ONTARIO

DEPARTMENT OF MINES

KYANITE AND SILLIMANITE IN ONTARIO

by

D. F. Hewitt

Table of Contents

KYANITE AND SILLIMANITE IN ONTARIO

by

D. F. Hewitt

INTRODUCTION

Kyanite and sillimanite are two common members of the sillimanite group of minerals, which are used chiefly in the manufacture of alumina-silica refractories. Kyanite and sillimanite both have the formula $Al_2O_3 . SiO_2$, and owe their usefulness to the fact that, on heating, they break down to form a mixture of mullite and silica. Mullite is an important refractory material, and kyanite and sillimanite are the chief source of mullite in nature. Mullite is highly refractory; it has low thermal expansion and therefore high resistance to heat-shock, medium thermal conductivity, high load-bearing ability even at high temperatures, and resistance to chemical corrosion especially by acid slags.

Kyanite and sillimanite are high-grade metamorphic minerals characteristically found in gneisses and schists that have been subjected to high temperatures and pressures. Kyanite deposits recently found in Ontario and which appear to warrant commercial development are described in this report. Kyanite and sillimanite gneisses and schists occur in several places in the province, the deposits in the Mattawa and Sudbury areas being of particular interest.

COMPOSITION AND PROPERTIES

Kyanite

The mineral kyanite, $Al_2O_3 . SiO_2$, has the composition: alumina 62.93 percent; silica 37.07 percent. It occurs commonly in blades, laths, or a radiating crystal habit, and ranges in colour from white, through grey, to brilliant blue or green. The lustre is pearly to vitreous. Kyanite shows good cleavage in two directions and basal parting, and has the peculiar property of exhibiting different hardnesses in different directions. It has a hardness of 4, parallel to its long axis, and a hardness of 7, across its width. It is triclinic in crystal system. Its specific gravity is 3.53 - 3.67. Optically it is biaxial negative, with indices: a, 1.712 - 1.717; b, 1.720 - 1.722; c, 1.728 - 1.729.

On heating, kyanite breaks down between 1,100°C. and 1,480°C. to form mullite, $3Al_2O_3 . 2SiO_2$, and silica. There is no fixed temperature of breakdown, and the rate of breakdown varies with grain size, temperature, and time of calcining. On calcining, kyanite shows a large increase of volume and must therefore be pre-calcined before being used in the manufacture of refractory bodies. This large increase in volume on the part of kyanite gives a rather porous product; cracking and exfoliation increase the porosity above what would be expected from the change in density involved in the transition from kyanite to mullite and free silica. Massive granular kyanite from India forms a much less porous, denser, harder, and tougher grog for refractory bodies than does domestic United States kyanite, which occurs chiefly as coarse-bladed crystals that form a soft, friable grog. Ceramic tests are necessary to determine the characteristics of the grog produced by calcining kyanite of the various types, and for this reason ceramic tests are necessary before evaluation of a kyanite deposit can be made.[1]

Sillimanite

Sillimanite also has the formula $Al_2O_3 . SiO_2$. It commonly occurs as fine, fibrous, needle-like aggregates, as radiating prismatic crystals, or as white, fibrous sheaves or plumose aggregates with a silky sheen. It is vitreous to silky in lustre, and has a hardness of 7 - 7.5. Its specific gravity is 3.23 - 3.24. Sillimanite is orthorhombic, biaxial positive, and the refractive indices are: a, 1.657 - 1.661; b, 1.658 - 1.670; c, 1.677 - 1.684. Sillimanite has perfect cleavage parallel to its length. It ranges in colour from white or grey to yellow or brown. Sillimanite is more stable than kyanite and breaks down into mullite and silica between 1,550°C. and 1,650°C. with a slight increase in volume. It is not necessary to pre-calcine sillimanite before using it in refractory bodies.

---

[1] F. H. Riddle and W. R. Foster, "The Sillimanite Group," chap. 42, Industrial Minerals and Rocks, Amer. Inst. Min. and Met. Eng., 1949.

Andalusite

Andalusite, a third member of the sillimanite group, also having the formula $Al_2O_3 . SiO_2$, is another potential source of refractory material. One deposit has been worked commercially at White Mountain, California, by the Champion Sillimanite Corporation. Andalusite usually occurs in coarse, stubby, prismatic crystals in schists and gneisses. It has perfect prismatic cleavage, a hardness of 7.5, and a specific gravity of 3.16 - 3.20. The lustre is vitreous; the colour white, pearl grey, rose red, reddish brown or olive green. It is orthorhombic, biaxial negative. Few occurrences have been reported in Ontario, but its appearance is such that it might easily escape recognition.

Refractories

Sillimanite or mullite refractories have the following physical properties: P.C.E. or softening point, 38 (1,835°C.); true specific gravity, 3; porosity, 15 - 22 percent; approximate weight of a 9-inch brick, 8.4 pounds; linear coefficient of expansion (20°C. - 1,600°C.), 0.0000045 per centigrade degree; thermal conductivity (200°C. - 1,000°C.), 0.0045 cgs. units; specific heat (20°C. - 800°C.), 0.175 cgs. units; spalling index (SiC, 100) 90; deformation under load (25 p.s.i) 0 percent at 2,462°F., 1.0 percent at 2,900°F.; constancy of volume, no shrinkage at 3,000°F., 2.5 percent shrinkage at 3,200°F. These refractories are relatively insoluble in most glasses and slags, particularly those high in lime, alkalis, or fluorides. They are attacked by strongly basic slags or those high in Fe_2O_3.[1]

USES AND SPECIFICATIONS

Owing to their ability to sustain loads at high temperatures and their resistance to thermal shock, kyanite refractories are widely used in those portions of refractory installations where there is considerable wear, unusually high temperature, and where difficulty of replacement is a factor in choosing a refractory with long life. For example, kyanite refractories are often used for furnace door jams and arches, for burner blocks and burner tunnels for heat-treating furnaces, and for glass tanks.[2]

Kyanite refractories are used in some furnace linings in brass and bronze foundries and in some indirect arc-steel and ferrous-alloy furnaces. Kyanite refractories are said to be superior to high alumina and alumina-magnesia refractories where temperatures are consistently over 1,650°C.

Kyanite is also used in porcelain bodies, for some spark plug insulators, and for saggers and kiln furniture for the ceramic trade. Recently kyanite has been successfully used as a ceramic lining for jets of jet engine and for gas-turbine rotor blades; it is also used as a source of alumina for the glass batch.

The United States government is stockpiling this mineral and their specifications for kyanite call for a minimum of 59 percent alumina, a maximum of 39 percent silica, and a maximum of 0.75 percent iron oxide.

MODE OF OCCURRENCE

Since kyanite is a high-grade metamorphic mineral, it is nearly always found in metamorphic schists and gneisses in close association with such minerals as garnet, sillimanite, staurolite, muscovite, and albite. In northern Ontario kyanite occurs in coarse-grained, kyanite-garnet-muscovite-quartz-feldspar gneisses interbanded with hornblende amphibolites and in close proximity to granitic gneisses. In the main occurrence in southeastern Ontario, kyanite occurs as metacrysts in a sericite-quartz-sillimanite schist interbanded with staurolite schist and garnet amphibolite.

In one type of occurrence seen by the writer, the grey to blue kyanite crystals occur as "logs" or "laths" from 6 or 8 inches long and 2 inches wide, down to 1 or 2 inches long and 1/4 inch wide, in a fine-grained sericite-sillimanite schist.

In another type of occurrence grey, blue, or green kyanite crystals averaging 1/2 - 1 1/2 inches long and 3/16 - 1/4 inches wide occur in parallel orientation in a medium-grained gneiss with red garnet, muscovite, quartz, and feldspar. Sillimanite and biotite are sometimes present. In contrast to the former type of occurrence, these gneisses appear to have a reasonably uniform distribution of kyanite within the gneiss bands.

---

1 The Chas. Taylor Sons Co., Cincinnati, Ohio, Bull. No.107.

2 R. B. Heuer, "How and Where Kyanite Refractories are Used," Brick and Clay Record, Vol.100, March, 1942, No.3, pp. 50 - 51.

In a third type of occurrence, massive aggregates of medium-grained, radiating and interlocking, blue, green, or grey kyanite crystals averaging 1/2 inch long form rich bands and lenses of almost pure massive kyanite interbanded with quartz veinlets and granite pegmatite within the kyanite-garnet gneiss sequence.

Large crystals of bright blue kyanite often occur in quartz-feldspar veinlets and pegmatite dikelets cutting the kyanite gneiss.

In general, kyanite gneisses are found in alumina-rich bands within a highly metamorphosed terrane of gneisses, schists, and granitic rocks. For this reason the border region between the Timiskaming subprovince and the granitic terrane of the northern part of the Grenville subprovince, that is the belt extending roughly from the Espanola area eastward to the foot of Lake Timiskaming, is good prospecting ground for kyanite gneisses. Similarly the belt in the Grenville subprovince between the granitic terrane of the northern part of the Grenville subprovince, in Parry Sound and Nipissing districts, and the southerly Grenville limestone terrane also offers possibilities for the location of other kyanite and sillimanite gneiss occurrences.

KYANITE OCCURRENCES IN ONTARIO

Crocan Lake Kyanite Deposit

The property of the Kyanite Corporation of Canada, Limited, consists of a block of twenty-five claims in Antoine and Butler townships, district of Nipissing, centred around Crocan lake. The main deposit on the northeast end of Crocan lake is accessible by motor road from Mattawa, 22 miles to the southeast. The Crocan lake property is 2 miles west of the Ottawa river and 8 miles east of the North Bay - Timiskaming highway.

The deposit was discovered in the spring of 1951, and exploration and development work on the property have been carried out by J. Kenmey and the Golwynne Chemical Corporation of New York continuously since the discovery. A total of 2,530 feet of diamond-drilling, as well as a considerable amount of clearing and trenching, has been done. An area of seven acres has been cleared for an open-pit operation on a 180-foot kyanite gneiss ridge which forms the B zone at the northeast end of Crocan lake.

The deposit consists of a wide band of kyanite-garnet-muscovite-biotite-quartz-feldspar gneiss striking in a northeasterly direction and dipping flatly, 30° to the northwest. At the south end of Crocan lake the kyanite-garnet gneiss band has an apparent width of over 1,200 feet. At the north end of Crocan lake the kyanite-garnet gneiss occurs in two bands separated by quartzo-feldspathic paragneiss. The main or east band has an apparent width of 1,200 feet and a probable true thickness of 600 feet; it is well exposed in numerous outcrops along the east shore of Crocan lake and for a distance of over 3/4 mile along prominent strike ridges running northeast from Crocan lake. A good cross-section of this main band of kyanite-garnet gneiss can be seen along the lumber road from Timber creek to Crocan lake. The westerly band of kyanite gneiss has an apparent width of about 300 feet and a probable true thickness of 150 feet.

A third, smaller band of kyanite-garnet gneiss is reported 3/4 mile northwest of Crocan lake.

The hanging wall gneisses to the northwest are biotite amphibolites, the foot-wall gneisses to the southeast, biotite amphibolites with strong foliation. Half a mile to the southeast, the country rock is pink leuco-granite gneiss. The kyanite-garnet gneiss and quartzo-feldspathic paragneiss are cut by white granite pegmatite and diorite dikes.

The kyanite-garnet gneiss band is fairly uniform and consists of coarse-grained, flat-bladed, grey to blue kyanite crystals 1/2 - 3 inches long and 1/8 - 3/8 inches wide, with pinkish-mauve garnet crystals, up to 1/2 inch in diameter, black biotite, muscovite, quartz, and feldspar. The rock is foliated, but the flat kyanite blades are oriented at random in the plane of foliation. By the writer's visual estimate the kyanite appears to average between 12 and 20 percent of the rock. Some portions of the gneiss are higher in quartz and muscovite and lower in kyanite than the average rock exposed in the clearing at the northeast end of Crocan lake.

In addition to the occurrence of kyanite as a constituent of the gneisses, there are narrow lenses of massive kyanite-rich material in places along the contacts of the kyanite gneiss bands. These narrow lenses may run as high as 80 - 90 percent kyanite; but so far the lenses exposed are small. The A zone is located just northeast of the lumber road on claim S.58023 at the foot-wall contact of the main or easterly kyanite-garnet gneiss band. Here a small pit has been blasted in the southeast face of a low ridge, exposing grey kyanite-garnet-biotite-quartz-feldspar gneiss, in which ink-blue kyanite crystals, 1/4 inch by 1 inch, occur. Graphite occurs along slips and in granite pegmatite cutting the gneiss. In the pit there is a narrow 6 - 18-inch band consisting of 80 percent massive interlocking 1/4 - 1/2-inch grains of kyanite with interstitial graphite and muscovite. The gneisses strike N.50°E. and dip 75°NW.

The B zone is located on the hanging wall or west side of the main kyanite-garnet gneiss band, at the northeast end of Crocan lake. A stripping, 35 by 10 feet, exposes sheared greenish kyanite-quartz-biotite rock abundantly mineralized with sulphides. A trench extends 60 feet westward from this stripping and exposes narrow bands of kyanite-rich material interbanded with quartzite, quartz veinlets, and disseminated sulphides. Green kyanite, biotite, muscovite, feldspar, quartz, and sulphides are the main minerals present. Narrow 6 - 15-inch bands of kyanite-rich gneiss occur in this zone. The rock contains abundant sulphides and some graphite, and appears to be strongly sheared.

The C zone is a showing on a point on the west shore of Crocan lake. Lenses of pure, blue and blue-grey, massive, medium-grained kyanite associated with green (chrome?) mica and sulphides occur interbanded with rusty fine-grained quartzite, quartzo-feldspathic gneiss, and amphibolite, which are well mineralized with pyrite, pyrrhotite, and a little bornite. Values in copper, zinc, and nickel are reported from these sulphide-bearing rocks.

Since the writer's visit to the property, other kyanite-rich lenses have been found. The massive kyanite present in these lenses, lying along the contacts of the kyanite gneiss band, is of considerable economic interest, as high grade occurrences of this type are rare. These lenses of massive kyanite are associated with quartz-graphite-sulphide veins, and the segregation of kyanite into rich pockets associated with these veins appears to be due to hydrothermal or pneumatolytic activity. These deposits appear to be structurally controlled, in that all the lenses discovered, so far, lie along the contacts of the main kyanite gneiss band. Three of the lenses lie along the foot-wall contact, and one on the hanging wall contact.

The muscovite mica, which is an important constituent of the kyanite band, can be recovered in the milling of the kyanite gneiss, and preliminary examination indicates that this muscovite is of a quality suitable for the ground mica trade.

Wanapitei Kyanite Deposit

The kyanite property of the Hoyle Mining Company, Limited, consists of forty-four claims east of the village of Wanapitei in central Dryden township, district of Sudbury. The block of claims extends from lot 9, concession III, northeastward to lot 3, concession IV, Dryden township. The kyanite-garnet gneiss bands dip nearly vertically and strike in a northeasterly direction, roughly paralleling No.17 highway and the Canadian Pacific railway. The kyanite deposits are located adjacent to, and both north and south of, the railway and highway.

This deposit of kyanite-garnet gneiss was first noted by A. E. Barlow in 1897. In the Geological Survey of Canada report for that year[1] he described the occurrence of kyanite in a railway-cut 1/2 mile east of Wanapitei station on the C.P.R. as follows:

> "Here it occurs in flattened blade-like crystals and fragments, in association with a reddish almandine garnet in a mica-diorite gneiss ..... Fibrolite (sillimanite) also occurs in this locality, developed chiefly along certain crevices in the gneiss. It is fibrous or finely columnar in structure, and is traversed at right angles to the fibres by numerous fine cracks. Sometimes it occurs in curious irregularly radiating or plumose aggregates."

The kyanite-bearing rocks of the area were further described by A. P. Coleman[2] as follows:

> "The prevalent rock of the Grenville southeast of Sudbury is schistose or gneissoid, but differs greatly from the reddish Laurentian gneiss often interbanded with it. It is generally coarse in texture and grey or greenish grey and consists mainly of biotite, muscovite, and sometimes hornblende, quartz, and plagioclase, with many crystals of pale blue kyanite and often also of garnet. Prof. Walker first called my attention to the presence of kyanite in these rocks, suggesting the original material was clayey sandstone .....
>
> The kyanite gneisses begin three and a half miles north of the crystalline limestone and extend for half a mile south of it, but are lost before one reaches Wanup, halfway between miles 114 and 115, where diorite penetrated by coarse red pegmatite rises from the drift along Wanapitei river ....."

---

[1] A. E. Barlow, "Report on the Geology and Natural Resources of the Area Included by the Nipissing and Temiscaming Map Sheets," Geol. Surv. Can., Vol. X, 1897, rept. I, p.160.

[2] A. P. Coleman, "The Pre-Cambrian Rocks North of Lake Huron," Ont. Bur. Mines, Vol. XXIII, 1914, pt.1, pp. 209 - 11.

"Kyanite-garnet gneiss occurs at Wanapitei on the main line of the C.P.R., five miles northeast of the most northern outcrop of Grenville on the Toronto branch, but whether the Grenville gneisses extend farther in that direction is not known."

The Wanapitei kyanite was staked in June and July, 1952, by A. E. McVittie, J. P. McVittie, J. R. Cryderman, F. Chubb, and O. Maki. The main deposits are now held by the Hoyle Mining company. Up to the present time, very little development work has been done. The whole area is almost devoid of vegetation and the rock outcrops are well exposed. A 600-pound bulk channel sample across a 35-foot width of kyanite gneiss was taken in September for test purposes.

The kyanite is a coarse-grained, bladed, metamorphic mineral making up to 15 - 30 percent of the kyanite-garnet-biotite-quartz-feldspar gneiss in which it occurs. The bands of gneiss range from a few feet to 400 feet in width and have been traced in some cases for over 1/2 mile along strike. The kyanite gneiss bands dip nearly vertically and strike N.50° - 80°E. The kyanite is blue, green, or grey in colour and occurs in bladed and prismatic crystals from 1/4 to 4 inches in length, and from 1/16 to 1/2 inch in width. On weathered surfaces the kyanite stands up in prominent relief above all the other minerals, and the rock usually weathers to a distinctive reddish-brown, in contrast to the black-weathering garnet amphibolites with which it is associated. The minerals of the gneiss are strongly aligned; the kyanite in this area shows pronounced lineation in the plane of foliation, and care must be taken in estimating grade visually to take the orientation of the kyanite into account. On surfaces parallel to the elongation of the kyanite blades, a visual estimated grade is likely to be too high.

The garnets, which form a common constituent of the gneiss - ranging from 10 to 20 percent of the rock - are reddish-violet in colour, and occur not as well-formed single crystals, but as granoblastic aggregates from 1/4 to 4 inches in diameter. Frequently these garnet aggregates contain numerous inclusions of kyanite, quartz, and feldspar. In feldspar-rich bands of gneiss, the garnets stand up in relief, and may weather out to form loose concentrations of "snowball" garnets on the surface of the rock.

The foot-wall and hanging wall of the kyanite gneiss bands are dark coloured, medium to fine-grained, black-weathering, biotite and biotite-garnet amphibolites. Some narrow bands of biotite paragneiss and garnet-feldspar paragneiss also occur in the metasedimentary sequence. White granite pegmatites, cutting the kyanite-garnet gneiss and garnet amphibolite, are strongly sheared and mylonitized indicating a period of strong dynamic metamorphism of post-pegmatite age. Bright blue crystals of kyanite and fibrous aggregates of white sillimanite of the variety described by Barlow occur in these white pegmatite stringers.

The area as a whole shows much evidence of strong folding and faulting, which has resulted in considerable thickening, thinning, and drag-folding of the incompetent kyanite-garnet-biotite gneiss bands between bands of relatively competent garnet amphibolite. In some cases it is difficult to trace individual kyanite gneiss bands along strike because of faulting.

The main band of kyanite gneiss is well exposed 100 yards south of No.17 highway, 2 1/2 miles east of Wanapitei. Here there is a 400-foot band of kyanite-garnet gneiss, which can be traced for 1/2 - 3/8 of a mile eastward along strike. The gneiss is made up of coarse-grained kyanite and garnet in a finer aggregate of kyanite, biotite, quartz, and feldspar. The kyanite stands up in relief above the garnet, quartz, and feldspar on a weathered surface. The elongated kyanite crystals show a strong lineation pitching steeply eastward, parallel to the foliation of the rock. A visual estimate of the average grade of this kyanite gneiss was 25 percent, with some sections running somewhat higher.

To the north and south of this band of kyanite gneiss, the country rock is biotite-garnet amphibolite. There are some narrow 3 - 6-foot bands of kyanite gneiss interbanded with the garnet amphibolite.

A second band of kyanite gneiss is located 100 yards north of the Canadian Pacific railway 2 1/2 miles east of Wanapitei. Here there is exposed a 45-foot band of kyanite-garnet-biotite gneiss striking N.50°E. and dipping 65°N. A trench 35 feet long, 5 feet wide, and 6 - 18 inches deep has been excavated across the strike of the kyanite gneiss.

A larger zone of kyanite gneiss lies 100 yards north of the Canadian Pacific railway 2 3/4 miles east of Wanapitei. Here coarse-grained kyanite-garnet-biotite-muscovite-quartz-feldspar gneiss is well exposed on bare outcrops. The kyanite, by visual estimate, appears to make up from 25 - 35 percent of the rock and is coarsely crystalline, sometimes the crystals being up to 3 inches in length. The percentage of garnet is low, and muscovite is more common than in other localities in the area. There is much close folding and crenulation within the kyanite gneiss band and its true thickness is not determinable. A width of over 300 feet is exposed on surface, but this width is probably due to local thickening within the kyanite gneiss band. Irregular tongues and embayments of biotite-kyanite gneiss extend in various directions for some hundreds of feet into the garnet amphibolite country rock.

Other occurrences of kyanite gneiss have been reported in Street and Loughrin townships, district of Sudbury.

Fernleigh Kyanite Occurrence

The occurrence of kyanite on lot 26, concession X, Clarendon township, Frontenac county, was first reported by W.Miller and C. Knight[1] in 1913, in their report on the Precambrian geology of southeastern Ontario.

B. L. Smith[2] describes the occurrence as follows:

> "Remarkable for its continuity, a band of distinctive schist, which is seldom more than 100 yards wide, can be traced across the 9-mile width of Clarendon township and a further 15 miles northeastward across the townships of Palmerston, South Canonto, and Lavant. Over most of this distance, the schist is made up of muscovite, biotite, and feldspar and contains garnet and sillimanite. The presence of abundant hard "knobs", the size of hen's eggs, is characteristic.
>
> In the central part of Clarendon township, near Fernleigh, the schist contains, in places, considerable kyanite along with sillimanite and staurolite. The Fernleigh portion of the band is considered worthy of attention, having regard to the possibility of locating a commercial deposit of kyanite, which has use as a refractory material, as does sillimanite.
>
> The kyanite occurs in elongated crystals up to 8 inches in greatest dimension. Some of the best material is closely related to quartz veins, suggesting that hydrothermal activity may have been important in the formation of the deposit.
>
> One typical outcrop may be seen on the power line a little over half a mile northeast of Fernleigh post office, and there is another about 100 feet beyond the end of the road which runs northwest from the Ardoch-Fernleigh road at a point about 2 miles northeast of Fernleigh.
>
> This band of schist is much too small to be shown on the preliminary map, but it occurs across the township close to, and immediately north of, the fault which is shown on the map as forming the northwest boundary of the younger sediments."

The kyanite schist is well exposed in outcrops near the Ontario Hydro-electric power line, on a road running north from the Ardoch-Fernleigh road, 1/2 mile east of Fernleigh post office. Blue kyanite occurs as rounded, log-like crystals up to 6 inches long, 1 inch in diameter, and 1/2 - 5/8 inches thick. These crystals occur in a fine-grained, sheared sericite-sillimanite-quartz schist. The distribution of kyanite in the schist band, which is itself about 300 feet wide, is irregular. One band observed by the writer was 30 feet wide, and, in addition to the log-like kyanite crystals, it contained aggregates of radiating kyanite blades up to 1 inch long. The best grade of material may run 10 - 20 percent of kyanite over a 30-foot width. Some of the kyanite is dark grey to black in colour on fresh surfaces. Some bands of schist contain 1/4 - 2-inch, well-formed, brown staurolite crystals, which stand out on weathered surfaces.

Another occurrence of kyanite in the same band of schist is on lot 27, concession IX, Clarendon township. Here, in a farmer's field just north of the end of the farm lane, there is a low ridge of variable metamorphic schists and gneisses that include kyanite-sericite-sillimanite schist, garnet-kyanite gneiss, garnet amphibolite, and biotite paragneiss. The best showing of kyanite-sericite-sillimanite schist is on the north face of the east-west striking ridge; here radiating blue kyanite crystals make up from 10 - 15 percent of the rock over a width of 10 feet.

W. G. Miller[3] reported an occurrence of kyanite at the Golden Fleece mine, lot 25, concession VI, Kaladar township, Lennox and Addington county.

> "Quite recently while visiting the Golden Fleece mining location, lot 25 in the sixth concession of Kaladar, the writer found the mineral kyanite or cyanite in place on the southern half of the lot ..... In Kaladar it was found embedded in small masses or stringers of quartz in mica schist which is associated with a mass of coarse metamorphosed conglomerate of the so-called Hastings series."

---

[1]W. G. Miller and C. W. Knight, "The Pre-Cambrian Geology of Southeastern Ontario," Ont. Bur. Mines, Vol. XXII, 1913, pt.2, p.82.

[2]B. L. Smith, "Preliminary Report on the Geology of Clarendon Township, Frontenac County," Ont. Dept. Mines, P.R. 1951-3.

[3]W. G. Miller, "Economic Geology of Eastern Ontario," Ont. Bur. Mines, Vol. VII, 1898, pt.2, p.237.

A light-coloured fine-grained kyanite schist was reported by D. R. Derry and G. S. MacKenzie[1] on the north shore of a small lake northeast of Gorman lake on the Ontario-Manitoba boundary, district of Patricia. Fine-grained kyanite is reported to make up 40 percent of the rock.

Kyanite schist is reported by E. S. Moore[2] at the northeast end of Abbess lake, Atikokan area, Rainy River district.

SILLIMANITE OCCURRENCES IN ONTARIO

Sillimanite is known to occur in schists and gneisses in a number of places in Ontario, but no deposits of commercial interest are known to exist. Andalusite, cordierite, and sillimanite schist is reported in the North Spirit lake area, Patricia portion of Kenora district, by J. D. Bateman.[3] Sillimanite gneiss is described by W. W. Moorhouse[4] in the Eagle lake area, district of Kenora.

Sillimanite-garnet-hornblende gneiss forms narrow bands in amphibolite on lot 34, concession XV, Lyndoch township, Renfrew county. The sillimanite consists of fine-grained fibrous radiating aggregates which make up 20 - 30 percent of the rock. Sillimanite also occurs as a constituent of a sillimanite-garnet augen gneiss, associated with hornblendite, just west of Wolfe post office, in the eastern part of Lyndoch township. Narrow bands of garnet-sillimanite amphibolite occur at the contact of granite gneiss and amphibolite just east of Wadsworth lake, Radcliffe township, Renfrew county. Clots of radiating needlelike crystals of sillimanite up to 3/4 inch in diameter make up as much as 15 percent of the rock. The bands are narrow and do not appear to be of economic interest.

A wide band of paragneisses containing sillimanite and garnet trends northeast along the east shore of McWhirter (Stony) lake in northern Carlow township, Hastings county. The sillimanite occurs as fine-grained fibrous radiating aggregates with garnet, in a light-coloured paragneiss. Garnet and sillimanite occur sporadically over a width of 1/4 mile in the paragneiss.

A 30-foot wide band of sillimanite-rich biotite-garnet schist occurs on lot 22, concession X, Dungannon township, Hastings county.

As already described under Kyanite Occurrences, sillimanite occurs associated with kyanite in the Wanapitei and Fernleigh deposits.

GRADE AND EVALUATION OF KYANITE DEPOSITS

The Kyanite Mining Corporation of Cullen, Virginia, is reported to be working kyanite schists at Baker mountain, near Pamplin, Virginia, and to be developing a deposit at Willis mountain, Virginia, 40 miles to the northeast. In both of these deposits the kyanite is reported to average 20 - 30 percent.[5] A deposit of kyanite gneiss worked on Celo mountain near Burnsville, North Carolina, is said to average 11 percent kyanite and 8 percent garnet.[5] Kyanite schists in Georgia run from 6 - 8 percent kyanite.

It appears likely that a tenor of about 20 percent kyanite would be required to develop a commercial deposit. In the event that the associated muscovite and garnet can be marketed, a gneiss of somewhat lower grade may be profitably worked. The Ontario kyanite gneisses appear to be somewhat coarser in grain size than the American kyanite schists now being worked, and it is possible that a coarser grade of kyanite more acceptable to the refractory trade may be produced.

Ordinary methods of assaying are not applicable to kyanite ores, and it is necessary to crush, grind, and make a physical separation of the kyanite to determine the grade of a kyanite deposit. In sampling a kyanite deposit, large bulk samples must be taken and mill tests run to determine percentage and size of recoverable kyanite in the rock. Milling procedures will vary depending on the associated minerals. When a concentrate is obtained, ceramic tests are necessary to determine the suitability of the material for refractory use. Chemical analyses for silica, alumina, iron, titania, and alkalis are usually made. If the kyanite is to be marketed as a source of alumina for the glass batch, the iron oxide content must be low; for use in glass and electrical porcelain it should be under 0.2 percent.

No deposits of sillimanite have been worked on a commercial scale in North America.

---

[1] D. R. Derry and G. S. MacKenzie, "Geology of the Ontario-Manitoba Boundary," Ont. Dept. Mines Vol. XL, 1931, pt.2, p.7.

[2] E. S. Moore, "Geology and Ore Deposits of the Atikokan Area," Ont. Dept. Mines, Vol. XLVIII, 1939, pt.2, p.17.

[3] J. D. Bateman, "Geology of the North Spirit Lake Area," Ont. Dept. Mines, Vol. XLVII, 1938, pt. 7, p.60.

[4] W. W. Moorhouse, "Geology of the Eagle Lake Area," Ont. Dept. Mines, Vol. XLVIII, 1939, pt.4, p.11.

[5] F. H. Riddle and W. R. Foster, op. cit.

MINING, MILLING, AND BENEFICIATION

Mining is normally carried out by open-pit quarrying. For the milling and recovery of kyanite from gneisses or schists containing a mineral assemblage such as those found in Ontario, complex mineral dressing methods are required. In the Burnsville, North Carolina, plant, formerly operated by Celo Mines, Incorporated, the kyanite gneiss was crushed and then pulverized, with as little powdering of the kyanite as possible, in a hammer mill. It is important to free and recover the kyanite in as coarse a grain size as possible. The product from the hammer mill was screened, with some concentration of kyanite in the coarser fractions. Iron, sulphides, garnet, and biotite were removed by electromagnetic separation. The kyanite was separated from muscovite, quartz, and feldspar effectively, because of its heavy specific gravity, by air tabling. Fine grinding of the kyanite was carried out in a silex-lined pebble mill.

Jigging has been employed on some American ores. Selective flotation of kyanite and muscovite from the feldspar and quartz gangue has also been successfully carried out. Flotation is reported to give a higher rate of recovery than gravity methods on kyanite ores.[1]

MARKETING KYANITE

The Kyanite Mining Corporation of Cullen, Virginia, mines kyanite and markets raw and calcined kyanite in 35-mesh and smaller sizes. Commercialores, Incorporated, produces kyanite from a property near Clover, South Carolina. The Chas. Taylor Sons Company, Cincinnati, Ohio, imports and markets raw and calcined African and Indian lump kyanite. Kyanite refractories manufactured from imported and domestic United States kyanite are marketed by the P.B.Sillimanite Company, an associate of the Chas. Taylor Sons Company. The Golwynne Chemical Corporation of New York city imports and markets raw and calcined Indian and African lump kyanite, and its associated company Mullite Refractories Limited, Shelton, Conn., produces kyanite refractories. Kyanite refractories are also manufactured by the Laclede-Christy Clay Products Company, General Refractories Company, Denver Fire Clay Company, and the A. P. Green Fire Brick Company. The latter company mines its own kyanite in the United States. The Canadian Refractories, Limited, of Kilmar, Quebec, manufactures kyanite refractories from imported kyanite.

The current kyanite prices quoted in the E. & M.J. Metal and Mineral Markets for October 2, 1952, are as follows:

> "Kyanite, per ton, f.o.b. point of shipment, Va., and S.C., 35-mesh, carload lots, in bulk $29; in bags $32. For 200 mesh, in bags, carload lots, $40. Imported kyanite, 55 to 59% grade, in bags, c.i.f. Atlantic ports $60. @ $65. per short ton."

These prices are nominal, since the largest users produce or import kyanite to meet their requirements. The record of production in the United States indicates that the captive mines have a much more successful record than those selling on the open market to the general trade.

The following is a partial list of users of kyanite:

Canadian Refractories, Limited	- Canada Cement Building, Montreal 2, P.Q.
General Refractories Company	- Philadelphia 2, Pa.
A. P. Green Fire Brick Company	- Mexico, Mo.
The Golwynne Chemical Corporation	- 420 Lexington Ave., New York, N.Y.
Laclede-Christy Clay Products Company	- 1706 Ambassador Bldg., St.Louis, Mo.
The Chas. Taylor Sons Company	- Cincinnati 14, Ohio.

PRODUCTION AND CONSUMPTION OF KYANITE

In 1949 the production of domestic United States kyanite was reported to be 12,115 tons, valued at $403,169. The figures published by the United States Department of Commerce on the quantity of kyanite imported for consumption in the United States are as follows:

Year	Tons	Value
1945	15,074	$182,140
1946	11,374	130,341
1947	12,182	150,674
1948	17,091	259,055
1949	12,119	324,856

---

[1] F. H. Riddle and W. R. Foster, op. cit.

In 1949 United States imports were distributed as follows:

Source	Tons	Value
Kenya	6,342	$146,520
India	5,434	163,653
Mozambique	336	14,614
Australia	7	69

In 1949 assistance by the Economic Co-operation Administration was given to producers of kyanite in Kenya, British East Africa, to assist in raising their production from 25,000 to 37,000 tons a year. The increased production was to meet United States stockpile requirements.[1]

BIBLIOGRAPHY

Ontario Deposits

A. E. Barlow, "Report on the Geology and Natural Resources of the Area Included by the Nipissing and Temiscaming Map Sheets," Geol. Surv. Can., Vol. X, 1897, rept. I, p.160.

A. P. Coleman, "The Pre-Cambrian Rocks North of Lake Huron," Ont. Bur. Mines, Vol. XXIII, 1914, pt. 1, pp. 209 - 11.

W. G. Miller, "Economic Geology of Eastern Ontario," Ont. Bur. Mines, Vol. VII, 1898, pt. 2, p.237.

W. G. Miller and C. W. Knight, "The Pre-Cambrian Geology of Southeastern Ontario," Ont. Bur. Mines, Vol. XXII, 1913, pt. 2, p. 82.

B. L. Smith, "Preliminary Report on the Geology of Clarendon Township, Frontenac County," Ont. Dept. Mines, P.R. 1951-3.

General Information

R. F. Heuer, "How and Where Kyanite Refractories are Used," Brick and Clay Record, Vol. 100, 1942, pp. 50 - 51.

N. C. Jensen, "Marketing Kyanite and Allied Minerals," Bur. Mines, U.S. Dept. Int., Information Circular 7234, Feb., 1943.

F. H. Riddle and W. R. Foster, "The Sillimanite Group," Chap. 42, Industrial Minerals and Rocks, Amer. Inst. Min. and Met. Eng., 1949.

---

[1] Minerals Yearbook, 1949, Bur. Mines, U.S. Dept. Int.