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THE MT. MONTRO KYANITE DEPOSIT
GRAND BASSA COUNTY, LIBERIA

by

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U. S. GEOLOGICAL SURVEY
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5. Aeromagnetic map of the McNair-Grand Portage area, northeastern Minnesota, by the U. S. Geological Survey. 1 sheet, scale 1:125,000.

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6. The Mt. Montro kyanite deposit, Grand Bassa County, Liberia, by S. Anthony Stanin and Bismarck R. Cooper. 33 p., 4 pl., 1 fig., 1 table.

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THE MT. MONTRO KYANITE DEPOSIT

GRAND BASSA COUNTY, LIBERIA

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ABSTRACT

The Mt. Montro kyanite deposit, 14 miles north of Buchanan, Grand Bassa County, Liberia, is near the middle of a belt of kyanite-bearing gneisses and schists that is 9 miles long and 1 mile wide. The deposit, which seems to be the most persistent and the largest single body of kyanite rocks in the belt, is approximately 12,600 feet long, as much as 480 feet in outcrop width, and from 25 to 350 feet thick. Kyanite-quartz-biotite-feldspar-garnet-muscovite gneiss, local interbeds of kyanite-mica schist, and lesser amounts of biotite-quartz gneiss, are the principal rocks in the deposit. Other rocks in the kyanite belt include garnet-biotite gneiss, undifferentiated quartzo-feldspathic gneiss, quartzite, and amphibolite. The rocks are the product of regional metamorphism to almandine amphibolite facies. The regional strike is northwest and dips are southwest.

Kyanite crystals are as much as 3 inches long. The kyanite content ranges from 5.8 to 46.7 percent, but most rocks contain between 10 and 35 percent. Garnetiferous beds contain as much as 15 percent red garnets that range to half an inch in diameter. In general, the garnet-rich beds are found in the upper part of the deposit.

The total reserves of the Mt. Montro kyanite deposit are estimated at about 10 million tons of kyanitic rock containing approximately 2.5 million tons of kyanite. These estimates include measured, indicated, and inferred reserves, calculated to depths of 25 to 100 feet, on the assumption that open-cut mining to those depths would be feasible. The largest part of the deposit underlies Mt. Montro and contains about 8 million tons of kyanitic rock containing nearly 1.9 million tons of kyanite. Residual soil overlying the deposit averages about 5 feet in thickness and is estimated to comprise slightly more than 400,000 cubic yards of material containing about 186,000 tons of kyanite.

The proximity of the kyanite deposit to a paved highway, to port facilities at Buchanan, and to water, electrical power, and timber resources are considered favorable factors relevant to possible development.

Introduction

Purpose and scope of the report

Evaluation of a kyanite deposit located in the Mt. Montro area, Grand Bassa County, Liberia (fig. 1), was undertaken cooperatively by the Liberian Geological Survey and the U. S. Geological Survey as part of the Geological Exploration and Resources Appraisal Program sponsored by the Government of Liberia and the U. S. Agency for International Development. This report presents the results of that investigation.

Location and accessibility

The area investigated is 14 miles north of Buchanan and lies midway between the Mechlin River and the town of Harrisville (fig. 1). It is named after Mt. Montro, a conspicuous ridge about 3,600 feet long that rises slightly more than 200 feet above the surrounding countryside.

Many small villages, of which the largest are the communities of Fortsville and Hartford, are scattered throughout the region. The Harbel-Buchanan paved highway, which crosses the northwestern part of the area adjacent to Mt. Montro, provides excellent access. The climate is tropical with a rainy season from June to October and a dry season from October to May. Second-growth jungle, broken by patches of rice, cassava, sugar cane, corn, coffee, fruit, and rubber cultivation, covers the area.

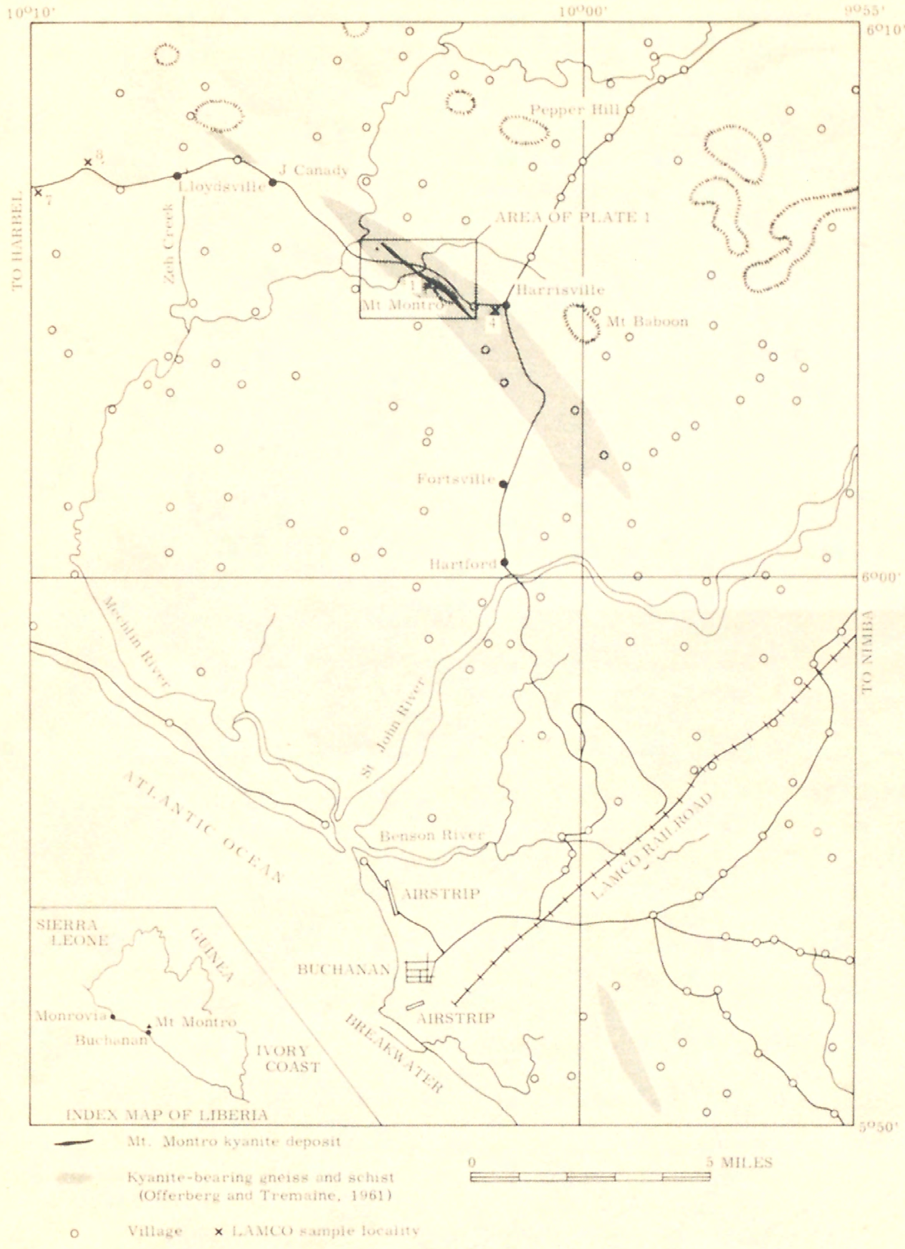

Figure 1.-Index map showing the location of the Mt. Montro area and the regional pattern of the kyanite formation

Previous investigations

Geologic investigations by the Liberian American-Swedish Minerals Company (LAMCO) between 1958 and 1960 included studies of the Mt. Montro area (Offerberg and Tremaine, 1961, p. 20, 50-55). They delimited a belt of kyanite-bearing rocks (fig. 1) about 9 miles long and 1 mile wide, which includes Mt. Montro, and roughly estimated the volume of the hill as 4 million cubic meters. Beneficiation tests and chemical analyses of kyanite-bearing samples indicated that some of the rocks contain as much as 22 percent kyanite by weight (Offerberg and Tremaine, 1961, p. 55).

Present work

The investigation reported herein was made during the latter part of 1966 and early 1967. A reconnaissance of the main zone of kyanite-bearing gneiss mapped by Offerberg and Tremaine (1961, p. 20-21, 51) confirmed that the most persistent and possibly thickest zone of kyanite-rich rocks underlies the Mt. Montro area. Our investigations were, therefore, concentrated on rocks in that region.

Comparatively small areas of outcrop are separated by large areas of soil cover, and most exposures are further obscured by thick vegetation. For this reason a series of exploration traverses was cut across the prospect area perpendicular to the regional strike of the rocks. These lines, ranging from 700 to 1,500 feet in length and spaced at intervals of 250 to 1,000 feet, were surveyed with Brunton compass, tape, and Abney level. Traverse lines parallel to the flanks and along the crest of Mt. Montro and its extensions were also cleared and surveyed.

Bench marks at the Mechlin River, 0.7 mile west of the mapped area, and in the town of Harrisville, 0.8 mile east of the mapped area, provided the mean sea level datum. Altitudes calculated at more than 800 surveyed stations provided the data for plotting the contours shown on plate 1.

Outcrops found along the survey lines were measured and sampled. In covered areas 41 pits and trenches sunk to bedrock also were sampled. The distribution of outcrops and pit locations is shown on plate 1. Field descriptions of some of the rocks examined are on file in the depository of the Liberian Geological Survey.

Chip samples weighing 10 to 20 pounds were collected from outcrops and from bedrock reached in pits. In several pits the rock was sufficiently decayed to permit taking channel samples, but most of the rocks are extremely hard and attempts to take channel samples resulted in obtaining only insignificant amounts of powdery material.

All samples were crushed to minus 1/4-inch and smaller splits were ground to minus 20 mesh for mechanical analysis. Nearly pure concentrates of kyanite were obtained by heavy liquid and magnetic separations, and the percent of kyanite was determined by weight.

Acknowledgments

The assistance of field foreman Varney Freeman and the laboratory technicians of the Liberian Geological Survey who processed and concentrated samples for analyses is gratefully acknowledged. The authors especially appreciate the invaluable assistance of S. P. Srivastava who undertook the analytical work and determined the percentages of kyanite and specific gravities used for this report. The authors also acknowledge the cooperation and helpful suggestions offered by staff members during the course of report preparation.

Regional geologic setting

Offerberg and Tremaine (1961) mapped kyanite-bearing gneisses and schists underlying an area that extends from approximately 1.25 miles east of Fortsville northwest to beyond the Mechlin River (fig. 1). Within this semi-arcuate belt, topographic ridges and the foliation of geologic units strike N. 30°-50°W. in the southeastern part, N. 45°-62°W. near the central part, and N. 50°-55°W. farther to the northwest; dips range from 40° to 75°SW. Kyanite zones appear to be lenticular in places and either pinch out or grade into non-kyanitic biotite-quartz gneiss, quartzite, or rocks of variable biotite-quartz-feldspar-garnet-muscovite composition.

Kyanite, quartz, and biotite are the principal minerals in the kyanite zones and generally compose as much as 90 percent of the rocks. Several percent of feldspar, garnet, and muscovite are found in places, and, less commonly, ilmenite and magnetite. Individual kyanite crystals in kyanite-rich layers are coarser on the average than those in layers in which kyanite is sparse. Quartz veins, lenses, and pods are more abundant in kyanite-poor rocks than in kyanite-rich rocks. In many quartzose zones, radiating and irregular clusters of kyanite laths as much as 4 inches long are concentrated along the contact of the quartz segments and the enclosing gneissic country rock.

The kyanite-bearing gneisses probably represent recrystallized argillaceous sandstone or intercalations of argillaceous and arenaceous units. The juxtaposition of kyanite-rich layers with veins and lenses of quartz suggests metamorphic differentiation of the original argillaceous sediments (Turner and Verhoogen, 1960, p. 583). Espenshade and Potter (1960, p. 37) in their studies of aluminum silicate deposits in the southeastern United States suggest the possibility that sequences of biotite gneiss in some parts of that region originally were graywacke. Kyanite-bearing gneisses and schists in the Mt. Montro region include thick sequences of biotite-quartz gneiss or biotite gneiss, and possibly represent metamorphosed graywacke.

In addition to kyanite-bearing gneisses and schists, Offerberg and Tremaine (1961) mapped several other types of metamorphic rocks near the belt of kyanite rocks, including garnet-biotite gneiss, undifferentiated quartzo-feldspathic gneiss, and amphibolite. Intercalated quartzite and mica gneiss have also been noted in the course of present investigations. Gneisses containing zoisite, clinopyroxene, or hornblende in addition to quartz, plagioclase, garnet, and micas crop out locally, immediately adjacent to or interlayered with kyanite-bearing gneisses. Most of these rocks are probably metasedimentary, although some amphibolite may be of igneous origin. The metamorphic grade generally corresponds to the kyanite-almandine-muscovite subfacies of the almandine facies. In view of the proximity of the kyanite belt to metasedimentary sequences containing iron formation (Goe and Fantro Ranges), as well as the presence of kyanitic schists and gneisses within these ranges, it has been conjectured (Offerberg and Tremaine, 1961, p. 21) that the kyanite gneisses of the Mt. Montro area may represent a part of those metasedimentary sequences rather than the crystalline basement.

Veins, lenses, stringers, and pods of quartz are found in all rock types. In several places, the veins are highly contorted; in other places both highly deformed and seemingly undeformed quartz veins and veinlets are found in the same outcrop. Diabase dikes cut the metamorphic rocks at a number of localities.

Mt. Montro kyanite deposit

The zone containing the bulk of the kyanite-rich rocks in the Mt. Montro area (pl. 1) is approximately 12,600 feet long and ranges from 30 to 480 feet in outcrop width and from 25 to 350 feet in stratigraphic thickness. Areas of outcrop are small and dispersed; therefore, the thickness of the deposit, attitude of beds, lithologic characteristics, and kyanite content were interpolated between outcrops investigated. The thickest continuous kyanite-bearing section is about 350 feet. The kyanite content ranges from 5.8 to 46.7 percent, but most is in the range of 10 and 35 percent (table 1).

Most of the outcrops are thin beds and lenses of fine- to medium-grained gneiss consisting of kyanite, quartz, biotite, feldspar, garnet, and muscovite; in places, biotite is abundant and the rocks are schistose. Thin beds and laminations of fine-grained biotite-quartz gneiss, quartzite, and biotitic quartzite, which are locally garnetiferous and contain disseminated grains or very thin layers or lenses of fine-grained kyanite, lie structurally above and below the kyanite deposit. In some places, interlensed schist and gneiss or mica schist are in contact with the kyanite deposit. Most of these rocks

Table 1.--Percentages of kyanite in samples from Mt. Montro kyanite deposit

Kyanite content (percent)	Stratigraphic thickness sampled (feet)	Percent of samples (weighted for sample interval per grade percent)
10	69	3.9
10-14.9	242	13.5
15-19.9	455	25.4
20-24.9	278	15.6
25-29.9	347	19.4
30-34.9	192	10.7
35-39.9	107	6.0
40-44.9	74	4.1
45	25	1.4
	1789	100.0

contain only local concentrations of kyanite. Barren or slightly kyanitic, fine-grained biotite-quartz gneiss and quartzite form layers up to several inches thick in many outcrops.

The upper part of the kyanite deposit is garnetiferous and, in places, medium-grained red garnets up to half an inch in diameter make up as much as 15 percent of the rock. Light-green, white, pale bluish-green, and gray kyanite laths, many ranging from 1 to more than 2 inches in length, are intermixed with other minerals or form layers in many intervals throughout much of the kyanite deposit. The kyanite crystals lie within foliation planes and their C-axes generally plunge southwest. Both kyanite and garnet crystals generally are larger in the upper part of the deposit.

Outcrops of kyanite gneiss commonly have rough and jagged surfaces caused by the resistance of kyanite and quartz to weathering; however, exposures of fresh rock are rather sparse because of tropical weathering. Hornblende-and feldspar-rich rocks tend to be altered to a much greater degree than rocks rich in kyanite, quartz, and muscovite. The mantle of decayed rock and residual soil ranges in thickness from a few feet to about 12 feet, although in places it may be much thicker. The thickness of the residual soil cover over the deposit ranges from 1 to 2.5 feet on ridge crests to 10 feet or more on the flanks, and the average thickness for the entire area is approximately 5 feet. Composite soil samples were found to contain between 19.9 and 40.2 percent kyanite by weight, and to average 31.1 percent. The content of kyanite in the residual soil overlying the kyanite deposit was generally found to be about 10 percent greater than the average determined for the underlying rocks.

The Mt. Montro kyanite deposit has been divided arbitrarily into five blocks (plate 4) to facilitate the discussion of local lithologic and structural features: the Northwest Block, the Gaga Hill Block, the Small Mechlin River Block, the Mt. Montro Block, and the Southeast Block.

Northwest Block

The Northwest Block includes the area northwest of the Harbel-Buchanan highway. The kyanite deposit is 30 to 50 feet in outcrop width for the northwest 2,100 feet. Small outcrop areas are intermittent over this distance and the measured thicknesses of exposed rocks range from 6 to 45 feet. The dominant rock exposed is fine- to medium-grained kyanite-quartz-biotite-feldspar-muscovite-garnet gneiss. Underlying the next 1,500 feet to the southeast, the width of the kyanite deposit ranges from 50 to 190 feet. At cross section A-A' (plate 1) the deposit is 150 feet thick, of which 85 feet is exposed in outcrop, pits, and trenches. An upper unit, 60 feet thick, is composed of fine- to medium-grained, slightly garnetiferous kyanite-biotite-quartz gneiss, micaceous gneiss, and kyanite-mica schist in the uppermost part, and of medium-grained highly garnetiferous kyanite-quartz-feldspar-biotite gneiss in the lower part. About 65 feet of nonkyanitic gneiss and mica schist containing quartz veins and lenses underlies the upper unit. Below this barren zone, a 25-foot thick unit of moderately garnetiferous kyanite gneiss makes up the lower part of the deposit.

About 600 feet farther southeast, the kyanite deposit is approximately 170 feet thick (pl. 2, B-B'). Outcrops are somewhat scarce and the thickness is based primarily on information obtained from pits. Rocks exposed in the upper part of the section are typically garnetiferous; lower in the section, the rocks appear to be less garnetiferous and more feldspathic, a fact that might account for the paucity of outcrops in this area.

The kyanite deposit becomes narrower farther southeast; in an outcrop area a few hundred feet north of the highway, it appears to be 35 to 45 feet thick. Rocks there contain many kyanite crystals as much as 1 inch in length and many garnets up to 0. 4 inch in diameter.

Gaga Hill Block

Gaga Hill Block includes the area from the highway southeast to the Small Mechlin River. Kyanitic beds about 130 feet thick (pl. 2, C-C') crop out in the northwestern part. The actual thickness of the deposit may be slightly more than that exposed, but garnet-rich beds at the top of the measured section suggest that most of the deposit is exposed. The major constituents of the rocks are many 1- to 1-1/2-inch kyanite crystals, garnet, quartz, biotite, and feldspar. The amount of kyanite and garnet differs from place to place, and in many locations thin layers and lenses of rock are enriched with one or both minerals. The rocks are coarser grained in the uppermost part of the sequence, where many kyanite crystals are 2 inches long.

The width and thickness of the deposit decreases to the southeast; and only a few small isolated outcrops are exposed in a distance of about 900 feet. Approximately midway between the village of Gaga and the Small Mechlin River, the kyanite deposit is at least 95 feet thick (pl. 2, D-D'). Weathered gneissic bedrock found at the bottom of the southwest wall of a trench on the northeastern slope of the hill contains some disseminated fine-grained kyanite. If these beds are included in the base of the kyanite deposit, the deposit here may be about 110 feet thick. Bedrock uncovered in a trench on the southwestern slope of the hill disclosed that the upper part of the kyanite deposit consists of interfingering layers of feldspathic and slightly garnetiferous biotite-quartz gneiss and biotite schist that contains kyanite; kyanite appears to be more abundant in the gneissic layers. These rocks grade upward into gneiss and schist that contain veinlets and stringers of quartz and a small amount of kyanite, generally disseminated along laminations. At the crest of the hill, an outcrop of kyanite gneiss contains many kyanite crystals 1 to 1-1/2 inches long and from 5 to 10 percent garnet. In the lower part of the section, the kyanite gneiss is finer grained and contains less kyanite and garnet.

The kyanite deposit is about 135 feet thick (pl. 2, E-E') near the Small Mechlin River. Approximately 90 feet of the deposit is well-exposed on the northeastern flank of Gaga Hill. The deposit overlies a unit of fine- to medium-grained quartzite and fine-grained biotite-quartz gneiss which contain irregular veins and pods of quartz. A few thin streaks and laminations of kyanite are found in these rocks near or at the contact with the overlying kyanite deposit. The lower part of the kyanite gneiss is deeply weathered and tends to crumble when broken. The rocks become progressively less kaolinitic and more garnetiferous toward the top part of the outcrop. Gneiss composed principally of kyanite, biotite, muscovite, and feldspar, but containing very little quartz, and kyanite-mica schist comprise the upper zone of the kyanite deposit in this part of the area.

Small Mechlin River Block

Most of the Small Mechlin River Block, which trends roughly parallel to the south bank of the Small Mechlin River, is low lying and is dissected by a number of stream channels. Exposures are intermittent and the rocks are variable in strike and dip. The average thickness of the kyanite deposit is estimated to be about 100 feet.

Mt. Montro Block

The Mt. Montro Block includes all of Mt. Montro, on which the outcrop width of the kyanite deposit ranges from 225 to 480 feet. In the northwestern part of this area, the deposit seems to be about 320 feet thick (pl. 2, F-F'), but the rocks are poorly exposed and the thickness is based on scattered outcrops and information obtained from pits. Exposures consist mostly of kyanite gneiss composed of kyanite, quartz, biotite, feldspar, and garnet. The garnet content is generally greater in the upper part of the section than in the lower part. In some pits the bedrock contains much muscovite and is very schistose. The more schistose rocks and micaceous beds tend to weather more rapidly and deeply than the gneissic layers, and, therefore, are more likely to be buried under residual soil.

Approximately 300 feet to the southeast, well-exposed outcrops are found in the saddle that separates the northwestern peak from the rest of Mt. Montro. A thickness of 275 feet of rock (pl. 2, G-G') is exposed, of which the upper 140 feet is a part of the kyanite deposit. A fairly distinct contact separates the kyanite beds from the underlying rocks. The same contact can be traced on strike southeastward for about 500 feet, where the rocks are covered. The kyanite-rich layer is underlain by nonkyanitic fine-grained biotite-quartz gneiss and quartzite containing a kyanite-bearing gneiss as the lowermost exposed unit. These rocks display smooth surfaces, in contrast to the rough, jagged, and pitted surfaces of rocks in the kyanite deposit. Most of the kyanite deposit is a kyanite-quartz-biotite-feldspar-garnet gneiss that is very feldspathic in places, contains a number of 2- to 4-inch thick layers of poorly kyanitic rocks in the lower part, and is quartzose and garnetiferous in the upper part. Locally, the rocks contain clusters of kyanite crystals that range from 2 to more than 3 inches in length.

Outcrops are scarce over the next 1,100 feet to the southeast. The bottom contact of the kyanite deposit was traced to section H-H' (pl. 2), about 300 feet southeast of the well-exposed outcrop area. Based on isolated outcrops and pits along this section, the kyanite deposit seems to be approximately 185 feet thick. Outcrops are kyanite gneiss, and the bedrock in pits is generally mica-rich kyanite gneiss and kyanite-mica schist. Close to the top of the sequence, the bedrock in a pit on the southwestern slope of the ridge was found to be rich in kyanite and garnet. Most kyanite crystals are 2 to 3 inches long in radiating clusters and bunches. The garnets are both disseminated and crowded in layers throughout the rock. Samples of rock taken at this locality have the highest kyanite content (43. 9 percent by weight) obtained on samples from the Mt. Montro Block.

The kyanite deposit maintains a 185 foot thickness for the next 800 feet to the southeast (pl. 2, I-I'). Most outcrops are gneisses composed of kyanite, quartz, biotite, feldspar, and garnet, and in the upper part the deposit is more garnetiferous. Bedrock in pits appears schistose, rich in muscovite, and poor in quartz.

Along the highest part of Mt. Montro, the outcrop width of the kyanite deposit is between 290 and 330 feet over a distance of about 550 feet. The deposit is 255 feet thick along section J-J' (pl. 3). The only outcrops of the kyanite deposit in this area are found on the upper northeastern slope of the hill, where the rocks are rich in kyanite. The kyanite content (42. 9 percent) is the second highest of all samples collected on Mt. Montro. Most kyanite crystals are more than 2 inches long, and many massive layers contain crystals 3 inches or more in length. The bedrock in pits is somewhat schistose, and several layers in these rocks contain a large amount of muscovite.

The kyanite deposit continues to increase in width southeastward. About 500 feet to the southeast (pl. 3, K-K') the outcrop width of the deposit is 450 feet, and rocks are better exposed. The overall thickness is about 350 feet. Garnetiferous kyanite gneiss containing many 2-inch-long crystals of kyanite crops out in the upper part of the deposit. Lower in the deposit the rocks are finer grained and the kyanite crystals range from 1/2 to 1 inch in length. Many beds in the middle part of the deposit are somewhat schistose, and the outcrops on both upper slopes of the ridge are composed of interlayered schistose kyanite gneiss and kyanite-mica schist. The lower part of the deposit is mostly weathered gneisses which are very kaolinitic in places; they probably are richer in feldspar than the overlying beds.

The kyanite deposit attains its greatest outcrop width, about 480 feet, near the southeastern end of Mt. Montro. The deposit, most of which is exposed, is slightly more than 350 feet thick (pl. 3, L-L'). The uppermost 25 feet contains many veins and pods of quartz and several lenses of feldspar and kyanite. The underlying 75 feet of gneiss is more garnetiferous and locally contains patches and pods of coarse-grained muscovite. Some quartzose lenses in these rocks are fringed with radiating bunched kyanite crystals 2 to 3 inches in length. Many feldspar lenses are intercalated in the kyanite gneiss in the succeeding lower 150 feet of rocks. The lowermost interval is micaceous in part and the rocks contain numerous patches or books of muscovite; locally the rocks contain much quartz. Kyanite commonly forms needle-like projections on the rock surfaces.

Three hundred feet to the southeast (pl. 3, M-M'), the outcrop width of the kyanite deposit decreases to about 435 feet, with stratigraphic thickness of about 335 feet. The rocks in the upper part of the deposit contain at least 15 percent garnet. Quartzose lenses containing radiating clusters of kyanite and pods of muscovite are found in many beds in the middle part. Locally in this part of the deposit and more commonly in beds in the lower part, irregularly spaced layers as much as 2 inches thick of fine-grained biotite-quartz gneiss contain little or no kyanite.

The continuity of the kyanite deposit to the southeast over the remaining segment of the Mt. Montro Block is based on several outcrops, abundant float, and the concentration of kyanite in the residual soil. The deposit outcrop becomes narrower to the southeast so that at the southeast limit of the block the outcrop is about 225 feet wide.

Southeast Block

The kyanite zone in the Southeast Block, which includes the area southeast of Mt. Montro, is approximately 1,750 feet long and from 35 to 225 feet in width of outcrop. About 400 feet southeast of the Mt. Montro Block, weathered, ferruginous, and limonitic gneissic bedrock containing 6 to 12 percent kyanite was found in a group of pits located across the strike of the kyanite zone; the maximum width of the deposit seems to be about 200 feet.

Approximately 75 feet farther southeast, a 60-foot thick layer of kyanite gneiss is exposed over an area about 75 feet wide and 250 feet long. The rocks in the lower part of the deposit are fine- to medium-grained, slightly feldspathic, and micaceous. Many kyanite crystals in these beds are 1/4 to 1/2 inch long. Kyanite and garnet crystals increase in quantity and size upward in the deposit. The upper beds contain more than 30 percent kyanite, and most crystals are 2 inches or more in length. The same beds contain more than 15 percent garnet, and many garnets are between 1/4 and 1/2 inch across. Between the above-mentioned outcrops and the next outcrop, 750 feet to the southeast, the kyanite zone is represented by kyanitic float and soil.

Garnetiferous kyanite gneiss crops out in an area 75 feet wide and 275 feet long at the southeastern limit of the Mt. Montro kyanite deposit. The kyanite gneiss is 25 feet thick and is underlain by a fine-grained quartzite which is slightly garnetiferous in part and contains traces of pyrite. The deposit is overlain by foliated fine-grained biotite-quartz gneiss that is slightly garnetiferous and contains a few disseminated crystals of kyanite.

Reserves

The total reserves, in all categories for the Mt. Montro kyanite deposit, to depths of 25 to 100 feet, are estimated to be 10,150,000 tons of kyanitic rock and 411,000 cubic yards of overlying residual soil containing, respectively, 2,480,000 and 186,000 tons of kyanite mineral (table 2; pl. 4).

Different minable depths of 25 to 100 feet were assumed for different parts of the area on the assumption that opencut mining might be carried deeper on the higher parts of Mt. Montro, whereas open pits in the lower areas might be limited by ground-water levels. To determine the reserves of kyanitic rock in each block, the tonnages of smaller segments within each block (pl. 4) as influenced by the local thickness of beds, tonnage factors, grade, and assumed minable depths were determined first; the total of these calculations gave the reserve figures. Grade was calculated to the nearest 0.1 percent, thickness to the nearest 1 foot, and the tonnage factor, determined from specific gravity measurements, to the nearest 0.1 cubic foot per ton.

Table 2.--Total reserves of kyanitic rock, overlying residual soil, and contained kyanite mineral in the Mt. Montro kyanite deposit

Block	Kyanitic rock (thousand tons)	Kyanite (thousand tons)	Residual soil (thousand cubic yards)	Kyanite (thousand tons)
Northwest	1,049	372	55	27
Gaga Hill	623	157	39	22
Small Mechlin River	100	20	19	10
Mt. Montro	8,074	1,880	278	114
Southeast	304	51	20	13
Total	10,150	2,480	411	186

The estimated volume and kyanite content of residual soil overlying the deposit were calculated from data obtained from pits and trenches and interpolated between localities; local differences in volume, percent of kyanite, and tonnage factors were taken into account. The average kyanite content determined from a number of composite channel samples taken from the walls of pits and trenches is 31.1 percent. Tonnage factors range from 18.8 to 22.4 cubic feet per ton. The average thickness of soil overlying the entire area is about 5 feet, and, in general, the kyanite content of soil samples was found to be 10 percent greater than that of samples from underlying rocks. Volumes are calculated to the nearest thousand cubic yards and tonnages of kyanite to the nearest thousand tons.

Total reserves for the Mt. Montro kyanite deposit have been estimated for the area delimited on plates 1 and 4. This estimate includes measured, indicated, and inferred reserves; information on the grade and continuity of the deposit is not sufficient to justify separating these categories at present. Reserve figures are subject to error owing to a number of factors, some of which are: (1) kyanitic rocks were sampled at localities as much as a thousand feet apart and grade was interpolated between those localities; (2) the limits of the deposit are not everywhere exposed and were only approximated in a number of places; (3) most measured sections include large covered areas and the assumption was made that these are underlain by kyanite-bearing rocks; (4) all analyses were of samples of partially weathered rock collected from outcrops and from pits; and (5) the effects of possible structural and stratigraphic complexities cannot be taken into account because of lack of information.

Partial analyses of selected kyanitic materials and concentrates from the Mt. Montro area are shown in table 3. Comparison of the tabulated results of the partial benefication tests with U. S. National Stockpile Purchase Specification P-27-R of February 1960 for kyanite suggests that the Mt. Montro kyanite would meet specified quality standards and might be generally accepted by consumers.

However, laboratory batch tests, chemical and spectrographic analyses, and pyrometric cone equivalent values are required on a greater number of bulk samples to determine the commercial grade. These tests might also lead to the identification of potentially valuable by-products; at the Celo Mine near Burnsville, North Carolina, garnet and mica were recovered as salable products (Klinefelter and Cooper, 1961, p. 26). Minerals other than kyanite might make parts of the deposit unsuitable and expensive to process to meet consumer requirements. Feldspar, kaolin, and muscovite in kyanite concentrates tend to lower the alumina content and decrease the load-bearing strength and the electrical properties of the product. Kyanite used in ceramic products should have a low iron content, as iron causes undesirable discoloration at high temperatures (Mason, 1966, p. 10). Kyanite containing as much as 0.7 percent hydrochloric acid-soluble iron oxide is generally accepted by consumers (McVay and Browning, 1963, p. 7).

Economic aspects

The major uses of kyanite and related Al_2SiO_5 minerals are in the manufacture of refractories for metallurgical and glass furnaces, electric and chemical porcelain ware, and other ceramic products. Research has resulted in the discovery of numerous new uses for kyanite products. Newer applications include heat-resisting components for space vehicles and hypersonic aircraft (Johnson, 1967, p. 4) and in railroad brake shoes (Cooper, 1966, p. 586).

The demand for kyanite in the world market has increased steadily in recent years, according to Cooper (1966, p. 564). The latest available figures for production of kyanite and related minerals (andalusite, sillimanite, and topaz) are shown on table 4. The price of kyanite has increased from the $29 per short ton figure of 1958 to $47 in 1965.

Table 4. --Production of kyanite and related minerals, 1963-65 (in short tons), in some major kyanite producing areas.

	1963	1964	1965(9 months)
Southern Rhodesia	60[1]	258[1]	528[3]
South Africa	73,027[2]	75,643[1]	59,904[3]
Southwest Africa	not available	612[1]	not available
India	47,343[1]	51,206[1]	not available
South Korea	2,208[1]	123[3]	not available
Australia	3,937[1]	2,950[3]	not available

(1)Cooper, 1965a, p. 661

(2)Cooper, 1965b, p. 485

(3)Cooper, 1966, p. 565-6

The growing demand for kyanite products might provide the impetus needed for consideration of the Mt. Montro kyanite deposit by mining circles. In addition to the probability that the Mt. Montro area contains large workable deposits of kyanitic rocks, other important economic factors are favorable. Access to the area is excellent. The Harbel-Buchanan highway passes within 800 feet of most of the deposit and provides a paved route to the port of Buchanan, about 20 miles southeast.

The Small Mechlin River and the Mechlin River should provide ample water for mining and camp use. Whether the volume of water from these sources would be sufficient for milling and concentrating operations, particularly at the end of the dry season when the rivers run low, is not known. The St. John River, about 6 miles southeast (8 miles via highway) from the area, could supply all water requirements, or might be considered a site for a processing plant to which bulk ore could be transported by trucks.

Power transmission lines pass adjacent to the prospect area and could supply the electrical power needs for mine, plant, and camp operations. The thick forest in the region should be able to furnish most of the timber required for mining and construction purposes.

Recommendations

The Mt. Montro kyanite deposit seems to be of sufficient purity and size to be of interest to private industry, and the most desirable development would be for them to continue work at this stage. However, the deposits are poorly exposed and further proving of reserves by government agencies may be necessary.

Additional geologic exploration and appraisal should include test stripping across the width of the deposit by bulldozer and a drilling program to obtain information at depth. Bulk samples of ore should be taken for testing to determine its commercial grade and the possibility of recovery of valuable by-products. An economic feasibility study should be made of mining, ore processing, transportation, and marketing.

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