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THE PORT AUX BASQUES COMPLEX: A POTENTIAL SOURCE OF HIGH-ALUMINUM REFRACTORY MINERALS OF THE SILLIMANITE GROUP (KYANITE, SILLIMANITE, ANDALUSITE) AND INDUSTRIAL GARNET

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ABSTRACT

A reconnaissance assessment of industrial minerals in the Port aux Basques region was carried out. The survey showed that gneissic units within the Port aux Basques Complex host significant showings of refractory and abrasive minerals. Schist bands within the gneiss contain kyanite and sillimanite, and in particular concentrations of kyanite in the Grand Bay area. The kyanite occurs mainly in two modes; as relatively large crystal aggregates associated with pods of quartz in gneiss, and as much smaller blades of kyanite, disseminated through and forming part of the schistose fabric of the rock. Garnets are ubiquitous throughout the gneisses and schists, but the best in terms of size, colour, and crystal development, are found in biotite-rich schist bands. The inland region northeast of Grand Bay is a highly prospective area for deposits of disseminated kyanite.

INTRODUCTION

During the 1991 field season, a preliminary assessment of industrial minerals in the Port aux Basques gneiss was carried out. The survey focussed on occurrences of kyanite, a nonmetallic mineral that along with sillimanite and andalusite, share the chemical composition Al_2SiO_5, and are collectively known as the sillimanite group of minerals. All three are industrially important because their product of calcination, mullite ($Al_6Si_2O_{13}$) is highly refractory and in demand wherever high-temperature processes such as smelting of metals and the making of glass are carried on. Refractory applications consume about 90 percent of kyanite production. The remaining 10 percent finds use in numerous products such as ceramic linings, precision castings, and brake shoes and discs. It is also used in the aerospace industry as an insulating material in space capsules and jet aircraft engines.

Garnet is ubiquitous in the Port aux Basques gneiss, and is invariably associated with occurrences of kyanite. It is gaining favour as an abrasive medium because of environmental constraints against its competitors. It contains no free silica, for example, and thus avoids the silicosis problem associated with silica in sand blasting. Also, garnet's specific gravity (3.5 to 4.2) is higher than that of silica sand (2.65), therefore, it requires less air pressure to achieve the same impact in the sanding process. High-quality garnet is used for grinding and lapping glass, ceramics and other materials. Lower quality is used for cleaning and conditioning aluminum and other soft metals. Also, there is a growing nonabrasive use for garnet in water filtration, which requires a material that resists physical and chemical breakdown during filtering and back-flushing (Harben and Bates, 1990). In the United States, about 30 percent of the total garnet consumption is used in water filtration.

PREVIOUS WORK

Previous assessments of industrial rocks and minerals in the Port aux Basques—Isle aux Morts region (Figure 1) have focussed mainly on silica. Gale (1967), during the course of an assessment of pegmatites in the region, collected some chip samples from the quartz vein at Diamond Cove. The analyses revealed a high-silica content and prompted further assessments of the vein as a potential source of flux-grade silica (Butler, 1967; Fleming, 1968). Gale (*op. cit.*) also mentioned that some of the larger pegmatite veins were a potential source of commercial feldspar and further noted that metamorphic rocks of the western part of the region contained abundant kyanite. Prior to Gale's (*op. cit.*) work, Tater (1964) carried out a reconnaissance survey of pegmatite in the region.

Brown (1977), in a report based on his regional mapping of the Port aux Basques Complex noted that schist bands in the Port aux Basques gneiss contained up to 20 percent kyanite. O'Neill (1985) in a M.Sc. thesis study of the Isle aux Morts River zinc prospect described quartz—muscovite schist units containing a high percentage of kyanite. A deposit of garnet at Burnt Island Bay approximately 20 km east of Port aux Basques was mentioned by Snelgrove and Baird (1953) as a potential source of material for the abrasives industry.

Granites of the region were long recognized as potential sources of building stone and some quarry development was carried out around the turn of the century. At Petites, 7 km east of Rose Blanche, 5 small quarries were opened in a red-pink porphyritic granite and some of this material was used as a facing stone on the St. John's courthouse. Blocks of stone from the Rose Blanche granite were also quarried on a small scale for use in lighthouse construction.

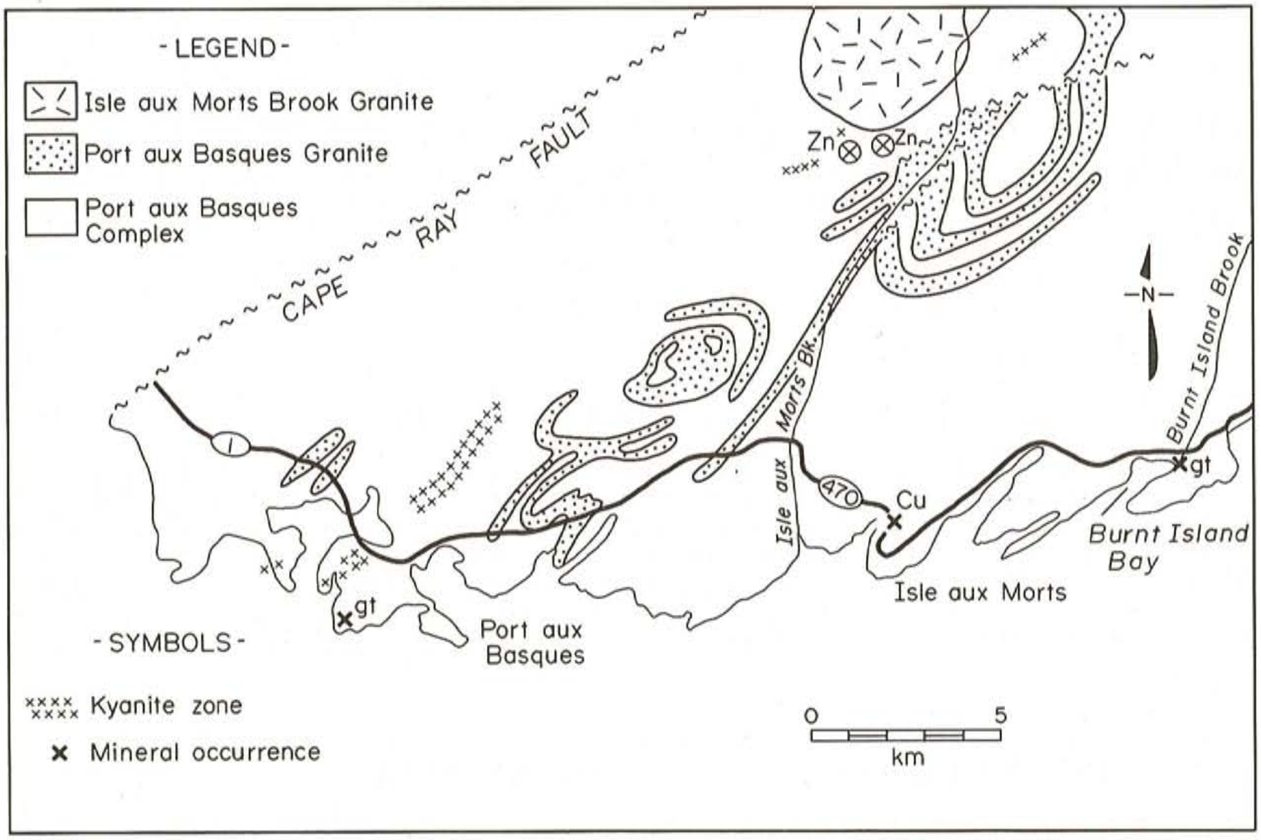

Figure 1. *Sketch map showing the regional geology of southwest Newfoundland (after Chorlton* et al., *1984).*

PRESENT SURVEY

OBJECTIVES AND PARAMETERS

The objective of the 1991 survey was to identify deposits of industrial-grade kyanite and garnet in the Port aux Basques gneiss. For the purpose of this report industrial kyanite means material suitable for use in the refractory industry. For garnet, the term industrial mainly implies suitability for use as an abrasive medium in sand-blasting. However, other potential industrial applications are also considered.

ACCESS, PHYSIOGRAPHY, AND METHODS

The Trans-Canada Highway, Route 470, and a network of smaller roads and trails provide good access to the coastal areas. More remote parts can be reached by boat depending on weather and sea conditions. Inland traverses from the coast, beyond the range of a few km, require ATV or, ideally, helicopter support.

Bedrock exposure on the coast is almost continuous except for some sandy beaches west of Grand Bay. Inland, it ranges from poor to good and typically consists of small lichen-covered outcrops along knobby northeast-trending ridges (Plate 1). Low areas and valleys are characterized by growth of stunted spruce trees that make traversing difficult.

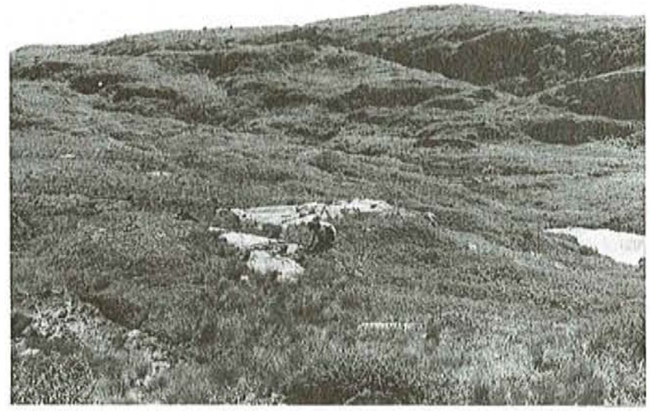

Plate 1. *Typical topography in the Port aux Basques region.*

The survey focussed on a 30 km² area around and north of Grand Bay, Port aux Basques (Figure 2). The general field method was to locate kyanite-bearing schist bands on the coast and trace them inland along their northeast strike. A significant amount of time was spent in detailed prospecting along individual outcrops. Representative samples of mineral occurrences were collected for analyses and display purposes. All mineral showings were plotted on air photographs and 1:50 000 NTS map sheets.

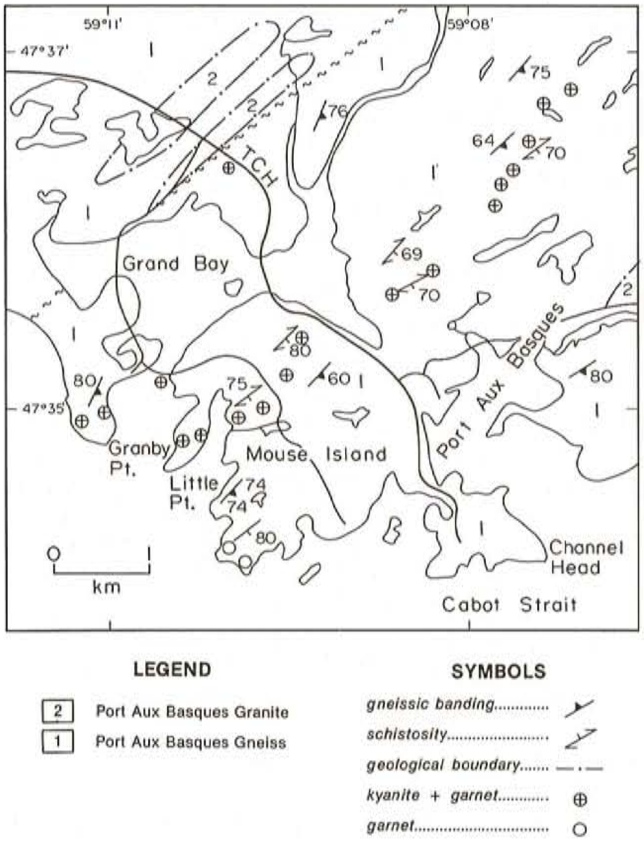

Figure 2. *Kyanite occurrences in the Port aux Basques region; geology after Brown (1977).*

GEOLOGICAL SETTING

The geology of the Port aux Basques region southeast of the Cape Ray Fault is dominated by the Port aux Basques Complex (Figures 1 and 2). As defined by Brown (1972), the Port aux Basques Complex consists of the Port aux Basques gneiss, a well-banded series of light and dark units intruded by granitic rocks, and by pegmatite, aplite, and diorite dykes. The bands, which occur on scales ranging from centimetres to metres, strike northeast and dip steeply to the southeast. The dark units consist of dark green hornblende-rich rock and epidosite. The lighter bands vary in composition from quartz–feldspar to muscovite–biotite garnet schist. Kyanite, sillimanite, staurolite, and garnet are developed in the bands. Schist bands within the gneisses around and northeast of Grand Bay are especially rich in kyanite (up to 20 percent or more) and these were the main focus of the 1991 survey.

Kyanite

A mineral's refractoriness depends mainly on its aluminum content. Theoretically, for the sillimanite group this is 62.93 percent, a figure rarely attained in nature because of impurities such as iron, titanium, and alkalies. Commercial grades of kyanite must contain a minium of 56 percent Al_2O_3 and 42 percent SiO_2 with less than 1 percent acid-soluble Fe_2O_3, 1.2 percent TiO_2 and 0.1 percent each of CaO and MgO (Harben and Bates, 1990).

The rapid depletion of the world's known reserves of massive kyanite has, in recent years, resulted in increased research into methods of recovering kyanite from schists (Varley, 1965). The methods developed involve crushing, milling, magnetic separation, and flotation. In the United States, Kyanite Mining Corporation of Virginia, the sole producer of kyanite in North America, uses flotation to produce a 91 percent concentrate, which is dried and passed through high-density magnetic separators to reduce iron content to less than 1 percent. The kyanite quartzite ore is a medium- to fine-grained rock containing 10 to 30 percent kyanite with quartz muscovite, pyrophyllite, rutile, lazulite, topaz and clay minerals (Johnson, 1990). Other countries that use flotation and magnetic separation techniques are France, Sweden and South Africa.

Garnet

The chief industrial use for garnet is in the abrasive industry, therefore, its physical properties are of prime concern. However, its efficiency for abrasive purposes cannot be determined solely by any standardized series of tests thus behaviour under working conditions is the final criterion (Johnstone, 1984). Hardness should be at least 7.5, and on crushing it should break into irregular fragments having rounded or curved edges. It should be capable of producing a full range of sizes between 8 and 200 mesh. Large crystals that have been badly shattered or weathered are undesirable because they are likely to crumble to dust on crushing.

By far the most important commercial garnet is almandine ($Fe_3Al_2Si_3O_{12}$). Its hardness ranges from 7.5 to more than 8.0 and it conchoidally fractures into sharp chisel-like fragments. This combined with a high resistance to physical and chemical attack make it a superior abrasive. The toughness, fracture and colour of almandine, can be improved by heating to 800°C for about 12 hours. This process is used by several manufacturers in the United States.

It is also desirable that grains of crushed garnet intended for use on paper or cloth should have a high capillary attraction so that the glue will cover them completely and adhere to them when they are attached to the backing medium (Johnstone, 1984).

RESULTS

KYANITE

Several zones of kyanite-enriched mica–garnet schist were identified along a northeast-trending belt that extends across Mouse Island and inland from Grand Bay (Figure 2). On Mouse Island, a line of knobby hills and ridges contains spectacular occurrences of coarsely crystalline kyanite along with schist-hosted disseminated kyanite. It was difficult to gauge the extent of the kyanite mineralization because of the discontinuous nature of the outcrops, but disseminated zones, up to 20 m long and several metres wide, were noted in separate outcrops.

Kyanite mineralization occurs in two distinct modes; as large blue crystals and bladed crystal aggregates up to 10 cm in length, usually wrapped around the rims of quartz pods (Plate 2), and (or) as thin-bladed blue and green crystals (up to 2 cm in length), which along with biotite and muscovite, form the schistose fabric of the rock (Plate 3). Both types of mineralization commonly occur together, especially on the peninsulas that form the east and west sides of Grand Bay. However, inland, northeast of Grand Bay, the disseminated form of kyanite is more prevalent. The following are brief descriptions of some of the best kyanite showings identified to date.

Plate 2. *Coarsely crystalline kyante associated with quartz pods in the Port aux Basques gneiss on Mouse Island.*

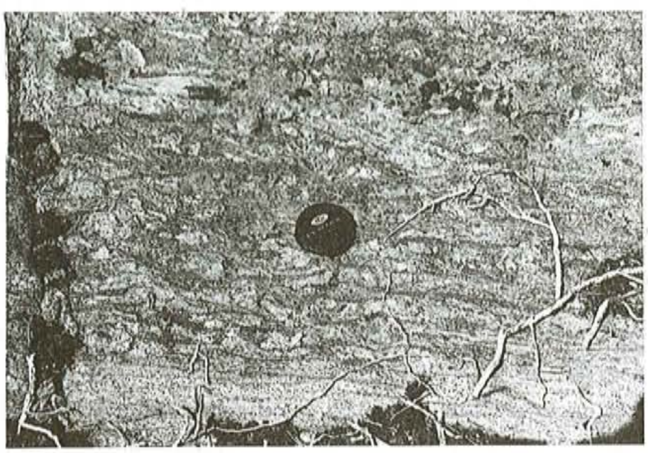

Plate 3. *Thin bladed kyanite in kyanite-muscovite-biotite schist bands located inland (2 km) from Grand Bay.*

Inland Showings

A northeast-trending band of kyanite-enriched schist is located about 2 km northeast of Grand Bay and is traceable for several hundred metres along strike. In one of the best occurrences along this zone (Figures 1 and 2), small, 1 to 2 cm blades of blue-green kyanite locally comprise up to 20 percent of the host garnet–mica schist giving the host rock a distinctly blue cast. The hanging wall of this steeply (southeast) dipping zone consists of a sill-like body of highly deformed and crenulated amphibolite schist. The strongest kyanite mineralization is found along a 2-m-wide band bordering this unit although significant amounts are found throughout the length (30 m) and width (8 m) of the mica–garnet schist outcrop. White quartz pods containing books of mica up to 6 cm wide are also present in the kyanite zone. However, this type of mica occurrence appears to be too small for commercial interest.

Grand Bay Showings

Numerous occurrences of kyanite were observed around Grand Bay, notably on the large peninsula on its southeast side, referred to locally (and in this report) as Mouse Island, and on the small peninsula on the southwest side of the bay (Figure 2). One such occurrence is located in a roadcut on the southwest side of the Trans Canada Highway about 500 m east of the Grand Bay intersection. This small showing is the area's most westerly documented occurrence and consists of blue-green crystals up to 4 cm in diameter associated with quartz pods in well-banded gneiss. The showing is too small to be of economic interest.

Granby Point Showing

Several interesting occurrences of kyanite $\pm$ staurolite and garnet are exposed in the Granby Point area on the southwest side of Grand Bay. Excellent examples of both coarsely crystalline and disseminated kyanite are present. At both ends of the sandy beach near Granby Point, outcrops of muscovite–biotite–garnet schist host large crystals of kyanite and staurolite. The occurrence at the south end of the beach, the most impressive of the two, features large porphyroblasts of kyanite and staurolite several centimetres in length. A 1-m-wide band of schist contains a high concentration of kyanite and garnet (estimated 20 percent kyanite). Thin biotite-rich schist bands in the rock contain large reddish-brown almandine garnets up to 1.5 cm in diameter.

Similar mineralization can be traced across Granby Point to its western shore about 500 m from the above outcrop. There, in well-exposed northeast-striking, southeast-dipping (80°) units, pale blue acicular crystals of kyanite up to 4 cm in length, are found in crenulated zones of biotite–garnet schist imparting a distinctly blue-green cast to the weathered host rock. A unit of biotite-rich, highly garnetiferous schist occurs near the hanging wall of the kyanite zone. This unit is about 50 cm wide and contains an estimated 40 to 50 percent garnet. Some of the garnets are eroded from their host rock and cover flat areas of the rock.

Causeway Showing

Kyanite occurs in muscovite–biotite–garnet schist at the east end of the causeway connecting Grand Bay East and Grand Bay West. Mottled and crenulated schist contains abundant green acicular crystals up to 2 cm in length. The apparently random orientation of the crystals in the rock gives it a somewhat unique texture. Garnets in the schist are of an uneven size and are deformed and flattened. The showing occurs on a small rock island that now forms part of the causeway and is of no economic significance.

Mouse Island Showings

Several bands of mica–kyanite–garnet schist were identified along a northeast-trending belt that extends across Mouse Island. The showings are best exposed at the crests of low knobby hills and ridges. In some outcrops, the kyanite is quite spectacular, occurring as bladed aggregates up to 10 cm or more and wrapped around the rims of quartz pods. The best examples of this type of kyanite were noted west of Hardy's Arterial Road at the northwest central region of the island. Due to the discontinuous nature of the outcrops, it was difficult to estimate the extent of the kyanite in the schistose bands, although zones up to 20 m strike length and widths up to 5 m were observed. Also noted, especially on the northeastern side of the island, were several outcrops where flat depressions and grooves contained small crystals of eroded kyanite mixed with a sandy matrix (Plate 4). Float, in the form of an angular boulder of banded schist containing disseminated kyanite, was noted about 500 m east of the Hardy's Arterial.

Plate 4. *Small crystals of kyanite eroded from underlying schist band in the Port aux Basques gneiss.*

GARNET

Garnets were observed throughout the Port aux Basques gneiss. Brown (1972) noted an increase in the number of occurrences from the Cape Ray fault toward Port aux Basques with a maximum frequency and size in the Grand Bay area; this observation is supported by the present work. There is considerable variation in the quality of the garnets. The best, in terms of size, colour, and crystal development, were noted in biotite-rich schist bands. In these units, almandine garnets, euhedral to subhedral in outline, comprise up to 40 percent of the rock. However, these units appear to be thin (generally less than 50 cm). Garnet deposits of this type were noted in several outcrops on Mouse Island notably at Granby Point (described earlier) spatially associated with kyanite zones, and in the south cental tip of the island.

Garnets were invariably observed with kyanite in the schist. They are small (usually less than 5 mm), various shades of red and commonly contain other minerals as inclusions. Garnets were also commonly noted at the contact of amphibolite bands with the other rock units and also within the amphibolite (Plate 5). Some of the garnets are up to 1 cm in diameter, are fractured, and contain mineral inclusions.

Plate 5. *Garnetiferous amphibolite in the Port aux Basques Complex.*

A garnet showing in Burnt Island Bay, near the mouth of Burnt Island Brook (Figure 1), was investigated during the present survey. The occurrence was mentioned by Snelgrove and Baird (1953), and again by Carr (1958) as a potential source of commercial industrial garnet. The garnet is exposed in concentrated zones in schist bands (050°/80° northwest) and can be traced along a string of small island outcrops that extend offshore for about 400 m. The richer zones range in width up to 2 m and the garnet can be traced more or less continuously through a width of 20 m. The garnets are mottled brown, subhedral and attain diameters up to 1 cm, although the average size is considerably smaller. The showing could not be traced inland because of overburden and the presence of houses due to the expansion of the community of Burnt Island.

SUMMARY

Bands of mica–garnet schist in the Port aux Basques gneiss are good prospective units for high-aluminum refractory minerals of the sillimanite group (mainly kyanite). Locally, kyanite content in the rock ranges up to 20 percent. It occurs mainly in two modes, as large blue-green crystals associated with quartz pods, and as smaller bladed crystals that form part of the schistose fabric of the rock. These crystals can be colourless, light or dark blue or light green, and range up to 2 cm in length. This disseminated type of kyanite mineralization is the most commercially interesting because it is pervasive and can be traced over significant strike lengths. The inland area northeast of Grand Bay is a promising area for further work in light of the showings already identified.

Garnets are ubiquitous in the Port aux Basques gneiss and are abundant in the schistose bands. They are particularly large and well developed in biotite-rich schist bands. In some rock units, the garnets are fractured and contain inclusions of other minerals. This would probably preclude their use in industry.

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