed is indicated on the map. The source and original distribution of the coarse gravel 80 feet above the present drainage level, like similar features of the high gravel referred to in the description of the placer mine at the Black property (p. 11), are unknown. This occurrence emphasizes the drainage changes that have taken place. The thin beds of kyanite gravel interbedded with sandy clay just south of the schist bed may indicate still another period of transportation and redistribution, as these deposits form a terrace 50 feet above the present stream. The kyanite schist belt itself in this area is about 200 feet or more wide, but the width over which kyanite is present is increased by these occurrences of placer kyanite in close connection with the kyanite of the schist.

J. M. INGLIS FARM

Farther northeast the kyanite belt widens to about 600 feet, possibly through the occurrence of placer kyanite not easily separable from the other in wooded country, and then contracts again to about 300 feet in crossing the next valley through the farm of J. M. Inglis (no. 3, pl. I), about 4 miles northeast of Clarkesville. Here dornicks of massive kyanite are present along with the crystals.

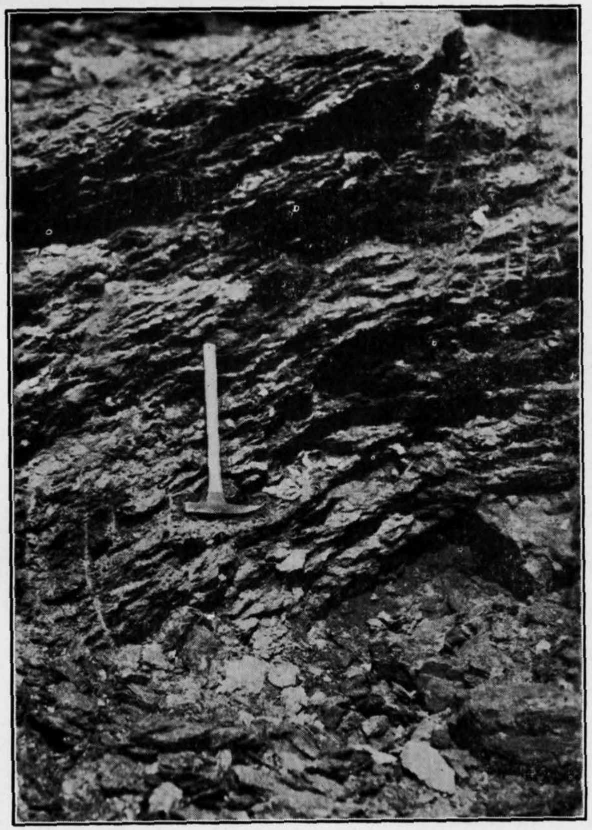
This area brings older gravel again into prominence. In the marginal areas of the open valley several localities were found where kyanite gravel lies 30 feet above the present streams and is overlain in places by 6 feet of fine sandy alluvium similar to that of the Kollock farm road. These deposits covered originally a wide area and are represented now only by isolated patches.

One of these areas was located on the farm of J. M. Inglis. The privilege of using this gravel was given to the town of Clarkesville by the owner. A steam shovel was installed, and work was continued for 3 months removing the gravel for resurfacing about 25 miles of road. The remnants of this deposit show that the gravel was rich in kyanite, apparently as rich as the placer mine near Clarkesville.

The schist crosses the next ridge to the northeast, where it is about 250 feet wide, as shown by the distribution of crystals littering the ground. It continues half a mile farther, crosses Deep Creek, where the crystals are much smaller, and seems to terminate a short distance beyond. A mile farther northeast, however, there is another area of schist that contains not only the crystals of kyanite but also a small amount of the massive kyanite.

DEPOSITS NEAR TURNERVILLE

The next locality is west of Turnerville (see pl. I), where kyanite schist is present on both sides of a low ridge trending north and shedding its material to small streams on each side. Massive kyanite is rather common on this ridge along with the crystals. Along the east side of the ridge is a small deposit of placer kyanite extending a quarter of a mile downstream from the east-west road at an altitude of 35 feet above the stream and 200 feet west of it. A road exposure shows 6 to 12 inches of gravel under an overburden of 3 to 5 feet. The crystals are smaller than those of the main belt of schist, and the interest of the occurrence is the presence of a kyanite placer in gravel older than that of the present stream. Search was made for the schist in the area both northeast and northwest of this locality, but it does not appear to extend far beyond Turnerville.



A. KYANITE SCHIST, ALEC MOUNTAIN, HABERSHAM COUNTY.

B. SHOVELING DECOMPOSED SCHIST WITH KYANITE CRYSTALS INTO FLUME, ALEC MOUNTAIN, HABERSHAM COUNTY, GEORGIA- CAROLINA MINERALS CORPORATION.

WESTERN PORTION OF KYANITE BELT

ADDISON PROPERTY

The schist was traced from the A. and M. College to Sutton Mill Creek, where it appears on the north side of the road east of the creek. The belt trends northwest and widens to 1,000 feet or more at the Addison property, three and a quarter miles northwest of Clarkesville (no. 4, pl. I). The distribution of the residual kyanite over the fields at this locality gives a cross section of the distribution of the kyanite in the bedrock. In crossing the belt from east to west many small kyanite crystals begin to appear about 450 feet west of the road and are distributed over a width of about 250 feet. Few crystals are showing on this surface for the next 100 feet to the west, followed by another belt of about 200 feet with thickly scattered small crystals. Still further westward is another 200 feet of fine and medium-sized crystals, and finally about 100 feet with many large crystals wrapped to a large extent in muscovite. The schists in this vicinity contain in places small amounts of brown iron ore, indicated by scattered fragments on the surface. The kyanite crystals also appear locally to be more ferruginous. Several small pegmatite bodies in the schists have been prospected for mica.

STONEPILE CHURCH AND ALEC MOUNTAIN

The schist continues toward the northwest and about half a mile from Stonepile Church is exposed for a width of about 250 feet in an old road that runs southwest from the church. There is a fine display of the crystals beyond the woods and in the fields to the northwest. The belt can be followed over the ridges and across the valleys to the Piedmont Orchard Company property on Alec Mountain where the decomposed bedrock has been mined (no. 5, pl. I). Corundum has been found at two localities in this area in the decomposed gneiss about half a mile south of the mine.

The schist belt at the Alec Mountain mine is about 250 feet wide. It is closely crumpled, and greenish quartzite beds interbedded with the schist show minor folds. The schist is underlain by gneisses, prominent outcrops of which appear along the eastern base of the hill. Farther east are schists crowded with small garnets and a negligible amount of small kyanite crystals.

The kyanite schist that is being mined at Alec Mountain and the mining operations are shown in plates IV and V. The top soil containing the loose kyanite is shoveled into a flume that carries the material to a crude mill, where the larger crystals are screened out. These are put through a muller in which rubber-covered solid wooden wheels travel over the crystals in a tub and rub off the adhering flakes of mica and quartz grains. The crystals are then handpicked to remove fragments of quartz and decomposed mica schist. The kyanite shipped ran about 3 per cent iron and 3 per cent free silica.

SOQUE RIVER AND RAPOR CREEK

From Alec Mountain northwestward to Soque River and still farther to Rapor Creek the gneisses afford a fine key bed for locating the position of the schists west of them. In many parts of the region, however, these gneisses have become thoroughly decomposed and do not form conspicuous outcrops. The abundance of residual kyanite along the continuous exposures of the schist from Alec Mountain to Soque River indicates a good proportion of kyanite in the bedrock. At Soque River much biotitic quartzite is interbedded with the kyanite schist. A subordinate belt of kyanite schist 500 to 1,000 feet or more west of the main belt occurs at several places from Soque River northeastward in the mountainous region toward Burton Dam. There are fine exposures of the main belt from Soque River to Rapor Creek. This creek flows in a narrow, steep-walled valley, and the schist extends from the tops of the ridges nearly to the level of the stream, a vertical distance of 200 feet.

If the time should come when a mining operation in hard rock could be carried out, the schist at Rapor Creek could be mined northeast and southwest along the strike of the rocks for long distances. The quantity of material is sufficient for prolonged mining. Any guess regarding the quality is of little value, but some of the material would appear to carry as much as 10 per cent of kyanite.

If the percentage of kyanite in the rock and the demand for kyanite do not warrant mining under present conditions, the deposit forms a potential reserve of possible importance in the future.

As the valley of Rapor Creek has been cut across the belt of kyanite schist placer deposits may occur in its valley, and small deposits are present on terraces above the present level of the stream.

BURTON DAM

The schist continues from Rapor Creek across the high ridges and deep valleys to Burton Dam, at the lower end of Burton Lake, and is well exposed at the highest point in the winding road to the dam. The decomposed bedrock that has been deeply cut to make the road illustrates on the smooth surfaces of the cut the folding, minute crumpling, pegmatitic intrusion, and faulting on a small scale that the rocks have undergone.

The kyanite schist at the east end of the dam is in close contact with the underlying gneisses. Fine exposures of the rocks can be seen along the shore of the lake north of the dam. The beds dip about 15° N. and strike nearly due east. Kyanite-bearing layers alternate with others containing no kyanite. One layer about 1,000 feet north of the dam is about 30 feet thick and displays on the weathered surfaces a profusion of crystals.

The section at Burton Dam is similar to that at Alec Mountain, where the principal kyanite beds are limited on the east by the banded gneiss and east of the gneisses are schists containing many small garnets and a small proportion of inconspicuous kyanite crystals. The road

A. PART OF KYANITE WASHER, ALEC MOUNTAIN, HABERSHAM COUNTY, GEORGIA-CAROLINA MINERALS CORPORATION.

B. PICKING TABLE AND KYANITE WASHER SHOWING PILE OF KYANITE CRYSTALS, ALEC MOUNTAIN, HABERSHAM COUNTY. GEORGIA-CAROLINA MINERALS CORPORATION.

after crossing Tallulah River below the dam passes along a bench, with the river far below on the south and a quarry forming a cliff 100 feet high above the road on the north. The rocks from the road to the river are like those east of the gneiss at Alec Mountain—garnetiferous schists with small kyanite crystals. The sequence in both places is one of garnetiferous kyanite schists overlain by banded gneisses 100 feet or more thick and these in turn overlain by schists with larger kyanite crystals.

BRIDGE AND SAWMILL CREEKS

The schists after passing through the high ridge east of Burton Lake and above the quarry cross Bridge Creek, where a good section of them nearly 1,000 feet wide is exposed along the road. The rocks appear to be nearly horizontal, owing to small folds which have been overturned to a nearly horizontal position. The schists have also been intruded by rather massive coarse pegmatite. A thin bed of gravel containing kyanite occurs here 30 feet above the level of the stream.

The region from Bridge Creek northeastward to the ridges south of Tiger Creek is one of high wooded ridges and deeply cut valleys. The schists have a wide distribution here, and their relation to the streams has been favorable for the development of placer deposits.

Sawmill Creek is one of the streams especially favored in this respect. It flows between high parallel ridges. Kyanite schist forms the top of the ridges for nearly 2 miles. On the ridge southeast of the stream the schist, containing some quartzite, is nearly 60 feet thick. The schist is also present in the valley itself near the stream level. The presence of the schist on the ridges and also at the bottom of the valley is apparently the result of much minor folding.

From the point where a farm road from Rock Grove Church reaches Sawmill Creek the schist extends half a mile farther upstream. From this point to the mouth of the creek, a distance of over 2 miles, the gravel of Sawmill Creek is rich in kyanite, derived in part from the ridges on each side and in part from the schist in the valley itself. The valley floor widens to 250 feet, and few places are too narrow to permit an accumulation of gravel. Crystals of kyanite are present even below the junction of Sawmill Creek and Bridge Creek, not far from Tallulah River. There is, then, in the valley of Sawmill Creek a reserve of placer kyanite of considerable magnitude.

MCCLAIN AND STONEWALL CREEKS

From Sawmill Creek the schist crosses the divide to the headwaters of McClain and Stonewall Creeks. Its course is marked by a profusion of crystals in the woods and fields, and placer kyanite is present in the valleys of small streams on the west side of the belt.

The high divide separating the Sawmill drainage basin from that of McClain Creek has a steep slope on each side, and the locality where the schist crosses would be favorable for mining if the value of kyanite should ever justify it. This appears to be true also of the other ridges farther north.

McClain and Stonewall Creeks are both deeply incised in an area of high, steep ridges, one of which lies between the two streams. The schist crosses their headwaters, and much kyanite has been carried down the streams to form kyanite placer deposits 150 feet wide. Both creeks have apparently a considerable reserve of kyanite in these deposits of gravel. These placer deposits in the valleys of Sawmill, McClain, and Stonewall Creeks are shown on plate I.

KESON AND LOVEN PLACES

Near the headwaters of Stonewall Creek, where the schist approaches the ridge south of Tiger Creek, large numbers of the crystals are scattered over the surface. This is especially well shown at the Keson place (no. 7, pl. I), overlooking the valley of Tiger Creek, about a mile in a straight line southwest of Liberty Church. The Civilian Conservation Corps was rebuilding the road from Bridge Creek to the town of Tiger in 1934, and this new road will render all these localities more accessible. From the highest point in this road, at the top of the divide, a farm road leads south to the Loven place (no. 6, pl. I), and a trail climbs the high ridge a mile south of the Loven place, down the eastern slope of which the schist belt crosses.

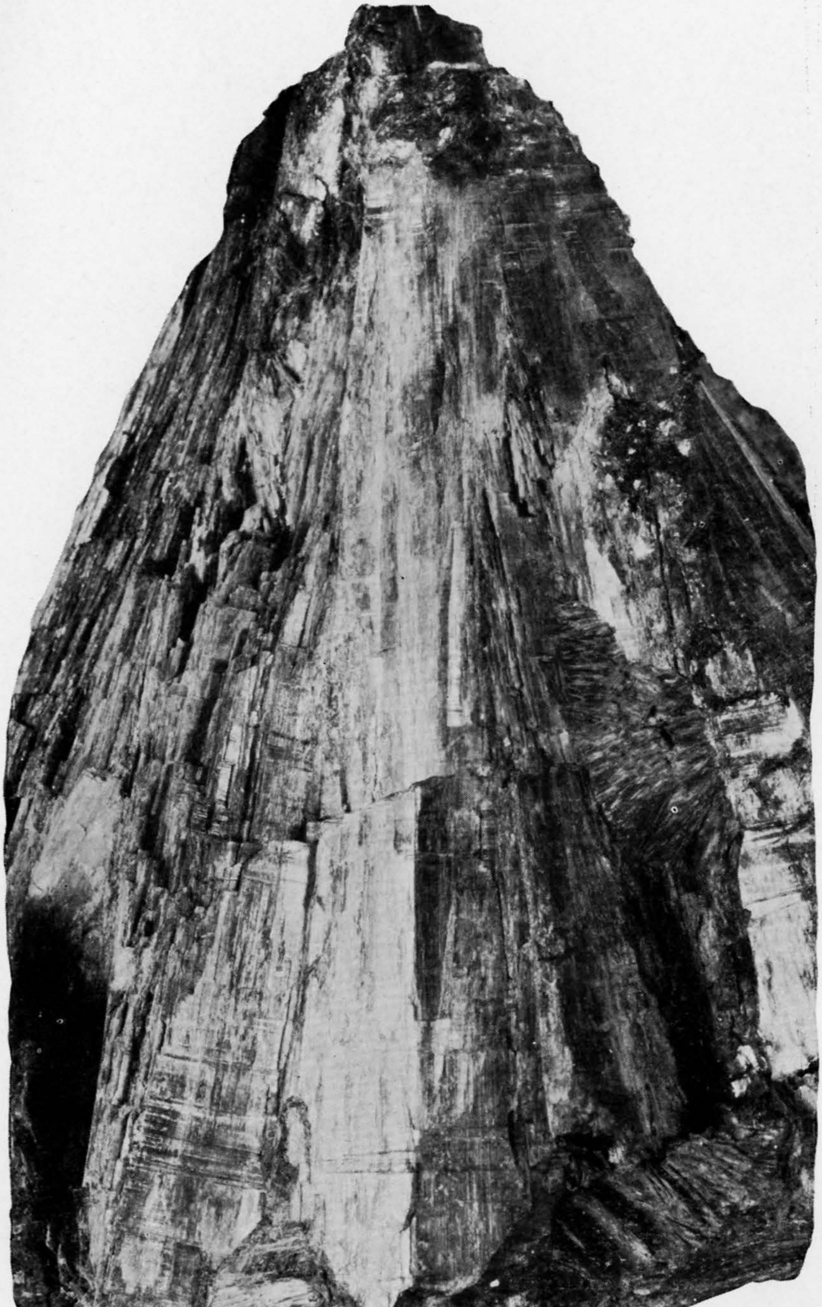
TIGER CREEK

Bench gravel containing small crystals of kyanite is present over a width of 200 feet in the lower part of the valley of Tiger Creek on the south side of the valley 30 feet above the present level of the stream.

A specimen collected in the area where the schist turns toward the east, south of Tiger Creek, shown in plate II, illustrates the quantity and size of the kyanite in this part of the belt. The curving course of Tiger Creek, the curving strike of the gneisses south of Tiger Creek, and the curve of the schist toward the east are all nearly parallel and repeat in opposite phase the peculiar course of the schist at Clarkesville. The narrowing and widening of the schist exposures are due to the attitude of the schists, which are steep in some places and nearly horizontal in others, to variations in the thickness of the beds, and to the crowding together of the material in the curving areas, where the rocks are in places intensely crumpled.

OCCURRENCES OF MASSIVE KYANITE

Massive kyanite occurs locally throughout the belt of kyanite schists but nowhere in notable amount. Pieces 100 pounds in weight have occasionally been found and at one place half a ton or more had been recovered. A small amount of massive kyanite occurs in the schist associated with pegmatitic material at a locality southwest of Turnerville. It has been reported in other parts of these counties, and one locality was visited, but none of these occurrences appear to be of economic importance.



MASSIVE KYANITE FROM GUMLOG, ABOUT 7 MILES NORTH OF BLAIRSVILLE. SHOWING THE CLEAVAGES OF KYANITE AND RADIAL CRYSTALLIZATION FROM A MASS OF CORUNDUM AT THE APEX. NATURAL SIZE.

ORIGIN OF KYANITE

The origin of kyanite is not very definitely known. It is at home in the crystalline schists, like garnet, staurolite, and other minerals regarded as the result of regional metamorphism. The schists were probably argillaceous shales rich in alumina. Under the conditions of temperature and pressure prevailing during the period of metamorphism this material was transformed to new minerals, the most prominent of which is kyanite. Massive kyanite was found only in the belt of kyanite schist. Tourmaline is associated with it, and the origin is regarded as hydrothermal. Kyanite also occurs in gold quartz veins with sulphides at Dahlonega.

SUMMARY

The kyanite deposits in Habersham and Rabun counties described above appear to offer the most promising field in Georgia for commercial exploitation. The reserves of kyanite in the schist itself and the reserves in the placer deposits derived from these schists are sufficient to supply a considerable future demand. Their use will depend on the demands of the refractory industry. These demands in turn will be influenced by the costs of mining and preparation of the kyanite and the adaptability of kyanite to the needs of industry.

KYANITE DEPOSITS OF TOWNS, UNION, AND FANNIN COUNTIES

RELIEF

The area included on plate VII differs somewhat from the upland and highland of the eastern counties. Here are the peaks and ridges of the part of the Blue Ridge that extends from North Carolina into Georgia. North of the main Blue Ridge are isolated peaks and ridges. Brasstown Bald, 4,762 feet above sea level, is the highest point in Georgia. It is over half a mile above the adjacent valley and is the culminating point of ridges that extend north and south and join east-west ridges that trend west toward Wilscot Mountain. A prominent ridge with several peaks more than 4,000 feet above sea level extends from Lemons Gap nearly to Hiwassee. Gumlog Mountain (3,743 feet) and Ivylog Mountain are outlying ridges north of Blairsville (1,892 feet above sea level).

DRAINAGE

The spacious valleys are drained by Hiwassee River and its tributaries, the largest of which are Nottely and Toccoa Rivers. These all flow in a general northwesterly direction to join the Tennessee beyond the limits of the area mapped. A part of the valley of Toccoa River west of Morganton has been transformed by a power dam into a lake 10 miles long. The ridges and valleys in the vicinity of the town of Blue Ridge have a pronounced northeast trend and a small part of the drainage finds its way into the Coosa River in Alabama.

A highway from Clayton passes through Hiwassee and Young Harris to Blairsville. From Blairsville there is a good road to Murphy, N. C., northwest of Blairsville, beyond the limits of the area mapped. Another good road connects Blairsville and Blue Ridge.

Blue Ridge is on the Louisville and Nashville Railroad, a branch line of which extends to Murphy, N. C., which is also served by a branch of the Southern Railway. The road from Hiwassee to Gainesville, by way of Unicoi Gap, was being greatly improved and new roads were under construction in 1934. These improvements are making the country more accessible by giving the remote areas closer connection with the main trunk lines.

GENERAL GEOLOGY

The rocks in the area east of the geologic boundary trending northeast between Morganton and Blue Ridge have been described as predominantly of pre-Cambrian age; those west of the boundary as Paleozoic.[1] In many respects this boundary is artificial and arbitrary as has been recognized by O. B. Hopkins.[2] A. I. Jonas[3] has maintained that most of the metamorphic rocks of the southern Appalachians that have been classed as Paleozoic, are pre-Cambrian. New evidence found by G. W. Crickmay strongly favors the view that the metamorphic rocks in the western part of the Ellijay district are pre-Cambrian in age, but, in order to avoid confusion, the terminology employed on the existing maps of the region is here followed. There was no opportunity to study in detail the many areas of kyanite schist in this region, and the distribution of them shown on the sketch map (plate VII) is taken mainly from the Ellijay folio, with minor additions by the writer. The localities of massive kyanite that were visited are also represented on the map. Other localities were reported but not investigated. A few areas of granite as mapped in the folio cited are included.

The gneisses and schists of the pre-Cambrian area are similar to those of the Clarkesville region. Less metamorphosed rocks of sedimentary origin in the pre-Cambrian area include fine-grained conglomerates with quartz pebbles.

The most common igneous rocks are granites and pegmatites. The pegmatites contain in places sufficient mica to encourage prospecting. They are of importance also in connection with the occurrence of massive kyanite. Dark massive igneous rocks include pyroxenite, olivine rocks and serpentine. Vermiculite occurs associated with some of these ultra-basic rocks.

Quartz is present in abundance. Veins both large and small occur throughout the area and seem to be more widely distributed than in the

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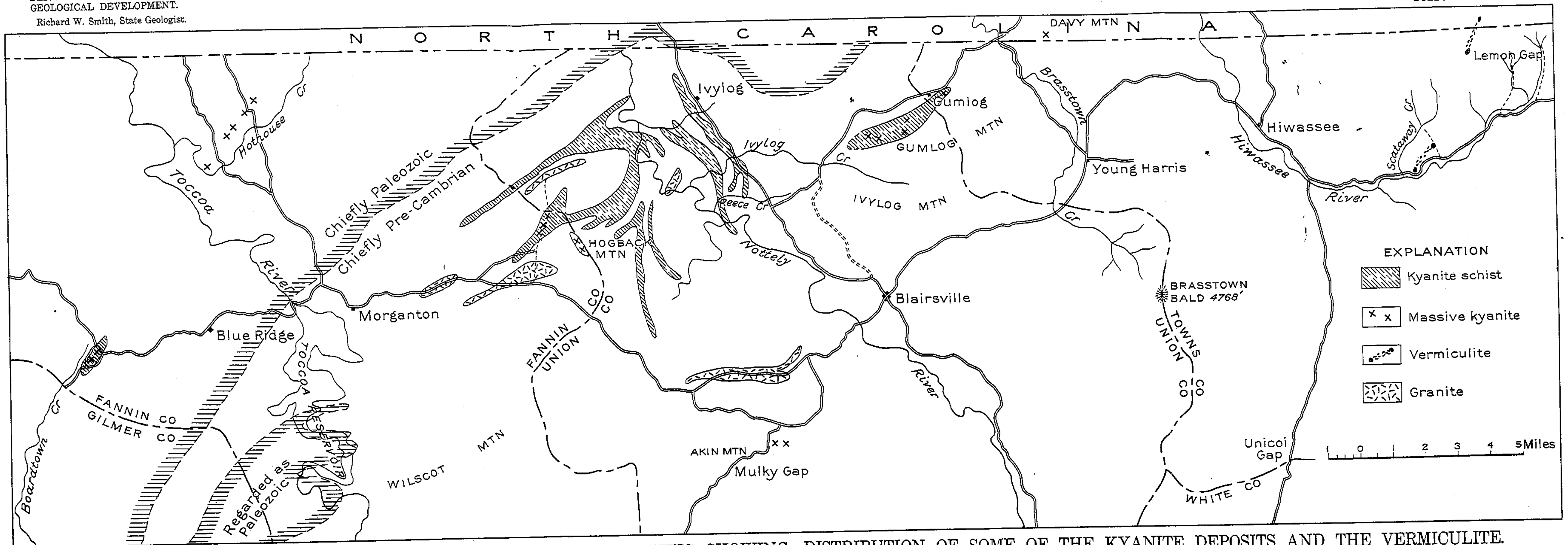
[1]LaForge, Laurence, and Phalen, W. C., U. S. Geol. Survey Geol. Atlas, Ellijay folio (no. 187), 1913.

[2]Hopkins, O. B., The Asbestos, Talc, and Soapstone Deposits of Georgia: Georgia Geol. Suvey, Bull. 29, p. 9, 1914.

[3]Jonas, A. I., Structure of the metamorphic belt of the southern Appalachians: Am. Jour. Sci., vol. 24, 1932.



SKETCH MAP OF PARTS OF TOWNS, UNION, AND FANNIN COUNTIES, SHOWING DISTRIBUTION OF SOME OF THE KYANITE DEPOSITS AND THE VERMICULITE.

Clarkesville region. Vein quartz in the northwestern part of the area has been used as a flux in the copper smelters of the Ducktown district.

THE KYANITE SCHIST

The complicated structure of the rocks in the pre-Cambrian area is illustrated by the peculiar distribution shown by the kyanite schists. They are widely distributed, especially in the northeastern part of the Ellijay quadrangle,[1] a part of which is included on the sketch map, where only the larger areas are represented. Like the schists in the counties to the east, they appear as curving masses widening to half a mile or more where they bend round and then dwindling to long, thin bands and shreds of strata. In tracing them in the field it is difficult to set a boundary between them and the enclosing rocks. Although the schists are widely distributed, the kyanite crystals are in general smaller than those of the eastern counties and in many localities have been so thoroughly replaced by mica and quartz as to be of no value. They resemble those shown on plate VIII, B.

The distribution of the kyanite schists in these counties does not mean, therefore, that usable kyanite is present throughout the area represented. The crystals are of a size and quality to be of value only in certain localities.

REECE CREEK

One such locality is in the valley of Reece Creek, about a mile below the point where the creek crosses the highway about 5 miles northwest of Blairsville, on the land of C. S. Mauney (lot 174, 9th land district). Although some of the crystals measure 2 inches in length, the average size is somewhat smaller than that of the crystals in the Clarkesville region. Reece Creek has cut across the schist and distributed crystals of kyanite in the gravel downstream. It is probable that the kyanite is equally well preserved at other localities in this area. In some places, however, the replacement by mica and quartz is nearly complete.

MASSIVE KYANITE

The massive kyanite is more prominent in this region than in the Clarkesville area, and numerous pieces or dornicks are present in the kyanite schist of Reece creek.

HOGBACK MOUNTAIN AREA

Prospecting has been done on the southern slope of Hogback Mountain in an area of kyanite schist, and several tons of the massive kyanite has been recovered. It occurs apparently in many small veins associated with quartz.

Work has also been done on the P. H. Thomas property, 1½ miles northwest of Hogback Mountain. The massive kyanite occurs associated with quartz and some graphite in a kyanite schist. The kyanite

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[1]The east boundary of the Ellijay quadrangle, not shown on plate 7, passes south immediately east of Gumlog Mountain.

was taken from many shallow pits along quartz veins 2 feet or more wide, parallel with the strike of the schists. The amount taken out from this locality and Hogback Mountain was about a carload.

GUMLOG MOUNTAIN AREA

Massive kyanite is found at several localities in the kyanite schist area of Gumlog Mountain. The deposits trend northeast, and others were reported in the same general direction toward the State boundary. Similar deposits occur also on Davy Mountain, over the line in North Carolina.

The deposit of massive kyanite on Gumlog Mountain is on the southwest slope of a hill in an area of kyanite schist striking northeast. Loose fragments of kyanite are common over the surface of the slope, and considerable prospecting work has been done by the A. C. Spark Plug Company. A trench 100 feet long and a shaft over 20 feet deep were excavated along the strike. Several tons of kyanite was found in the trench at intervals of 15 feet or more, and kyanite was still in place at the upper end of the trench. Some was found also in the shaft near the surface, but none near the bottom. Here, as in other localities, the massive kyanite appears to be pockety, the pockets ranging in size from pieces a foot or less in diameter to masses weighing half a ton or more. The specimen shown in plate VI came from the trench and illustrates the massive kyanite radiating from corundum at the apex. Tourmaline is in places associated with the kyanite and suggests a hydrothermal origin for this deposit.

The kyanite schist can be followed southwestward along the strike, and on the western part of the ridge line of Gumlog Mountain it is half a mile wide and in places rich with crystals. Massive kyanite also occurs at other localities in this belt.

AKIN MOUNTAIN AREA

Massive kyanite is reported north and northeast of Hogback Mountain and also south of the main highway from Blairsville to Blue Ridge. One of these occurrences south of the highway and half a mile northeast of Akin Mountain is shown on plate VII. Many pieces occur there in the fields and woods, in an area of kyanite schist. According to the information available kyanite is present at other localities along the north base of the hills extending from Akin Mountain to Wilscot Mountain.

KYANITE IN PALEOZOIC ROCKS

The rocks west of the geologic boundary drawn between Morganton and Blue Ridge include thin-bedded banded slaty-appearing schists and schistose or rather massive quartzitic rocks and conglomerates. These rocks have been mapped by LaForge[1] as Paleozoic. Fine-grained schists appear to predominate. The rocks west of the boundary occur in long,

[1]LaForge, Laurence, and Phalen, W. C., U. S. Geol. Survey Geol. Atlas, Ellijay folio (no. 187), 1913.

narrow strips trending northeast. There has been much faulting, and the rocks have in places been overthrust from east to west. They have been so thoroughly metamorphosed that geologic boundaries have become obscured, and the different formations have taken on a deceptive similarity. The Paleozoic age of these rocks, as noted above (page 20), is now in doubt.

FRANK BAILEY PROPERTY

At the locality marked on plate VII east of Boardtown Creek and 4 miles southwest of the town of Blue Ridge a bed of kyanite schist contains a considerable amount of massive kyanite. Numerous pieces were observed over a distance of half a mile parallel with the structure of the schists. The material was well exposed in a prospect hole on the property of Frank Bailey. The kyanite occurs as long, thin crystals, some of them curving, penetrating vein quartz. A chloritic mineral is also present, and some of the kyanite is green. The kyanite appears to have been formed by hydrothermal replacement of the quartz. Most of the crystals in the enclosing schists are altered to mica and quartz.

HOTHOUSE CREEK

There are several northeastward trending bodies of massive kyanite 4 to 6 miles north of the town of Blue Ridge on the west side of the valley of Hothouse Creek (plate VII). They are distributed at intervals over a distance of about 2½ miles. In the Hothouse Valley half a mile down stream from the bend toward the northwest (the southernmost of the localities indicated) massive kyanite occurs at intervals over a width of 100 feet. Prospecting has been done at several places farther northeast over a distance of nearly 2 miles, but only a small quantity of massive kyanite has been found. All these localities lie on the strike of the deposits southwest of Blue Ridge just described. The occurrence of the kyanite in the areas west of the geologic boundary seems to differ in no essential respect from that of the kyanite present in the pre-Cambrian areas farther east.

KYANITE IN PICKENS AND CHEROKEE COUNTIES

The geology of the Tate quadrangle, which includes parts of Pickens and Cherokee counties, has been described by Bayley.[1]

The major features of relief in the Tate quadrangle are the steep westward-facing escarpment of the eastern upland, the valley west of it, and the western upland. The main highway, the railroad, and the concentration of population parallel this escarpment.

The principal drainage also parallels the escarpment. The meandering subordinate streams are deeply incised in the upland.

[1]Bayley, W. S., Geology of the Tate quadrangle: Georgia Geol. Survey Bull. 43, 1928.

GENERAL GEOLOGY

A sketch map of a part of this quadrangle (fig. 2) shows the boundary lines of the different formations as they have been mapped by Bayley and the location of kyanite deposits. The rocks in the western part of the area are predominantly schists and have been regarded as Paleozoic by Bayley. But some differences of opinion have arisen regarding this age assignment, and on the geologic map of the United States published by the United States Geological Survey in 1932 most of these formations have been included in the pre-Cambrian.

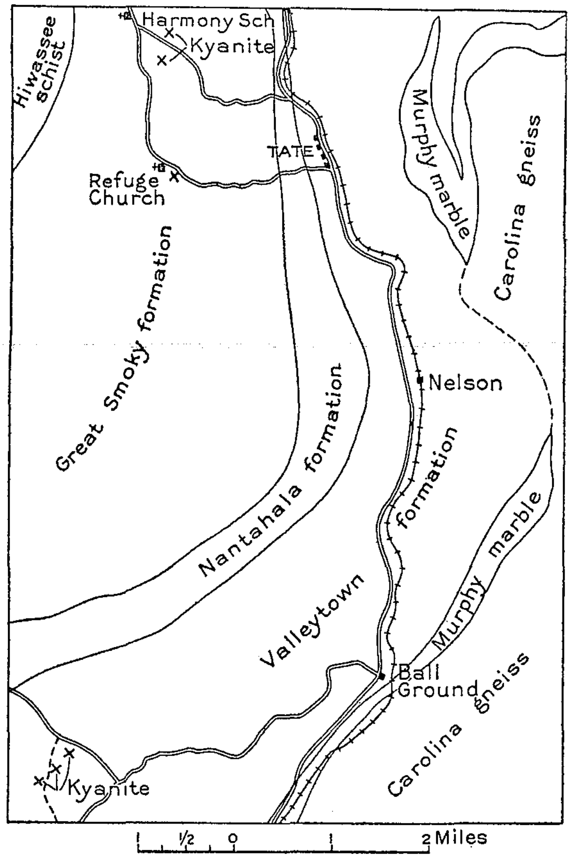
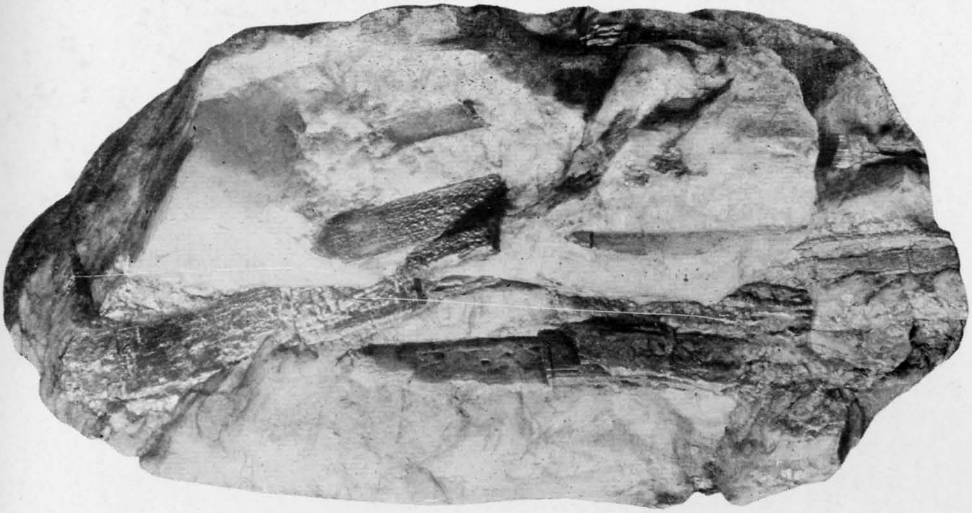
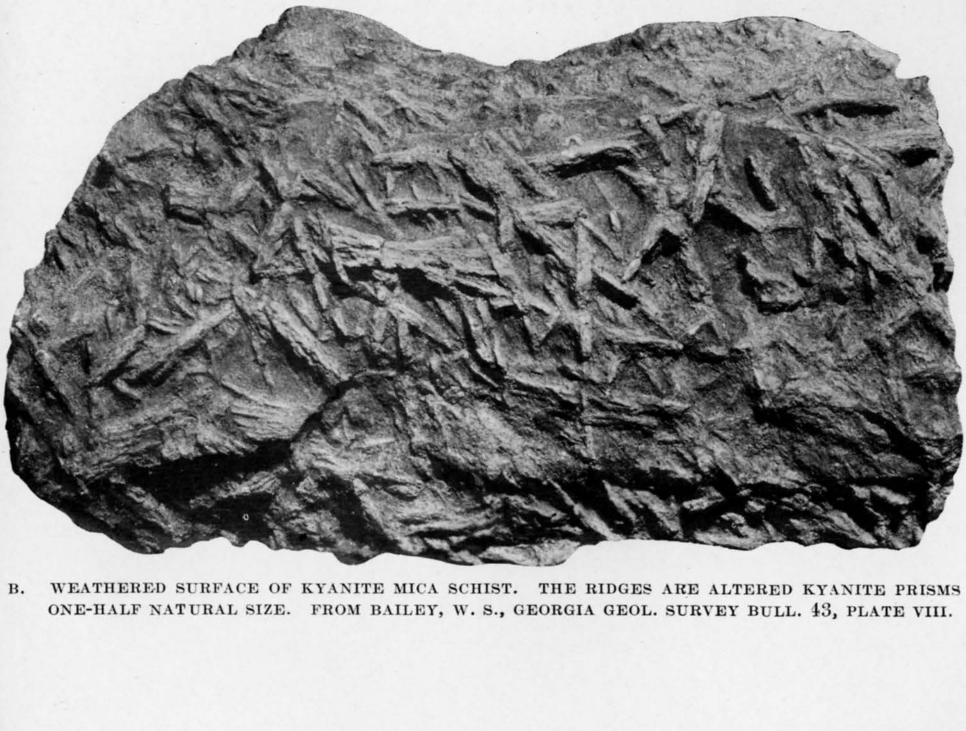


Fig. 2.—Sketch map of a part of the Tate quadrangle showing location of Kyanite deposits.

The gneisses and schists of the eastern part of the area, regarded as predominantly pre-Cambrian, have been thrust westward over the possibly Paleozoic rocks to the west. With rocks so highly metamorphosed, age distinctions lose their value and the problem becomes one of metamorphism. Paleozoic rocks may be present in the western



A. KYANITE CRYSTALS (BLADES) IN QUARTZ VEIN. ONE-THIRD NATURAL SIZE.



B. WEATHERED SURFACE OF KYANITE MICA SCHIST. THE RIDGES ARE ALTERED KYANITE PRISMS ONE-HALF NATURAL SIZE. FROM BAILEY, W. S., GEORGIA GEOL. SURVEY BULL. 43, PLATE VIII.

part of areas regarded as pre-Cambrian, but through metamorphism they have lost their stratigraphic significance. Through shearing and renewed metamorphism pre-Cambrian gneisses may come to resemble slates or phyllites of a younger age. Such processes have been active in many places throughout the Appalachian Mountains, and their results have been recognized.[1] Relatively young-looking quartzites are present in the part of the Tate quadrangle covered by this report, but the dominant rocks are schists, most of them highly garnetiferous.

KYANITE DEPOSITS

REFUGE CHURCH AND HARMONY SCHOOL

The localities of kyanite near Refuge Church and Harmony School, in the northwestern part of the area shown on the map, have been prospected to a small extent, and the belt can be traced only by numerous pieces of the massive kyanite in the fields.

BALL GROUND AREA

The Ball Ground area is described by Bayley as follows:[2]

"The best illustration of the relations of the kyanite to quartz is to be seen at an opening about 3½ miles a little south of west from Ball Ground. The opening which is on the west side of the road has exposed a portion of a 2-foot wide quartz vein cutting mica schists. The schist in contact with the vein contains some kyanite, but the main mass of this mineral is in the quartz [plate VIII, A]. The vein is roughly layered. The west layer, which is in contact with the schist, consists of quartz and large penetrating crystals or blades of kyanite. Next to this on the east is a barren layer of quartz, and next a little mica-kyanite schist and then another layer of quartz and kyanite. The kyanite seems to have grown from the outside inward. Along the borders it occurs in radiating aggregates that are in many places so compactly crowded as to appear massive. Usually, however, the masses are composed of large crystals of kyanite more or less divergently grouped, with large plates and crystals of a white glistening micaceous mineral between them. This mineral resembles muscovite very closely but is more brittle, and apparently it grades into kyanite. At any rate, large plates of the mica are mottled with bluish areas, which upon close study are seen to be masses of thin plates of kyanite. Here and there are large grains of quartz partially bounded by crystal planes, and elsewhere in the mass are cavities like the gem-bearing cavities in pegmatites. * * *

"There is not much evidence from which the manner of origin of the kyanite can be inferred, but it appears clear that it has replaced the quartz, in consequence of reactions between the silica and the aluminous components of the schists. Where the quartz entered as a vein the crystals grew from its margins; where the schist was saturated with siliceous emanations the kyanite was produced irregularly through the mass near the intrusions."

The vein trends northeast, and pieces of kyanite are common along this trend. Trenches have been cut across the vein at intervals of about 100 feet for a distance of about 500 feet. The kyanite is not continuous in the vein, areas where a few hundred pounds are present being separated by barren areas. Nearly a carload had been transported to the railroad.

[1] Jonas, A. I., and Watkins, J. H., Kyanite in Virginia: Virginia Geol. Survey Bull. 38, 1932.

[2] Bayley, W. S., op. cit., pp. 71–72.

KYANITE AT GRAVES MOUNTAIN

By W. D. Johnston, Jr.

Long famous among mineral collectors for its cabinet specimens of rutile, lazulite, and pyrophyllite, Graves Mountain, in Lincoln County, about 40 miles northwest of Augusta, is an asymmetric monadnock rising 400 feet above the surrounding countryside. (See fig. 3). It is about 1 mile long from northeast to southwest and less than half a mile wide. The north and east sides rise gently; the south and west sides are steep. Viewed from the southwest end, quartzite crags stand out against the timber-covered slope. Capping the monadnock are two summits separated by a saddle. The altitude of the higher summit is 901 feet, and the average altitude of the surrounding land is 500 feet. Graves Mountain is in the Crawfordville quadrangle, a topographic map of which, on a scale of 1 to 125,000 (about 2 miles to the inch) and a contour interval of 50 feet, has been published by the United States Geological Survey.

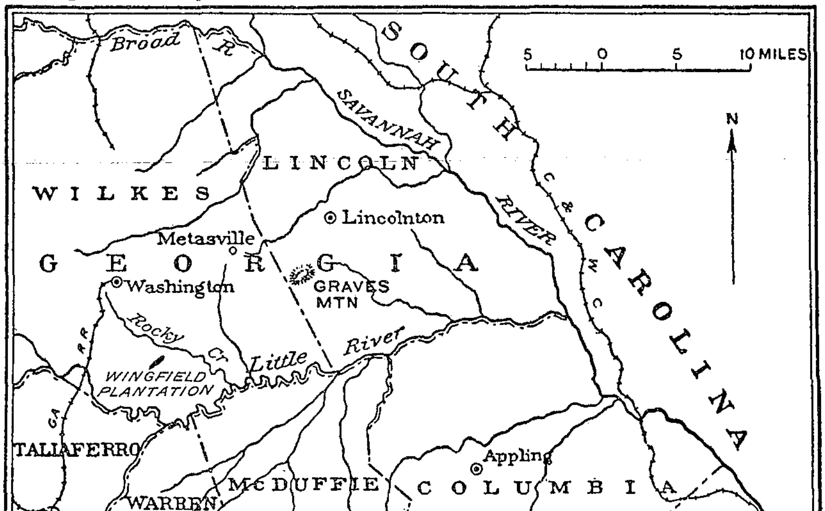


Fig. 3. Map showing location of Graves Mountain and the kyanite deposit on the Wingfield plantation.

PREVIOUS STUDIES

Shepard[1] first called attention to the remarkable mineral assemblage at Graves Mountain in a paper published in 1859. Soon mineral specimens were sought by the German mineralogists, and there resulted a series of studies, mainly crystallographic, published during the period

[1]Shepard, C. U., On lazulite, pyrophyllite, and tetradymite in Georgia: Am. Jour. Sci., 2d ser., vol. 27, pp. 36–40, 1859.

MASSIVE SILLIMANITE FROM HYATT MILL CREEK, 3 MILES SOUTH OF HAYESVILLE, N. C. IN THE CENTRAL PART OF THE SPECIMEN KYANITE IS INTERGROWN WITH AND APPARENTLY IS ALTERING TO SILLIMANITE. NATURAL SIZE.

1860 to 1897 by Haidinger,[1] Von Rose,[2] Von Lasaulx,[3] Vom Rath,[4] and Mugge.[5]

Between 1912 and 1921 Watson[6] published three papers on the mineralogy and geology of Graves Mountain. His paper of 1912 contains the most complete account yet written. To it I am indebted for much of my data.

GENERAL GEOLOGY

Graves Mountain lies in a belt of sericite schists intruded by granites, diorites, and greenstones which are characteristic of much of the Piedmont geologic province. The regional strike of the schists is northeast, and the long axis of the monadnock trends in the same direction.

Graves Mountain itself is made up of fine-grained quartzite with anhedral, angular interlocking grains averaging 0.1 to 0.25 millimeters in diameter. Characteristic texture is shown in plate XI.

The weathered quartzite is soft and friable, in places crumbling when rubbed between the fingers. Samples of very fresh quartzite, obtained in an open cut in the saddle of the mountain, were dense and hard. Photomicrographs of the fresh quartzite are shown in plate XI.

Kyanite in single crystals and in aggregates of various sizes replaces the quartzite, particularly along the margins of the innumerable quartz veins that cut the quartzite. Pyrite, mostly altered to hematite on exposed surfaces, lazulite, and rutile are lesser constituents. It is the kyanite, however, with the network of quartz veins, that has largely given the great resistance to weathering of which the monadnock is evidence.

Along the road paralleling the northwest side of the mountain a freshly cut bank exposed quartz-sericite schist composed of quartz grains as much as 1 millimeter in length embedded in a foliated matrix of small quartz grains, clear sericite, and sericite stained by limonite. Such a rock could well be formed by shearing of the quartzite.

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[1]Haidinger, M. W., Die Rutilkrystalle von Graves' Mount in Georgia, U. S. N. A.: Akad. Wiss. Wien Sitzungsber, vol. 39, pp. 5–9, 1860.

[2]Von Rose, G., Uber eine neue Kreisformige Verwachsung des Rutils: Annalen der Physik (Poggendorff), vol. 115, pp. 643–49, 1862.

[3]Von Lasaulx, A., Optisch-mikroskopische Untersuchung der Krystalle des Lazulith von Graves Mountain, Lincoln County, Georgia, U. S. A.: Niederrhein. Gesell. Sitzungsber., p. 274, Bonn, 1883.

[4]Vom Rath, G., Die Krystalle aus Arkansas and Georgia eingehend verglichen: Naturh. Ver. preuss. Rheinlande Verh., 1877, p. 185; idem, 1884, p. 297; Ein neuer Beitrag zur Kenntnis der Krystallization des Cyanit: Groth's Zeitschr. Kryst. Min., vol. 5, p. 23, 1881.

[5]Mugge, O., Bemerkungen uber die Zwillingsbildung einiger Mineralien: Neues Jahrb., 1884, Band 1, p. 221; Zur Kenntnis der Flachen veranderungen durch Secondare Zwillingsbildung: Idem, 1886, Band 1, pp. 147–154; Mineralogische Notizen: Idem, 1897, Band 2, pp. 82–84.

[6]Watson, T. L., and Watson, J. W., A contribution to the geology and mineralogy of Graves Mountain, Georgia: Virginia Univ. Philos. Soc. Bull., Sci. ser., vol. 1, pp. 200–221, 1912. Watson, T. L., The rutile deposits of the eastern United States: U. S. Geol. Survey Bull. 580, pp. 391–392, 1915; Lazulite of Graves Mountain, Georgia, with notes on other occurrences in the United States: Washington Acad. Sci. Jour., vol. 11, pp. 386–391, 1921.

MINERALOGY

QUARTZ

The quartzite is cut by innumerable quartz veins ranging in width from less than 1 inch to 10 feet or more. The vein quartz is white, translucent, and vitreous in appearance, and although some strain shadows appear in thin sections, no evidence of granulation was observed. The contact between vein quartz and quartzite is generally sharp. Bladed kyanite and minute rutile crystals occur in the quartz.

PYRITE AND HEMATITE

Hard fresh quartzite from an open cut in the saddle of the mountain contains abundant pyrite, as shown in plate XI,A. Weathered quartzite from the same place contains hematite, and some specimens, particularly those containing rutile crystals, are composed chiefly of granular hematite. It seems reasonable to infer that the widespread development of hematite in the monadnock is the result of weathering of equally widespread pyrite. Botryoidal and reniform hematite, of apparently secondary origin, is abundant in the corn field on the north slope.

There is much limonite in both the quartzite and the kyanite. Commonly weathered kyanite crystals are coated with a brown mixture of sericite and limonite having the superficial appearance of weathered siderite.

ILMENITE

Several specimens of vein quartz containing large tabular crystals of ilmenite were found on the north slope of the mountain, but none was observed in place.

RUTILE

Graves Mountain is famed for the size and perfection of its rutile crystals, and in the last century several trenches were made just below the saddle on the north side in search of specimen material. Loose rocks from the trench highest in the saddle yielded highly lustrous sharp-faced crystals of small size. Larger crystals with more or less rounded edges are abundant on the slopes below the trenches, particularly in the cultivated field on the north side of the mountain, where fresh colluvial material is exposed each year by plowing. The largest crystal found during my visit measured 1½ by 2 inches and was once twinned. Many multiple-twinned crystals were collected here in the last century.

Rutile, in minute crystals, was present in all the thin sections examined as inclusions in vein quartz, kyanite, and lazulite.

LAZULITE

Lazulite is a hydrous phosphate of aluminum, iron, magnesium, and calcium. Belonging to the monoclinic system, it forms well-developed euhedral crystals of pyramidal habit and bright-blue color. The chemical and optical properties of this mineral have been given by Watson.[1] On the south slope of the higher summit are a number of exposures of weathered quartzite containing numerous lazulite crystals three-quarters of an inch or less in length. With the lazulite is abundant kyanite. The lazulite appears to be confined to a zone 2 or 3 feet wide, and all the observed exposures fall on a line striking N. 30° E., up the hillside toward the saddle. It was not possible to determine whether or not this strike was determined by a bedding plane. As quartz veins transect this zone without marginal enrichment, they do not appear to account for the distribution of the lazulite.

PYROPHYLLITE

Pyrophyllite is a hydrous aluminum silicate. It forms radiating fibrous aggregates a quarter of an inch to an inch in diameter, of pearly luster when fresh or shades of yellow and brown when iron-stained. In croppings on the southwest and south sides of the mountain the pyrophyllite occupies veins cutting the quartzite.

KYANITE

Kyanite, next to quartz, is the most abundant mineral in Graves Mountain. It is widely distributed throughout the quartzite, and, because it resists weathering, it controls the degree of roughness of exposed quartzite surfaces. The crags on the southwest end of the mountain show a characteristic weathering surface (plate X, A).

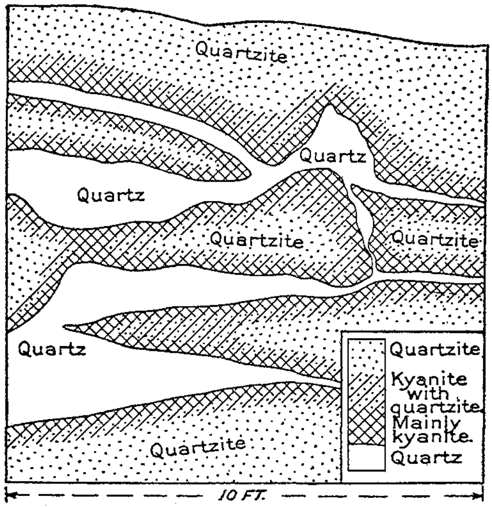


Fig. 4.—Sketch of a vertical face of quartzite on the southside of Graves Mountain near the summit. Kyanite is developed in the quartzite adjacent to quartz veins.

[1]Watson, T. L., Lazulite of Graves Mountain, Georgia, with notes on other occurrences in the United States: Washington Acad. Sci. Jour., vol. 11, pp. 386–391, 1921.

Three types of distribution through the quartzite were observed:

1. In more or less regular narrow planes of random orientation which, on weathered surfaces, resemble the pattern commonly shown by septaria in concretions. Plate X,B, is a photograph of an occurrence of this type which strongly suggests the filling of minute intersecting fractures by kyanite.

2. In zones of varying width marginal to the quartz veins, as shown in figure 4. This habit suggests replacement of the quartzite along the fractures now filled by quartz. The suggestion is strengthened by the fact that the kyanite is most abundant at the quartz contact and becomes less so away from the quartz.

3. In single crystals or groups of crystals without systematic arrangement in the quartzite and less commonly in the vein quartz.

Although no estimate of the total quantity of kyanite in Graves Mountain was attempted, estimates of the percentage of the area occupied by kyanite in several quartzite outcrops were made. Such estimates—more properly, perhaps, termed "guesstimates"—showed kyanite to constitute from 1 to 30 per cent of the quartzite.

Much of the kyanite has undergone sericitic alteration, the results of which are more conspicuously shown in thin section (plate XI,B) than in hand specimens.

Watson[1] gives the following analysis of the kyanite:

Analysis of kyanite from Graves Mountain

[J. Wilbur Watson, analyst]

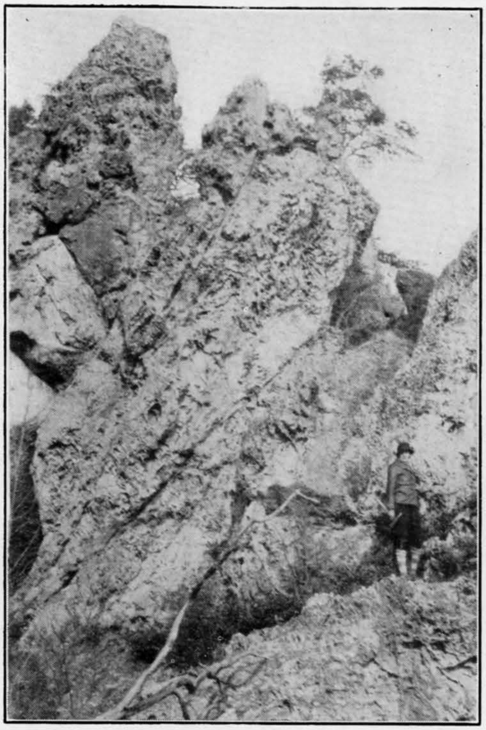
	Percentage	Molecular ratio
SiO_2	39.14	0.652 —1
Al_2O_3	59.52	0.581 } —1
Fe_2O_3	1.09	0.07 }
CaO	.18	0.004
MgO	0.40	0.009

Specific gravity 3.282.

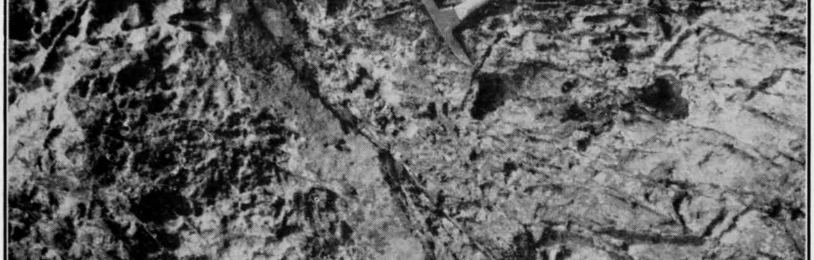
KYANITE ON THE WINGFIELD PLANTATION

Quartzite impregnated with kyanite crops out on the E. B. Wingfield plantation, 7 miles southeast of Washington on the Wrightsboro road. The outcrop extends for several hundred feet along a low ridge striking N. 60° E., approximately in line with Graves Mountain, 11 miles away. Near the center of the outcrop, where a ravine crosses the

[1]Watson, T. L., and Watson, J. W., op. cit., p. 218.



A. KYANITE-IMPREGNATED QUARTZITE FORMING CRAGS ON THE SOUTHWEST END OF GRAVES MOUNTAIN.



B. DETAIL OF A SHOWING THE DISTRIBUTION OF THE KYANITE.

ridge, is a large block of quartzite about 15 feet on a side, having the rough pitted surface with protruding kyanite that is characteristic of the quartzite of Graves Mountain. Further similarity is offered by the presence, in the quartzite of the Wingfield plantation, of disseminated pyrite crystals which have been altered to granular hematite, of quartz veins cutting the quartzite, and of quartz-sericite schists adjoining the quartzite on the northwest in the same position as at Graves Mountain. Dissimilarity is suggested by failure to find rutile, pyrophyllite, or lazulite in the quartzite of the Wingfield plantation. The strike of the long axis of the outcrop of this quartzite, the long axis of Graves Mountain, and a line connecting them are roughly parallel, trending N. 60° E. However, no quartzite could be found along the 11-mile line between the two outcrops.

ORIGIN OF THE KYANITE-RUTILE-LAZULITE MINERALIZATION

Watson[1] concluded that mineralization at Graves Mountain has been of three types:

(1) Kyanite, lazulite, and some rutile he regarded as the product of dynamic regional metamorphism; (2) the quartz veins carrying rutile and hematite as products of the deep vein zone; and (3) pyrophyllite, "from solution as the final stage of genesis."

Jonas[2] regarded the alteration of kyanite to muscovite as evidence of retrogressive metamorphism.

The principal observations pertinent to the genesis of the Graves Mountain mineralization are:

1. The distribution of kyanite is determined mainly by fissures and quartz veins.
2. Kyanite occurs in the quartz veins.
3. Pyrite is the source of the hematite.
4. Rutile is most common where hematite is most abundant.
5. Lazulite and disseminated kyanite occur together.

Observations on other Georgia deposits which give genetic information are:

1. Quartz veins in the Tate quadrangle, described on pages 23–25, contain large bladed kyanite crystals.
2. At Gumlog Mountain tourmaline is associated with the quartz and is not regional (p. 22).

These observations lead me to conclude that the mineralization at Graves Mountain is of hydrothermal origin. The kyanite-rutile-lazulite-quartz group of minerals were deposited in the deep vein zone. The pyrophyllite, though probably a later and lower-temperature mineral, is likewise hydrothermal. It is possible that the sericitization of the kyanite coincided with the introduction of the pyrophyllite and was not true retrogression.

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[1]Watson, T. L., and Watson, J. W., op. cit., p. 220.

[2]Jonas, A. I., Kyanite in Virginia: Virginia Geol. Survey Bull. 38, p. 14, 1932.

ECONOMIC VALUE OF THE GRAVES MOUNTAIN DEPOSIT

At the present time it appears unlikely that the Graves Mountain kyanite deposits could be mined with profit. Though large quantities of quartzite carrying possibly 10 per cent of kyanite are in sight, much experimental work on methods of concentration must be done before the value of the deposit is established.

KYANITE IN TALBOT AND UPSON COUNTIES

by Geoffrey W. Crickmay[1]

TOPOGRAPHY

Western Midland Georgia consists of a maturely dissected upland, the Greeneville Plateau[2], whose altitude over most of its areal extent ranges from 700 to 900 feet. In Upson and Talbot counties the rolling upland surface is surmounted by a number of sinuous quartzite ridges, which rise 100 to 400 feet above the upland. These ridges are part of a belt of hills that extend, with interruptions, from Chattahoochee River in Harris County to Barnesville, Lamar County, a total distance of about 65 miles. The belt consists of two main ridges, a northern one called Pine Mountain, and a southern one known as Oak Mountain. The mountain belt is crossed by only two streams, Flint River and Potato Creek, which have carved out valleys 100 to 400 feet deep. Due to the ruggedness of the ridges and the stony character of the soils that cover their slopes, they are but sparsely settled. The upland that surrounds the hill section is, however, one of the most populous rural sections in the state.

GENERAL GEOLOGY

The mountain belt described above is underlain by mica schist, biotite gneiss, and quartzite probably of pre-Cambrian age, collectively known as the Pine Mountain series.[3] The series comprises two formations: the Hollis quartzite,[4] overlain by the Manchester formation.[5] The Hollis quartzite consists of about 400 feet of medium to fine-grained micaceous quartzite, which, on account of its resistance to erosion, forms the core of many of the ridges. The Manchester formation is made up mainly of scaly mica schist and garnet-biotite gneiss. It includes a prominent quartzite member, 50 to 300 feet thick, about 850 feet above the base. All these rocks are classed as metamorphic for their original characteristics have been entirely surplanted by a new

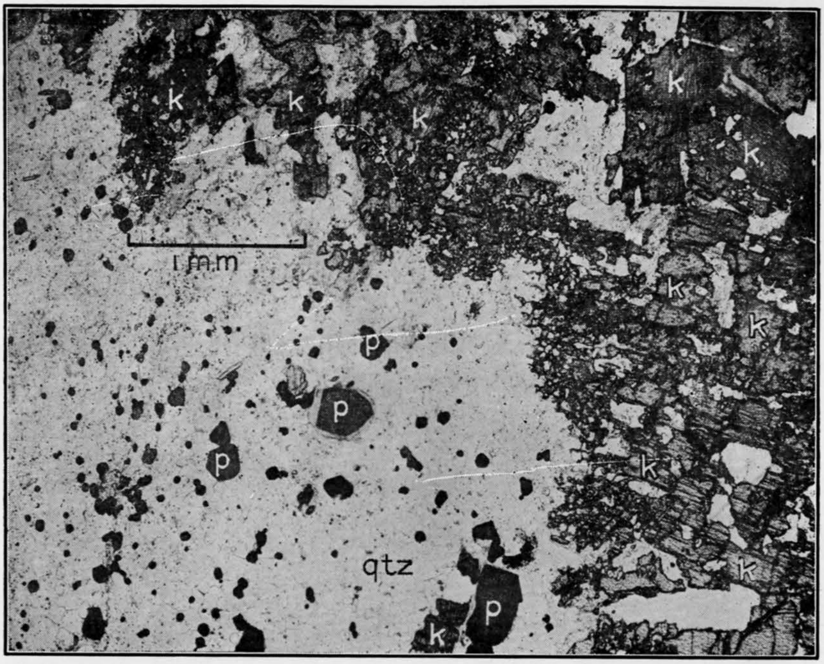
[1]Assistant State Geologist of Georgia.

[2]LaForge, Laurence, Physical geography of Georgia—The central upland: Georgia Geol. Survey, Bull. 42, pp. 77–80, 1925.

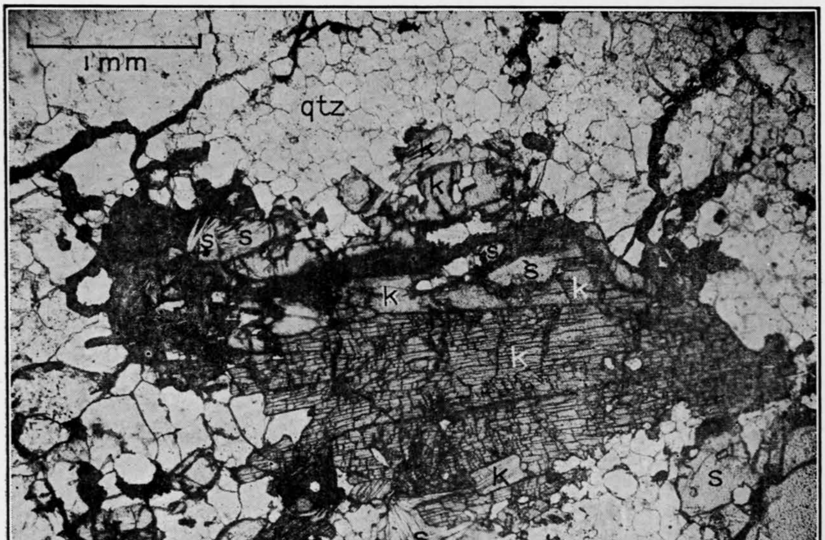
[3]Galpin, S. L., Feldspar and Mica Deposits of Georgia: Georgia Geol. Survey, Bull. 30, pp. 74–76, 1915.

[4]Named by George I. Adams from exposures near Hollis, 6 miles southeast of Opelika, Lee County, Alabama.

[5]A new name introduced here to include the schists and gneisses exposed between Manchester and Warm Springs, Meriwether County, Georgia.



A. THIN SECTION OF FRESH QUARTZITE FROM OPEN CUT IN THE SADDLE OF GRAVES MOUNTAIN. QUARTZITE (QTZ) IS REPLACED BY KYANITE (K) AND PYRITE (P). ONE NICOL, X 30.



B. THIN SECTION OF QUARTZITE FROM THE SOUTH SIDE OF GRAVES MOUNTAIN. QUARTZITE (QTZ) IS REPLACED BY KYANITE (K), WHICH IS ALTERED ON THE EDGES TO SERICITE (S). THE DARK CRACKS ARE FILLED WITH LIMONITE. ONE NICOL, X 30.

mineralogy and texture under the influence of high temperatures and compressive earth stresses. Typical minerals in the schist include biotite, muscovite, garnet, graphite, feldspar, and kyanite. At a few localities in Upson and Talbot counties, kyanite occurs in such concentration as to constitute possible commercial deposits.

The sedimentary series described above is intruded by igneous rocks, mainly biotite augen gneiss and garnet-hypersthene granite. Thin layers and stringers of pegmatite in places penetrate the schists parallel to the schistosity. The metamorphic rocks are cut by northward-trending dolerite dikes of Triassic age.

TALBOT COUNTY

WOODALL PROPERTY

Kyanite occurs on lot 99, 23d district, Talbot County. The property, owned by S. W. Woodall of Woodland, occupies a small valley, a quarter mile south of Oak Mountain. It lies one and a half miles east of Woodland, which is the nearest shipping point on the Atlanta, Birmingham and Coast Railway. The kyanite-bearing schist crops out a quarter of a mile west of Coleotchee Creek, and from 20 to 60 feet above its level.

Oak Mountain is composed of Hollis quartzite which here strikes N. 60°–85° E. and dips 40° to 60° S. The overlying Manchester formation consists mainly of fine-grained mica schist, in part graphitic, with thin interbeds of garnet-biotite gneiss and quartzite. The schistosity conforms in attitude to the Hollis quartzite, although in places it is contorted and puckered into minute regular crenulations. The kyanite-bearing schist occupies a position about 200 feet above the base of the Manchester formation and is about 30 feet thick. In this zone the schist contains quartz veins, pegmatite stringers and lenses, and thin cherty-quartz layers crowded with small euhedral garnets. The pegmatites, composed mainly of quartz, feldspar, and muscovite, are in general less than 2 inches in width and conform to the schistosity of the enclosing rocks.

Kyanite occurs in the pegmatite, quartz veins, and in the adjoining schist. The crystals possess the typical bladed form with a white to blue color. The surfaces of the crystals are commonly speckled with small flakes of muscovite and graphite. The last-named mineral is present in many of the thin quartz veins that contain no kyanite. Many of the kyanite dornicks that lie about on the ground surface contain open spaces into which prisms of kyanite project, but it is possible that these cavities are secondary and due to the removal of kaolinized feldspar.

The large number of kyanite crystals that occur in the reddish-brown residual soil on this property prompted the owner to cut a series of trenches across the strike of the underlying rocks in order to determine the abundance of the mineral in the schists. The sections thus displayed show that the kyanite is not as abundant as surface indications might lead one to suspect. In a large measure it is restricted to thin lenses of pegmatite and quartz. The sparse distribution of the kyanite through the schist does not offer much encouragement for further development.

GARRETT PROPERTY

Kyanite is reported to occur on the south side of Oak Mountain on the east half of land lot No. 154, 22nd district. The property is 9 miles west of Woodland and 5 miles southeast of Shiloh. The owner, C. E. Garrett, of Woodland, reports that the crystals are fairly common on the ground surface. Specimens from this locality are a dark-gray kyanite whose color is determined by the abundance of included graphite flakes. The crystals are grouped in fan-shaped aggregates, 1 to 1½ inches in length. Further prospecting will be necessary to determine the extent and concentration of the mineral on this property.

UPSON COUNTY

RICHARDSON PROPERTIES

Kyanite occurs on a tract of land owned by M. Richardson on the west slope of Pine Mountain, about a mile north of Crest. The property extends eastward from the highway between Molena and Thomaston, being 6½ miles from Molena, and 10½ miles from Thomaston. A spur of the Central of Georgia Railway, used mainly for freight, extends from Crest to Thomaston.

Pine Mountain is a ridge of Hollis quartzite which froms a broad U-shaped loop east of Crest. Kyanite occurs in the overlying Manchester formation at approximately the same horizon as that on the Woodall property in Talbot County. The formation is made up of fine-grained, silvery mica schist in which biotite, muscovite, quartz, feldspar, and garnet are the commonest minerals. Tourmaline needles and irregular veinlets of pyrite, the latter partly altered to limonite, are locally abundant in thin layers. The schist is everywhere deeply weathered to a red to yellowish red soil. The ground surface is strewn with boulders of quartz and quartzite, and here and there with kyanite crystals.

The only exposures of the kyanite-bearing rocks is in a small gully on the edge of a field on lot 159, 15th district, a quarter of a mile west of the Richardson residence. Here the schist strikes north and dips 10° W. The kyanite occurs mainly in quartz veins and most abundantly near the margins of the veins. The crystals are in part coated with flakes of muscovite and graphite. Many of the kyanite blades have nearly square cross-section with average dimensions of 2 inches in length, half an inch in width, and slightly less than half an inch in thickness. Wedge-shaped aggregates with drusy open spaces, possibly of secondary origin, are not uncommon. Some of the crystals are bent and a few are broken and healed with quartz.

The lack of prospecting on this property prohibits an estimate of the value of the kyanite deposits. A ten-pound sample of weathered schist, stained red by iron oxides, was crushed and washed by panning, but only a few kyanite crystals were thus obtained. Practically all the kyanite appears to be restricted to the quartz veins which are but sparsely distributed through the schist. Due to the paucity of exposures the extent of the kyanite along the strike is undetermined. In view of these facts it seems doubtful if kyanite can be profitably recovered at this locality.

Half a mile east of the Richardson residence on lot 148, 15th district, crystals of kyanite are abundant in the stony soils on the lower slope of Pine Mountain. The mineral is said to occur sporadically along the mountain slope to within a short distance of Crest. A few test pits dug on the hillside reveal much-weathered mica schist striking N. and dipping westward. Several samples of the schist were crudely washed by Mr. Richardson and in all cases he obtained numerous small crystals of kyanite.

Prospecting of this property has not yet revealed any great concentration of kyanite. The mineral is certainly widely distributed through the rocks and it is possible that further search may bring to light deposits that can be profitably mined. Special consideration should be given to alluvial and colluvial deposits near the base of Pine Mountain, for it is in such accumulations that kyanite is commonly concentrated.

SMITH PROPERTY

Crystals of kyanite occur surficially half a mile west of Crest, on the western part of lot 180, 15th district. The property owned by Mr. George B. Smith of Crest, is crossed by a tributary of Hurricane Creek. The underlying rocks, as exposed on the public road, 200 yards north of the locality where kyanite was found, consist of silvery garnet-mica schist with thin layers of dark biotite gneiss and black graphitic schist. The schistosity strikes N. 20° E., and dips 10°-45° E. A few small pegmatite lenses are interlayered conformably in the schist.

No attempt has been made to determine the extent of the kyanite-bearing rocks at this locality. Surface showings, however, offer little promise of any rich deposits that are now concealed.

CHERRY PROPERTY

The Dolly Cherry property, consisting of lot 36, 16th district, 3½ miles southwest of Thomaston, is on a rolling upland between Bell Creek on the east and Potato Creek on the west. Deep residual soils conceal the bed rock. Many fragments of medium-grained feldspathic biotite gneiss, all considerably weathered, are scattered over the ground surface and indicate the prevailing rock type. Similar gneisses, some containing feldspar "eyes," are exposed along roads to the southwest and northeast. Fragments of mica schist are associated with the kyanite and it seems probable that the mineral is derived from a schist similar to the Manchester schist in the northern part of the county.

Kyanite is scattered over the ground surface in a zone 60 feet wide and at least 500 feet long. The zone strikes N. 45° E., conformable to the prevailing structural trend. The kyanite crystals are stout prisms with average dimensions of 1.2 inches in length, 0.3 inches in width, and 0.2 inches in thickness. Many are bent and some are crinkled into little folds. Most of the crystals occur within an inch of the soil surface.

In an area of average concentration, 4 square feet yielded 5 ounces of the mineral, and a richer area of the same size yielded 9 ounces. From about a cubic foot of soil weighing 82 pounds, 12 ounces of kyanite were obtained by washing.

Although the Cherry property has not been prospected, the abundance of kyanite on the surface invites development. The mineral appears to have been derived from a mica schist containing garnet and staurolite, which probably forms a lenticular area in biotite gneiss. Further search should be directed toward the continuation of the kyanite zone to the southwest. It is possible that the mineral may be found in greater concentration in alluvial deposits near Potato Creek.

KYANITE IN FULTON COUNTY

by Geoffrey W. Crickmay

GENERAL FEATURES

The northern part of Fulton County consists of a rolling upland, the Atlanta Plateau[1], whose altitude ranges from 1,000 to 1,100 feet The upland is crossed by Chattahoochee River, which has intrenched itself in a valley 200 to 300 feet deep. The evenness of the upland is broken by a number of low quartzite ridges which trend in a northeast direction, revealing the strike of the underlying rocks.

The area is underlain by the pre-Cambrian Carolina series, which here consists of medium-grained biotite gneiss, biotite schist, and quartzite. The prevailing dip is 25°-70° SE. but the regional trend is commonly obscured by local contortions. The sedimentary metamorphic rocks are intruded by masses of granite gneiss, from which thin stringers of granite and pegmatite extend into the invaded rocks parallel to their schistosity.

CARTER PROPERTY

Kyanite occurs on lot 35, 17th district, Fulton County, owned by T. M. Carter. The property is on the north side of the Dunwoody-Sandy Springs road, 1½ miles southwest of Dunwoody. It is 6 miles N. NW. of Chamblee, the nearest shipping point on the Southern Railway, and 12 miles north of Atlanta.

Kyanite is freely scattered on the ground surface in a belt 320 feet wide that extends from the Carter residence for at least 600 feet to the northeast. These surface crystals mark a zone of kyanite-garnet-mica schist which strikes N. 30° E. and dips 20°-35° SE. The kyanite occurs as small blades in mica schist, oriented paralled to the direction of schistosity, and as pencil-shaped crystals in narrow pegmatite and quartz veins that penetrate the schist. The kyanite in the quartz has a strong tendency to be grouped in layers and oriented parallel to the margins of the veins. The kyanite-bearing rocks are bounded on the

[1]LaForge, Laurence, Physical geography of Georgia—The central upland: Georgia Geol Survey, Bull. 42, pp. 69–74, 1925.

southeast by quartzite and quartz-mica schist that form a low ridge whose crest is marked by the public road. It is possible that the quartzite, on account of its topographic expression, will prove valuable in tracing the kyanite zone where outcrops are absent.

Although the Carter property has never been thoroughly prospected, it is thought that surface indications justify further development. There is insufficient concentration in the residual soil to warrant recovery of kyanite from that source alone, but the schist of the bedrock is so completely weathered that little difficulty should be encountered in crushing and screening. The kyanite appears to be confined to thin layers separated by barren schist. It is important, as a first step, to determine the abundance of these kyanite-rich layers so as to evaluate the possible recovery from the whole zone. Concentration of the mineral by washing will necessitate a good supply of water which can not be obtained close at hand. Marsh Creek, a small tributary of Chattahoochee River, lies half a mile to the north and is the nearest continuously flowing stream.

ORIGIN OF KYANITE

by Louis M. Prindle

Kyanite in north Georgia occurs in schists of sedimentary origin and as massive kyanite in veins. At Graves Mountain it occurs in quartzite. At Dahlonega it is associated with sulphides in gold quartz veins.

When rocks are folded, overturned, and thrust one upon another the conditions of temperature and pressure undergo great changes, and minerals become transformed to others in closer equilibrium with the new conditions. Orogenic stress has been emphasized by Niggli[1] as an activating cause to bring about such transformations. Kyanite as a mineral resulting from regional metamorphism could thus be developed.

The increased pressures and temperatures due to the influence of intruding masses of igneous rocks also brings about changes in mineral composition partly by transforming material already present and partly by introducing new material. The influence of hydrothermal metamorphism has been far-reaching and regional metamorphism and hydrothermal metamorphism grade into each other[2].

The evidence available indicates a hydrothermal origin for the massive kyanite. It is associated with corundum, sillimanite, and tourmaline in a series of rocks ranging from pegmatites to quartz veins. The wide distribution of tourmaline in the western counties of Georgia and its presence in some places in impressive quantities afford evidence of extensive hydrothermal action. It is believed further that to this action has been largely due the migration of kyanite material in the

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[1]Niggli, Paul, Sachs. Gessell. Wiss., Math. phys. Kl., Ber. u. d. Verh., Band 76, p. 226, 1915.

[2]Daubree, M., Etudes et experiences synthetiques sur le metamorphisme et sur la formation des roches cristallines: Annales des mines. Mem., 5th ser., vol. 16, p. 455, 1859.

schists to form the massive kyanite in the veins. This is suggested in the above quotation from Bayley, where he states that the kyanite "has replaced the quartz in consequence of reactions between the silica and the aluminous components of the schists." The same may be true of the quartz-kyanite-graphite veins where carbonaceous material from the enclosing carbonaceous schist may have migrated along with the kyanitic material to form the graphite of the veins[1].

ECONOMIC POSSIBLITIES OF KYANITE IN GEORGIA

The development of a kyanite-mining industry in Georgia appears to be dependent for the most part upon the kyanite available in the schists.

The placer deposits that are being mined near Clarkesville contain a sufficient supply to last for several years at the present rate of mining. The placer deposits in the northern part of the belt on Sawmill, McClain, and Stonewall Creeks, in the Nantahala National Forest, contain a noteworthy additional supply of placer kyanite.

The localities best situated for hard-rock mining are those in the highland areas from Rapor Creek north, where the streams have cut deep, steep-walled valleys across the belt. Opportunity is thus afforded for mining operations parallel with the strike of the schist, with a water supply favorable for such operations.

Massive kyanite is widely distributed, but so far as known it occurs in many scattered small veins only a few feet thick. The distribution in the individual veins is such that parts of a vein may be found to be rich in kyanite and other parts comparatively barren. Although hundreds of pounds may be recovered from such occurrences, the pockety habit precludes reliance upon the massive kyanite for a constant supply.

In case supplies of massive kyanite should become available, the treatment of massive kyanite imported from India by the Chas. F. Taylor & Sons Co., of Cincinnati, Ohio, is of interest. This treatment has been described by Riddle[2] as follows:

"The ore is shipped to Cincinnati, Ohio, in the original boulder form. There the boulders are piled into a round down-draft brick kiln and calcined to a temperature well above the conversion temperature of cone 12. Calcining the ore requires several days and not only produces a product that will be free from any conversion volume changes in later burns but also breaks up the boulders so that they are easily crushed and ground to desired sizes for manufacturing purposes."

ADAPTABILITY

The wide distribution of kyanite gives assurance of quantity, but the low content of kyanite in the rock necessitates the handling of much

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[1]Winchell, A. N., A theory for the origin of graphite as exemplified in the graphite deposit near Dillon, Mont.: Econ. Geology, vol. 6, pp. 218–230, 1911.

[2]Riddle, F. H., Mining and treatment of the sillimanite group of minerals and their use in ceramic products: Am. Inst. Min. Met. Eng. Tech. Pub. 460, pp. 13–14, 1932.

waste material. For this reason efficient low-cost methods of mining and treatment will be necessary. Important work along this line is being accomplished by the United States Bureau of Mines. The preliminary results of their experiments are given below.

With the solution of the problems of mining and concentration the qualities of the mineral itself come into play. A difficulty that has been encountered with kyanite is the expansion it undergoes when heated to high temperatures. This has been emphasized by Greig[1] as follows:

"The expansion of cyanite during the alteration to mullite and silica is so great that any ware made largely from this mineral would probably be shattered on firing. The difficulty may be overcome by changing the mineral to mullite and silica before forming it into ware."

He states further that a few minutes at temperatures above 1,400° C. will suffice to change the mineral to mullite and that as the material then becomes friable it can be more easily ground.

A conspicuous quality of kyanite is its perfect cleavage and tendency to break into fibers repeating to a microscopic degree the shape of the original crystal. The fibrous rocks are in general the toughest, and it would appear that the fibrous character of kyanite would perhaps be one of its most valuable properties with reference to its adaptability for various present uses or uses that may develop.

Advantage has been taken of this fibrous character by the Vitrefrax Corporation in California in its applications of the ore at Ogilby, Calif., described by Riddle[2] as follows:

"One industrial application of the product takes advantage of the fact that small needlelike grains of the ore swell slightly and elongate considerably on conversion. If incorporated in a ceramic body prior to elongation, they elongate during firing and increase the mechanical strength of the body. The crystals work best if they are heated just below the conversion point and then incorporated."

The importance of the fibrous structure is further emphasized in an important article by Curtis[3].

The useful properties of kyanite have been summarized by Watkins[4] as follows:

"It has been found that the properties which make kyanite valuable as a constituent in refractory and porcelain bodies are (1) its high melting point, (2) high thermodielectrical resistance, (3) low coefficient of expansion, and (4) its resistance to the corrosive action of certain fluxing agencies and furnace gases."

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[1]Greig, J. W., Formation of mullite from cyanite, andalusite, and sillimanite: Am. Ceramic Soc. Jour., vol. 8, p. 482, 1925.

[2]Riddle, F. H., op. cit. p. 12.

[3]Curtis, T. S., The physical structure of refractory materials: Am. Ceramic Soc. Jour., vol. 11, pp. 904–916.

[4]Jonas, A. I., and Watkins, J. H., Kyanite in Virginia: Virginia Geol. Survey Bull. 38, p. 44, 1932.

BENEFICIATION OF KYANITE[1]

by B. W. Gandrud[2]

An investigation is being made by the United States Bureau of Mines at its Southern experiment station to determine the possibility of recovering a commercial-grade kyanite from kyanite-bearing schist. The ore samples being used were collected by the United States Geological Survey.

The only sample of kyanite ore on which ore-dressing tests have been completed contains kyanite crystals loosely embedded in a micaceous kyanite-garnet schist. Apparently it is representative of a number of samples that have been received for test. The ore contains about 4 per cent of kyanite, with a gangue composed mainly of mica, quartz, graphite, pyrite, garnet, and an oxidized iron mineral.

The ore is easily crushed; grinding in crushers, rolls, or ball mills is selective. The kyanite resists breaking and concentrates in the coarser sizes, while the micaceous gangue crumbles and segregates in the finer material. When the individual grain size of the mica is reached the grinding becomes difficult, but at this point the kyanite has already been liberated.

Float and sink and sizing tests have given considerable data on the physical character of the ore. A small amount of coarse, free kyanite, which sinks in a liquid of 3.3 specific gravity, is liberated in the size minus 0.371-inch plus 3-mesh. Material coarser than 8-mesh contains a large proportion of locked kyanite, most of which is freed by crushing through 6-mesh. The maximum mean size of the garnet is about 14-mesh; sizes coarser than this sinking in a liquid of 3.3 specific gravity contain little garnet, whereas the finer material contains appreciable garnet.

The ore is amenable to hydraulic classification and table concentration. The coarser spigot products of a classifier are markedly enriched in kyanite. The proportion of this mineral decreases rapidly from the coarse to the fine spigots, and the proportion of garnet and sand increases. The overflow is largely mica, with some fine sand, garnet, and iron; it can be rejected as a tailing.[3]

In preliminary table tests on spigot products a large amount of tailing was rejected, a concentrate was recovered, and a middling was collected for re-treatment. The middling was "tumbled" in a ball mill, classified, and tabled, and products were obtained that were comparable to those separated in the primary tabling. The recovery and grade of concentrate that are possible have not been determined, but concentrates containing about 90 per cent of kyanite were produced. The tabling of

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[1]Published by permission of the Director, U. S. Bureau of Mines (not subject to copyright).

[2]Supervising engineer, Southern experiment station, U. S. Bureau of Mines, Tuscaloosa, Ala.

[3]Note: The State Geologist wishes to call attention to the possibly of recovering a by-product of fine mica suitable for use in the manufacture of artifical roofings.

the finer sizes, in which both the kyanite and the gangue mineral are liberated, showed a good separation. The mica was obtained nearest the head motion end of the table, then the sand, next the kyanite, and finally, high up on the concentrate end, was a zone containing a large proportion of pyrite, oxidized iron, and garnet. The efficiency of removal of these last-named constituents has not been determined.

Flotation tests have been made on a kyanite product from laboratory table concentration. The graphite and pyrite were floated first, and then the kyanite. A clean concentrate was recovered, and mica, garnet, and various gangue minerals were depressed in the tailing.

The detailed results of those experiments will be published later by the United States Bureau of Mines.

VERMICULITE

by Louis M. Prindle and Richard W. Smith

INTRODUCTORY STATEMENT

The term "vermiculite" is applied to a group of hydrous micaceous minerals which, when heated to red heat or above, expand or exfoliate to a very light, fluffy material. It is this spectacular power of expansion, often resulting in a material weighing only 5 to 10 pounds per cubic foot, which gives it the name of "vermiculite," meaning "to breed worms." This exfoliation is probably due to the chemically-combined water being suddenly turned to steam, forcing apart the microscopic flakes or plates of which the material is composed. The expansion is always at right angles to the cleavage. Most varieties of vermiculite are of a brown or bronze color which brightens on exfoliation.

USES

Vermiculite, like kyanite, is another example of a mineral long known in mineral collections, but considered valueless until recent uses have brought it into commercial prominence. The uses to which exfoliated vermiculite has recently been put may be listed under two groups: first, those dependent on the bright bronze color of the material; and second, those dependent upon its extreme lightness and its heat-insulating and acoustical properties.

The brighter colors of ground and exfoliated vermiculite may be used in pigments and inks in place of powdered bronze. It is stated[1] that the bronze-colored background on the packages of a popular brand of cigarettes is printed with an ink made from vermiculite powder. The material may also be used as a paint pigment or kalsomine by tinting to the desired color, and is used as a decorative material on wall paper.[2]

[1]Smith, R. W., Vermiculite, the heat insulator of tomorrow: Forestry-Geological Rev., vol. 4, no. 5, p. 7, Atlanta, Georgia, May, 1934.

[2]Petar, A. V., Vermiculite: U. S. Bur. Mines, Information Circ. 6720, p. 2, May, 1933.

The exfoliated vermiculite is an excellent heat insulator. When used to fill the hollow spaces in walls and over ceilings it is said to make houses warmer in winter and cooler in summer. Manufactured into insulating boards, it can be used between two sheets of metal in the form of standard units for the pre-fabricated metal houses of the future that were predicted by the exhibits at the Century of Progress Exposition at Chicago. Similarly, it can be used to insulate air-conditioned Pullman cars, refrigerators, ovens, fireless cookers, incubators, etc. Vermiculite has the added advantage of being fireproof. Insulating board made from vermiculite is said to stand exposure to 1,700° F. without any appreciable expansion or contraction.[1]

Heat-insulating bricks made by using a suitable binder with exfoliated vermiculite can be used with a fire brick lining in boiler settings and furnaces with a considerable reduction in the weight and thickness of the walls necessary. Plastic cements containing vermiculite have good insulating qualities. Pipe and boiler coverings containing expanded vermiculite are said to be lighter in weight and more effective than with asbestos.

Wall board and wall plasters using exfoliated vermiculite are not only fireproof but are said to have excellent acoustic properties, making them of value in the construction of theaters, moving picture studios, apartments, etc.

The lubricating qualities of vermiculite are said to be comparable to those of flake graphite. It also has the property of coagulating or hardening oils so that it may be used instead of aluminum stearate, and at the same time serve as a valuable lubricant.[2]

ORIGIN

Vermiculite is commonly associated with intrusions of ultra-basic igneous rocks composed largely of pyroxene or olivine, such as pyroxenites and dunites. The deposits at places form a zone or envelope of alteration products surrounding the basic intrusion or occurring as irregular veins within the intrusion. The pure vermiculite is in discontinuous vertical layers or streaks up to a few feet in thickness, surrounded by clay containing flakes of vermiculite, chloritic material, and other alteration products. Corundum is very common. Small pegmatite streaks and "veins" parallel to the schistosity are numerous.

The commercial vermiculite appears to be a product of hydrothermal alteration of biotite mica. The biotite loses its elasticity and its glistening black color and becomes a golden yellow or bronze color. The final stages of the basic intrusion probably brought in heated mineralized waters that altered the surrounding rocks and perhaps portions of the basic intrusion. It is not known whether or not the alteration to vermiculite was completed at this stage. It is possible that the hydrothermal alteration accomplished by the waters accompanying the basic

[1]Petar, A. V., Op. cit., p. 2.
[2]Petar, A. V., Op. cit., p. 3.

intrusion simply formed an envelope of such products as muscovite, biotite, and chlorite schists which were later altered to vermiculite by heated waters that accompanied the intrusion of pegmatites. It is noteworthy that near Gladesville in Jasper County, Georgia, a large pegmatite dike contains crystals of biotite mica an inch or two across which have been altered to vermiculite.

OCCURRENCE

The largest known deposit of vermiculite is near Libby in northwestern Montana. This deposit, according to descriptions[1], is associated with an area of pyroxenite, 3½ miles long and 1½ miles wide. The rock ranges in character from one made up almost entirely of pyroxene to one composed mostly of biotite. The biotite has been altered to vermiculite on a large scale by hot solutions. At the time the descriptions referred to were written, the Zonolite Company had exposed one body of vermiculite 1,000 feet long, 100 feet wide, to a depth of over 100 feet.

Other deposits have been found in Montana and in Wyoming and Colorado.

NORTH CAROLINA

Deposits of vermiculite have been found at a number of places in North Carolina. Several of these deposits are described below.

The corundum deposits at Corundum Hill, about 9 miles southeast of Franklin in Macon County, N. C., were described by Pratt and Lewis[2] who noted the association of the corundum with vermiculite in a zone of alteration products surrounding the dunite intrusion. Several carloads of vermiculite were mined from this deposit in 1934 by the Georgia-Carolina Minerals Corporation of Franklin, N. C. The vermiculite at one place was found to be in the form of a vertical tabular body six feet in thickness. It was succeeded still farther away from the dunite by chloritic material of variable composition.

Vermiculite has also been found in an old corundum mine on Commissioner Creek in Macon County, N. C., a short distance north of the Georgia state line on the Clayton-Franklin highway. Recent mining has exposed a deposit of the vermiculite several feet thick in contact with a massive basic rock. Philip S. Hoyt, manager of the Georgia-Carolina Minerals Corporation, reports[3] that the basic intrusion has been traced southwestward to the upper valley of Betty Creek in Georgia where vermiculite has also been found.

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[1]Pardee, J. T., and Larsen, E. S., Deposits of vermiculite and other minerals in the Rainy Creek Cistrict, near Libby, Montana: U. S. Geol. Survey Bull. 805, pp. 17–28, 1929.
The stock of alkaline rocks near Libby, Montana: Jour. of Geology, vol. 37, pp. 97–112, 1929.

[2]Pratt, J. H., and Lewis, J. V., Corundum and the peridotites of western North Carolina: North Carolina Geol. Survey, vol. I, 1905.

[3]Personal communication.

Similar deposits of vermiculite are known to occur in the Shooting Creek section of Clay County, N. C. Some of these appear to be a continuation of the vermiculite deposits of Towns County, Georgia, described below.

DISTRIBUTION IN GEORGIA

Outcrops of ultra-basic rocks of the type associated with the known deposits of vermiculite occur at many places throughout the Piedmont plateau and mountain sections of Georgia and have been described in connection with the corundum deposits[1] and the deposits of asbestos, talc, and soapstone[2]. They are especially abundant in a belt that enters the State from Alabama in Troup and Harris counties and extends northeastward, entering North Carolina from Towns and Rabun counties. Vermiculite has been found with these basic rocks at many localities, for example, near Atlanta, Hapeville, Newnan, and Warm Springs, but the only known deposits of sufficient purity to be of possible commercial value are in Towns and Rabun counties.

TOWNS COUNTY

JETHRO BURRELL PROPERTY

Considerable prospecting for vermiculite has been done on the property of Jethro Burrell near the mouth of Scattaway Creek, about five miles east of Hiwassee on the Hiwassee-Clayton highway (plate VII). The deposits are in a rock of igneous origin so thoroughly altered that it is difficult to tell the nature of the original rock. The decomposed bedrock is soft enough to be cut almost like cheese. It is a reddish brown color, mottled with white derived apparently from pegmatitic material. A pegmatite dike, also decomposed, cuts across the other material with a strike N. 70° W. and a dip 45° SW. Patches and flakes of vermiculite are distributed irregularly through the reddish mottled material, some of the flakes being two inches or more in diameter. They appear to be larger near the pegmatite dike, but the exposures are not extensive enough to tell whether this was general or merely local. The proportion of vermiculite is not great, judging from the sparsely disseminated flakes, and it would be necessary to handle a large amount of material to obtain a small amount of vermiculite.

The trend of these rocks is northeast and they were followed for a mile to the point where they cross a road about a quarter of a mile north of the highway. A cross section of the beds exposed in the road showed a little vermiculite at intervals over a distance of 100 feet. Further prospecting throughout this area might possibly disclose a larger deposit.

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[1]King, F. P., The corundum deposits of Georgia: Georgia Geol. Survey, Bull. 2, 1894.

[2]Hopkins, O. B., A report on the asbestos, talc, and soapstone deposits of Georgia: Georgia Geol. Survey, Bull. 29, 1914.

LEMONS GAP

Vermiculite has been found on the Cozad Estate at Lemons Gap on the high ridge between Hightower Creek and Shooting Creek, about seven miles in a straight line northeast of Hiwassee. The locality may be reached by a road up Hightower Creek to the foot of the ridge, thence by a trail up the steep slope of the ridge some 800 feet above the valley and westward for a mile along the ridge to Lemons Gap. The Gap may also be reached from the north by a trail that climbs over 1,200 feet from the settlement on Giesky Branch of Shooting Creek in North Carolina. The narrow, level-topped ridge, cut by the depression known as Lemons Gap, trends N. 27° E. and merges with higher ridges and peaks to the northeast and southwest.

The ridges are underlain mainly by biotite gneisses, the gneissic structure trending N. 30° E. at the gap and dipping 25° SW. Fresh hornblende gneisses are present in the southwest part of the gap. A short distance farther along the ridge line to the northeast areas of partly altered rusty dike material alternate with areas of vermiculite. The width of this assemblage on the ridge line is about 80 feet. Vermiculite can be traced down the slope to the north a distance of 300 feet, a vertical distance of 30 feet. Farther down the slope briars, bushes, and timber bury the bedrock.

Several small prospect holes have been dug near the ridge. Some of these show a good grade of vermiculite. At other places much partly-altered rock is present with the vermiculite. The vermiculite appears to be a product of hydrothermal metamorphism and a continuation in depth would be expected. The altered rock contained no mica and no vermiculite but a considerable amount of iron, and the large quantity of this barren rock would detract from the value of the deposit. The amount of the original rock from which the vermiculite has been derived also seemed to be limited. This locality, therefore, can hardly be regarded as a dependable source for a supply of vermiculite.

The vermiculite at Lemons Gap appeared to be cut off to the southwest by the hornblende gneisses. It has been traced northeast into North Carolina along a line trending N. 20° E. Norman S. Poole of Hiwassee, who prospected the deposits at Lemons Gap, has found vermiculite at several localities at intervals over a distance of four miles in the area drained by Giesky Creek, a tributary of Shooting Creek.

RABUN COUNTY

LAUREL CREEK

A large part of the corundum at the famous Laurel Creek corundum mine in the northwestern part of Rabun County, 15 miles west of Clayton, was embedded in a matrix of vermiculite in a zone of alteration products surrounding the peridotite mass and in irregular veins cutting through the peridotite. The early corundum miners took advantage of the exfoliation of the vermiculite and its consequent light weight to clean the corundum. The ore from the mine was fed through a crude furnace, the heat of which expanded the vermiculite and the draft carried it out the stack, the corundum being discharged through the bottom of the furnace. No vermiculite is now exposed in the old workings, and the remaining deposits may be deeply buried.

BETTY CREEK

A little vermiculite has been found in the upper valley of Betty Creek, west of the Clayton-Franklin Highway, along the line of strike of the deposits on Commissioner Creek in North Carolina (see page 43). The extent of the deposits is not known.

SUMMARY

The localities described above at which vermiculite has been prospected in Georgia do not give much promise of deposits of commercial vermiculite of any size. It should be noted that the deposits in Towns County and those in North Carolina are nearly all on the same line trending northeast and southwest. It is possible that deposits in Georgia of more commercial importance may be found within this zone.

The vermiculite that has been mined and sold in North Carolina has been pure enough to be marketable after being mined by hand methods which allow a separation of the pure material from the inferior grades, followed by air-drying of the material. Considerable commercial material could probably be recovered from the deposits thus far discovered in Georgia by some washing process that would remove the clay, sand, and other impurities, but such a process would probably increase the cost of mining and recovery to a point at which the commercial vermiculite could not compete with that from the western deposits. The future of the vermiculite industry in Georgia probably depends on the discovery of deposits sufficiently pure to be marketed without an expensive treatment process before expansion. The expansion of the vermiculite must be done near the point of consumption as the exfoliated product is too bulky to stand shipment for long distances.

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