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THE INDUSTRIAL MINERAL POTENTIAL OF KYANITE AND GARNET IN BRITISH COLUMBIA

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SUMMARY

Within British Columbia, rocks containing garnet and kyanite group minerals are mainly distributed in two linear belts, the Omineca crystalline belt and the Coast Mountain belt; however, within these areas, strata which are sufficiently pelitic to contain major concentrations of these minerals are sporadically distributed. Within the Omineca Belt, garnet and kyanite-enriched strata are found in the Nelson map area (82F), the Vernon map area (82L), the Seymour Arm area (82M), the Canoe River map area (83D) of south-central British Columbia, and in the Mesilinka area (94C) further north. Garnet and kyanite-enriched strata in the Coast Mountain belt are found in the vicinity of Hope - Yale - Harrison Lake - Lytton (92H and I) and in the Prince Rupert - Skeena - Douglas Channel area (103G, H, I, J). Garnet and andalusite are also present in the Insular Belt on southern Vancouver Island (92B, C). Strata within these areas locally contain in excess of 10 to 15 per cent kyanite group minerals and in excess of 25 per cent almandine garnet which are potentially economically interesting concentrations. The economic viability in terms of accessibility, tonnage and beneficiation potential has not been determined. Although not addressed in detail, the potential also exists for secondary placer accumulations to be present in the vicinity of hardrock showings.
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Figure 1. Distribution of amphibolite facies of classical regional metamorphism in British Columbia. From Monger and Hutchison, 1970
INTRODUCTION

Garnet, kyanite, sillimanite and andalusite are minerals found in contact and amphibolite facies regional metamorphic rocks. In British Columbia such metamorphic rocks are confined mainly to two belts, the eastern Omineca crystalline belt and the western Coast Mountain belt (Figure 1), where they are accompanied by granitic plutons. Garnet, kyanite and the other aluminosilicate minerals which are present throughout these belts have potential industrial applications, although currently there is no production of these commodities in the province of British Columbia, or elsewhere in Canada.

Garnet is used as an abrasive; high-quality garnet, usually the variety almandine, is used in the form of powders and loose grains for grinding and lapping glass, ceramics and other materials. It is also used in coated and bonded abrasives such as sandpaper, and wheels for grinding and finishing wood, metal, rubber and plastic. Lower quality garnet is used for sandblasting aluminum and other soft metals by, among others, the aircraft industry, and for water filtration (Hight, 1983; Smoak, 1985).

Kyanite and the related minerals, sillimanite and andalusite, are prized mainly for their refractory properties. They are used directly, or calcined to form mullite, in the production of high-temperature mortars or cements and castable refractories, kiln furniture, insulating brick, firebrick and similar products. Finely ground kyanite is used in sanitary porcelains, wall tile and miscellaneous special purpose ceramics (Bennett and Castle, 1983; Potter, 1983, 1985). These refractory products are chiefly used by the metallurgical (steel) and glass industries, and secondarily, by the ceramics industry (Varley, 1968).

GARNET - CURRENT WORLD PRODUCTION AND ECONOMIC CONSIDERATIONS

The United States is the world's leading producer and consumer of garnet, accounting for approximately 75 per cent of the world output and 70 per cent of the world consumption (Smoak, 1983, 1985). The remainder of world production is from Australia, India and the U.S.S.R.; Canada is currently not a garnet producer. In the U.S. there are four producers of garnet, which are located in New York, Maine and Idaho. In the last two areas, only low-quality garnet used for sandblasting and water filtration is produced. The sandblasting industry is increasing its use of garnet which is replacing silica sand and a smelter slag posing potential health problems. The geographic areas in which garnet occurs are widespread, however, commercially attractive industrial garnet occurrences are relatively few.

Hardrock deposits mined in the U.S. grade from 30 to 80 per cent garnet, with crystal sizes reaching in excess of 90 centimetres; however, on average grains are less than 10 centimetres in diameter. The best abrasive garnets are almandines (hardness 7.5), but pyrope, andradite and grossular, which are all softer, are also used (Smoak, 1985). The presence of incipient fractures or mineral inclusions reduces the usefulness of the garnet (Hight, 1983). As with most industrial minerals, location of deposits and transportation costs are factors of paramount importance in determining viability. Studies by the U.S. Bureau of Mines (Smoak, 1985) indicate world reserves should be adequate to supply world demand for garnet at least until the year 2000; any new deposits would therefore have to be extremely high grade, high quality and well located in order to break into the market.
KYANITE - CURRENT WORLD PRODUCTION AND ECONOMIC CONSIDERATIONS

The United States, the Republic of South Africa and India are the leading world producers of aluminosilicate minerals (Potter, 1983). There is currently no production of sillimanite, andalusite or kyanite in Canada, although, in the past, attempts were made to recover kyanite from schists in the Timiskaming area (Bennett and Castle, 1983). The consumption of kyanite is concentrated in a relatively few highly industrialized areas, which are typically close to the major iron and steel producing regions in northern Europe, the eastern U.S., England and Japan (Bennett and Castle, 1983).

The majority of U.S. production comes from quartzites in Virginia and Georgia which contain 15 to 40 per cent kyanite. No schists are currently being mined for kyanite (Bennett and Castle, 1983); beneficiation of kyanite from schists has traditionally proved problematic, due largely to the presence of iron-rich mineral inclusions. Massive sillimanite is produced from residual deposits in India and coarse sillimanite from schists could potentially be produced; however, the beneficiation of fibrolitic sillimanite is usually impossible. Andalusite is being mined from weathered schists in France and from alluvial deposits in South Africa (Bennett and Castle, 1983).

The potential supply of kyanite group minerals from regional metamorphic terranes vastly exceeds the potential market; an important preliminary consideration in any exploration project is, therefore, the cost of delivering kyanite to the geographically limited markets. Also, grade and size of crystals must be considered; an economic kyanite deposit is one from which a -35 to -28 mesh concentrate can be produced which contains less than 2 per cent combined impurities (Fe$_2$O$_3$, TiO$_2$, CaO, MgO, etc.) (Bennett and Castle, 1983). As with garnet, studies indicate that an ample supply of kyanite group minerals is likely to exist at least until the year 2000 (Potter, 1985).
GARNET AND KYANITE LOCALITIES IN BRITISH COLUMBIA

Garnet and kyanite group minerals occur mainly in two belts in the Cordillera, the Omineca crystalline belt and the Coast Mountain belt, with minor occurrences elsewhere (Figure 1). Within these belts, pelitic metasedimentary rocks containing small percentages (less than 5 per cent) of these minerals are extremely abundant. Rocks containing significant concentrations of these minerals, however, are considerably less frequently found. The scope of this study is to identify areas of potential economic grade, for example, greater than 10 to 15 per cent kyanite group minerals and greater than 25 per cent garnet; economic viability as a function of transportation costs, market, beneficiation possibilities and other factors will not be addressed.

Information regarding garnet and kyanite group mineral abundances was compiled through an extensive literature search of journals, Federal and British Columbia Government publications, Open File reports and assessment reports, and from theses and other unpublished information available from The University of British Columbia, the University of Calgary and the Geological Survey of Canada. As well, workers actively involved in the study of metamorphic terranes were interviewed, whenever possible. Maps included in this report were compiled at a scale of 1:250,000 from pre-existing regional government mapping and updated to include recent detailed studies. Ten maps (Figures 2 to 11) are included, showing the geology of areas known to contain significant accumulations of garnet and aluminosilicate minerals. A bibliography of most garnet and kyanite group mineral occurrences in the province is also included.

This report deals with potential hardrock sources of garnet and aluminosilicate minerals. Virtually no information exists in the literature regarding secondary placer concentrations of these minerals. Common sense, however, dictates that the general areas in which hardrock enrichment occurs should also have good potential for placer accumulations; knowing these regions should help in identifying areas which could be prospected for garnet and kyanite placers. Secondary deposits could be economic with considerably lower concentrations of desired mineral species; as little as a few per cent may be all that is necessary, as opposed to 10 to 15 per cent kyanite and 25 to 40 per cent garnet in hardrock sources. Such garnet-rich placers were recently reported by a prospector from the Revelstoke area.

Southern Shuswap - Nelson Area (82F), Omineca Belt

Coarse metapelitic gneisses containing abundant sillimanite and garnet are reported from the Valhalla and Passmore dome area (Areas 1 and 2, Figure 2), west of Slocan Lake (Reesor, 1965). Valhalla and Passmore are two of a series of domal structures containing gneisses which form part of the core of the Shuswap metamorphic complex. The core of the Valhalla dome comprises orthogneisses (Map unit 1A) which are mantled by hybrid gneisses (Map unit 1B), predominantly metasedimentary in origin. Sillimanite locally comprises 20 to 25 per cent of sillimanite-garnet-biotite gneisses of the hybrid gneiss zone, particularly along the east flank of the Valhalla dome (Area 1, Figure 2) and may be very coarse. In the vicinity of the Passmore dome (Area 2, Figure 2), coarse sillimanite may occur in knots or groups of crystals over 2.5 centimetres long and 1 centimetre wide. These gneisses may also locally contain up to 30 per cent garnet, with an average crystal size of 0.5 centimetre or less. Garnet may also be present in interbedded amphibolitic rocks in amounts up to 40 per cent (Reesor, 1965).

Metamorphosed sedimentary strata, Triassic to Precambrian
in age, are exposed on the east flank of the Nelson batholith. East of Ymir (Area 3, Figure 2) a narrow band of Hadrynian Three Sisters Formation strata outcrops in the core of an anticline. Kyanite schists are present in this area that contain up to 15 per cent kyanite porphyroblasts that have an average size of 2.5 by 0.5 centimetres (McAllister, 1950). On the west flank of the Bayonne batholith, west of Kootenay Lake (Area 4, Figure 2) a band of quartz-muscovite-kyanite schist forms the youngest unit of the Helikian Dutch Creek Formation (Leclair, 1983). Kyanite porphyroblasts, up to 5 centimetres long are common in this area (Leclair, 1982). Garnets up to 2 centimetres in diameter are also common in the various pelitic units, flanking the Bayonne batholith (Leclair, 1982).

Coarse-grained kyanite has been reported from the Creston area (McCammon, 1965) in Helikian Purcell Supergroup micaceous quartzites and mica schists with minor pegmatite (Area 5, Figure 2). Kyanite forms clean, bladed crystals in clumps 15 to 20 centimetres in diameter associated with the pegmatites, which occur as irregular masses 0.3 by 1.0 metre to 2 by 10 metres in size. Kyanite is also disseminated throughout the schists and micaceous quartzites, where crystals vary from small needles to 1 by 5 centimetres in size (McCammon, 1964).

Shuswap Lake - Vernon - Okanagan Area (82L), Omineca Belt

In the Vernon map area, metamorphic rocks crop out in the Shuswap, Monashee and Okanagan complexes (Okulitch, 1980). Monashee Complex rocks are exposed in the Thor Odin dome and separated from other strata largely by faults. The Thor Odin dome consists of a core zone comprised of migmatized biotite-quartz-feldspar gneisses, granodiorite gneisses, some aluminosilicate-rich schists and amphibolite. Most core gneisses contain some sillimanite; rare occurrences of kyanite, andalusite and corundum are also reported (Reesor and Moore, 1971). In the southwestern part of the core zone (Area 1, Figure 3) a distinctive mafic, aluminosilicate-rich schist is exposed. The schist is characterized by coarse porphyroblastic garnets, up to 3 centimetres in diameter, and/or very coarse sillimanite aggregates, up to 10 centimetres long (Reesor and Moore, 1971). Sillimanite in these schists can comprise up to at least 15 per cent of the rock and is commonly rimmed by cordierite and corundum. These mafic schist layers are relatively thin, generally in the order of a few metres, but may be traced for nearly 2 kilometres along strike (Reesor and Moore, 1971).

Overlying the core gneisses of the Thor Odin dome is an autochthonous mantling succession which consists of paragneiss, schist, quartzite, marble, calc-silicate schist and amphibolite. In the Mount Odin - Mount Symonds - Mount Fosthall area (Area 2, Figure 3) paragneisses and schists are present which contain abundant coarse garnet and prismatic sillimanite. Typical exposures occur along the southern branch of Ledge Creek. These gneisses and schists may contain up to 15 per cent sillimanite which is present in the form of prismatic crystals up to 10 centimetres long, and abundant garnet porphyroblasts, up to 2.5 centimetres in size (Abraham, 1967; Reesor and Moore, 1971). In the same area, coarse garnet 1 to 2 centimetres in size may comprise up to 30 per cent of some amphibolite layers, but is more commonly present in quantities of 10 per cent or less (Reesor and Moore, 1971). Elsewhere within the Monashee Complex, schists are reported to contain garnets as large as 12 to 13 centimetres in diameter (Jones, 1959). The mantling gneiss succession is continuous to the north with mantling gneisses of the Frenchman Cap area (see below). Near Victor Lake, along the Trans-Canada Highway (Area 3, Figure 3) pelitic schists in the mantling succession locally contain abundant prismatic sillimanite (around 10 per cent), kyanite and garnet (Hill, 1975). North of Clanwilliam, pegmatites in these schists are reported to contain andalusite crystals as large as 4 by 3
centimetres in size. In this area, quartz veins containing bright blue kyanite blades, up to 6 centimetres long, are also common (Hill, 1975).

Shuswap Complex rocks in the Vernon map area consist mainly of metasedimentary strata of uncertain affiliation. In the Queest Mountain area, east of Shuswap Lake (Area 4, Figure 3), kyanite prisms, 0.5 to 2.5 centimetres in length, are relatively common in schists, and sillimanite is absent (Jones, 1959). Abundant kyanite has also been reported in schists exposed north of Glanzier Creek, 7 to 8 kilometres east of Armstrong (Cairnes, 1932).

Revelstoke - Frenchman Cap - Big Bend Area (82M, N), Omineca Belt

Coarse, sillimanite and kyanite-rich schists have long been known to exist in the Revelstoke - Frenchman Cap - Big Bend area (O'Grady and Richmond, 1932; Carnochan and Rogers, 1934; Cummings, 1948; Eichelberger, 1953). Metamorphic rocks in this region belong to the Shuswap and Monashee complexes. Predominantly metasedimentary strata comprise the Shuswap Complex, and its margin is defined as the sillimanite isograd. In the north and eastern part of the area (Figure 4), Shuswap rocks are simply high metamorphic grade equivalents of Hadrynian Horsethief Creek Group strata. In the western part of the area, rocks assigned to the Shuswap Complex are of uncertain affiliation, in part they may be Horsethief Creek equivalents, in part they may be metamorphosed equivalents of younger strata.

The Big Bend (Mica Creek) - McNaughton Lake area, located approximately 100 kilometres to the north and northeast of Revelstoke, is underlain by Hadrynian Horsethief Creek Group and Lower Cambrian strata (Figure 4). In the Kinbasket Mountain - Sullivan River area (Area 1, Figure 4) schists of probable Lower Cambrian age contain up to 50 per cent garnet and locally, abundant kyanite associated with large quartz veins and pegmatites (Eichelberger, 1953). In the Trident Mountain area, 15 kilometres east-southeast of Mica Creek (Area 2, Figure 4) kyanite is extremely abundant in pelitic schists and quartz-kyanite segregation veins; kyanite often comprises in excess of 10 per cent of the rock. This area is underlain by the Lower Aluminous Pelite division of the Horsethief Creek Group (Perkins, 1983), a unit which commonly contains abundant aluminosilicate minerals.

The Monashee Complex contains orthogneisses and paragneisses which are exposed in the Frenchman Cap dome (Figure 4). Frenchman Cap is one of a series of domal structures, and, together with the Thor Odin, Valhalla and Pinnacles domes, comprises the core zone of the Omineca crystalline belt. Aphibean orthogneisses (Brown, 1980) predominate in the lowest part of the Monashee Complex and are exposed in the core of the Frenchman Cap dome. These are overlain by an autochthonous cover or mantling succession of clastic and carbonate rocks.

Locally, kyanite may constitute 20 per cent of micaceous schists within the mantling succession, and individual crystals may be over 3 centimetres in length (T. Hey, personal communication, 1987). North of Kirbyville Creek, on the north flank of Frenchman Cap dome (Area 3, Figure 4) pelitic horizons contain abundant, coarse kyanite, some sillimanite and locally, up to 30 per cent garnet. A distinctive amphibolite layer in the same area is reported to contain garnets ranging from 2 to 20 centimetres in size and randomly oriented clusters of kyanite (Scammell, 1985). Kyanite has also been noted (Wheeler, 1965) in schists and gneisses south of Ratchford Creek and west of the headwaters of Perry River (Area 4, Figure 4). In that area, kyanite occurs as crystals from 1 to 2 centimetres in length. Sillimanite is also present in some strata; fibrolite intergrown with biotite may comprise in excess of 10 per cent of
the rock. In the Death Rapids - Priest Rapids area, along the west side of the Columbia River approximately 60 kilometres north of Revelstoke (Area 5, Figure 4), kyanite is abundant in quartz veins and pegmatites (O'Grady and Richmond, 1932; Carnochan and Rogers, 1934; Cummings, 1948). Along the southern flank of Frenchman Cap dome, near Eagle Pass Mountain (Area 6, Figure 4), andalusite-sericite schists have recently been found. These schists contain 30 per cent andalusite and some kyanite (up to 8 per cent) in a matrix of predominantly sericite and quartz (C.D.S. Bates, personal communication, 1987 to Z.D. Hora).

Canoe River - Valemont - Mica Creek Area (B3D), Omineca Belt

The Canoe River map area (Figure 5) is predominantly underlain by a sequence of Hadrynian metasedimentary strata, belonging to the Windermere Supergroup (Miette, Horsethief Creek and Kaza groups) and their basement gneisses. Horsethief Creek Group strata in the Canoe River area are locally sufficiently pelitic to produce abundant garnet and aluminosilicate minerals when subjected to high-grade regional metamorphism. In the Cariboo Mountains, north of Azure Lake (Area 1, Figure 5), strata which most likely correlate with the Horsethief Creek Group contain abundant pelitic layers. These pelites locally contain 2 to 15 per cent garnet, 0 to 15 per cent coarse kyanite porphyroblasts and traces to 15 per cent sillimanite, predominantly in the form of fibrolite (Pigage, 1978). In the southeastern Cariboo Mountains, approximately 30 kilometres southwest of Valemont (Area 2 and Area 3, Figure 5), pelitic schists locally contain up to 20 per cent kyanite, up to 15 per cent fibrolitic sillimanite and up to 25 per cent garnet (Pell, 1984). Kyanite grains are commonly in excess of 2 centimetres in length. These extremely aluminous pelitic strata are largely confined to the lower Kaza Group (=Horsethief Creek Group Upper Clastic division, Map Unit 2a), overlying the Horsethief Creek Group Middle Marble division (Map Unit 2b), and underlying a carbonate marker horizon in the lower Kaza Group. Less commonly, aluminous pelitic horizons are present in the Horsethief Creek Group Semipelite-Amphibolite division (Map Unit 2c), immediately underlying the Middle Marble division. Pelitic schists in this region also frequently contain quartz-kyanite-rich segregation lenses.

In the northern Monashee Mountains, approximately 30 kilometres southeast of Valemont, near the headwaters of Howard Creek (Area 4, Figure 5), schists in the Horsethief Creek Group Semipelite-Amphibolite division contain 20 to 25 per cent coarse-garnets which range in size from 2 to 6 centimetres in diameter. Kyanite is also present, but not abundant at this locality. Abundant coarse kyanite has been noted in the vicinity of Albreda, on the main line of the Canadian National Railway, approximately 25 kilometres south of Valemont (Cummings, 1948). Elsewhere in the Monashee and Selkirk mountains, the Aluminous Pelite division (Map Unit 2D) of the Horsethief Creek Group crops out. As its name suggests, this unit is characterized by pelites which are aluminous in composition and therefore produce abundant kyanite porphyroblasts and/or sillimanite when subjected to appropriate metamorphic conditions (P.S. Simony, personal communication, 1982). In the Warsaw Mountain area of the northern Selkirk Mountains (Area 5, Figure 5), kyanite is present in localized pelitic horizons near the base of the Semipelite-Amphibolite division (Mitchell, 1976). Kyanite porphyroblasts in these horizons are up to 5 centimetres in length.

Aiken Lake - Mesilinka River Area (94C), Omineca and Rocky Mountain Belts

Sedimentary and metasedimentary rocks of Hadrynian age, which belong to the Ingenika and Misinchinka groups, underlie much of the Aiken Lake - Mesilinka River area (Roots, 1954; Gabrielse, 1975). Ingenika
Group strata crop out west of the Rocky Mountain Trench (Figure 6) and include amphibolite facies rocks which were previously assigned to the Tenakihi Group (Roots, 1954) and migmatites of the Wolverine Complex. Misinchinka Group strata are exposed in the Rocky Mountains (Gabrielse, 1975). Pelites, sandstones, quartzites, marbles and amphibolites are present in both groups. The correlation between the Misinchinka and Ingenika strata has not been established (Gabrielse, 1975).

In the Tenakihi Range, near Jim May Creek (Area 1, Figure 6) Ingenika Group rocks (previously assigned to the Tenakihi Group) which are exposed in an anticlinorium, locally contain abundant garnet and kyanite. Garnets are by far the most common porphyroblasts developed. Approximately 2000 metres above the lowest exposed strata, favourable beds, up to 3 metres thick, are reported to contain garnets comprising as much as 50 per cent of the rock volume (Roots, 1954). The garnets may be up to 2.5 centimetres in size, but are more commonly 1 to 3 millimetres in diameter. A few hundred metres stratigraphically above the garnet-rich strata, pelitic layers locally contain approximately 10 per cent kyanite in crystals which are up to 7.5 centimetres in length (Roots, 1954). Minor amounts of sillimanite are present in the lowest stratigraphic units exposed in the Jim May Creek area.

Ingenika Group rocks, exposed near the west side of Williston Lake, north of Ole Creek (Area 2, Figure 6), include micaceous strata in which abundant porphyroblasts of kyanite, more than 2 centimetres long are present (Gabrielse, 1975). Metamorphosed Misinchinka Group rocks are exposed in the Deserters Range, east of the Rocky Mountain Trench. North of Chowika Creek (Area 3, Figure 6) pelitic strata in the kyanite zone contain abundant garnets, 5 to 8 millimetres in diameter, and locally, coarse blades of kyanite (Evenchick, 1985).

Hope - Yale - Harrison Lake - Lytton Area (92H, I), Coast Mountain Belt

Pelitic schists and gneisses crop out in a number of localities in the Hope - Yale - Harrison Lake - Lytton area of southwestern British Columbia, marginal to the Scuzzy, Spuzzum and Chilliwack plutons (Figure 7 and 8). Locally, the schists and gneisses contain abundant kyanite, sillimanite, andalusite and garnet. Two regional-scale map units may be defined, the first comprising predominantly gneisses, variably assigned to the Chilliwack Group, Breakenridge Formation, and the Custer and Skagit gneiss units. The second division consists of schists, amphibolites and phyllites of the Settler Schist and Cairn Needle formations.

In the Kwoiek Needle - Nahatlatch River area (Figure 7), south of Lytton, sillimanite, kyanite, garnet and andalusite are present in phyllites and schists which occur as roof pendants or screens in the Coast Range batholith (Duffell and McTaggart, 1952; Hollister, 1969a, 1969b). The schists may be equivalents of the Settler Schist, exposed to the south. The garnet and aluminosilicate minerals are clearly products of contact metamorphism related to the emplacement of the Coast Range plutons and isograds marking the first appearance of the various aluminosilicate polymorphs can locally be mapped around intrusions (Hollister, 1969a, 1969b). Garnets average 1 millimetre in diameter and commonly comprise up to 15 per cent of the rock (Hollister, 1969a). Aluminosilicate polymorphs commonly are 2 centimetres long and comprise 6 to 7 per cent of the rock (Hollister, 1969a); however, andalusite crystals up to 5 centimetres long are so crowded in certain layers as to form most of the rock (Duffell and McTaggart, 1952). Locally, the aluminosilicates are completely altered to muscovite.
Pelitic gneisses and schists of the Breakenridge and Cairn Needle formations of Upper Paleozoic and Mesozoic age crop out in the Harrison Lake area (Area 1, Figure 8). Locally, gneisses of the Breakenridge Formation are extremely pelitic and may contain up to 50 per cent garnet (average approximately 20 per cent) and up to 40 per cent coarse-grained kyanite (average approximately 15 per cent) (Reamsbottom, 1971, 1974). Schists of the Cairn Needle Formation are also locally pelitic, containing from 4 to 50 per cent garnet, with averages of approximately 10 to 15 per cent, minor kyanite or andalusite and from 0 to 35 per cent sillimanite (Reamsbottom, 1971, 1974).

The Settler Schist, of uncertain age, outcrops in the area between Hope, Yale and Harrison Lake. North of Cogburn Creek (Area 2, Figure 8) it contains up to 23 per cent kyanite porphyroblasts, which may reach 1.5 centimetres in length, and a few per cent of coarse sillimanite in prisms in excess of 4 centimetres long (Lowes, 1972). North of Yale Creek (Area 3, Figure 8) pelitic units within the Settler Schist contain up to 15 per cent sillimanite, up to 11 per cent garnet and a few per cent of kyanite (Bartholomew, 1979). North of Emory Creek (Area 4, Figure 8) streaky pelitic layers within a dominantly quartzo-feldspathic unit contain up to 12 per cent kyanite, 10 per cent sillimanite and 12 per cent garnet (Pigage, 1973). Streaky amphibolites in this area may contain up to 30 per cent garnet (Pigage, 1973). Coarse sillimanite prisms, over 5 centimetres in length, are developed in pelitic schists on Zofka Ridge adjacent to a plutonic contact (Area 5, Figure 8). Within these schists, sillimanite may comprise 14 to 15 per cent of the rock, with garnet accounting for another 22 to 25 per cent (Lowes, 1972). Pelitic gneisses exposed in the Fraser River valley between Hope and Yale (Area 6, Figure 8) may contain from 3 to 25 per cent almandine, 0 to 8 per cent kyanite and 0 to 10 per cent sillimanite (Read, 1960).

Near the International Border, lithologies assigned to the Skagit Gneisses crop out adjacent to the Chilliwack batholith (Areas 7 and 8, Figure 8). Garnet and fibrolitic sillimanite are present in biotite gneisses near the summit of Mount Holden (Area 7, Figure 8). The garnets are fairly large (0.5 centimetre), and visibly zoned (Haugerud, 1985). A metre-thick layer of rusty weathering aluminous gneiss crops out on both limbs of a large fold on Mount Daly (Area 8, Figure 8). It contains abundant elongate grey porphyroblasts which are composed of aggregates of sillimanite needles. Small relict kyanite grains are also present (Haugerud, 1985).

Prince Rupert - Skeena River - Douglas Channel Area (103H, I, J), Coast Mountain Belt

Pelitic schists and gneisses of uncertain age and affiliation occur in abundance as inliers and adjacent to granitic plutons in the Prince Rupert - Skeena River - Douglas Channel - Hecate Strait area of northwestern British Columbia (Figures 9 and 10). The Central Gneiss Complex of the Prince Rupert - Skeena map area contains layers of biotite-garnet-sillimanite-muscovite gneisses (Area 1, Unit 1A, Figure 9) 30 to 300 metres thick in the area south of Mount Ponder and southeast of Redcap Mountain, the area northeast of Kwinamass Peak and north of the headwaters of the Kateen River (Hutchison, 1982). Within this zone sillimanite forms up to 50 per cent of the rock and garnets up to 0.75 centimetre in diameter form an additional 15 to 20 per cent (Hutchison, 1982).
On Highway 16, 1 kilometre east of Kwinitsa, excellent exposures of garnet-sillimanite-biotite-quartz-feldspar gneisses contain 5 to 30 per cent garnet and 5 to 30 per cent sillimanite; the sillimanite generally is present in densely felted layers from 0.2 to 2.5 centimetres thick (Hutchison, 1982). Similar gneisses outcrop along the north and south shores of Khtada Lake, on the ridge top 3 kilometres south of the south end of Khtada Lake, and on the ridge north of Khtada Lake (Hutchison, 1982), apparently forming a continuous zone (Area 2, in Unit 1B, Figure 9).

On Tsimpsean Peninsula, micaceous pelitic schists outcropping along the shores of Tuck Inlet (Area 3, in Unit 2, Figure 9) and near Port Simpson may contain up to 43 per cent garnet porphyroblasts and minor kyanite. On the shores of Tuck Inlet (Area 3, Figure 9) garnet porphyroblasts are up to 5 centimetres in diameter (Hutchison, 1982). A zone of highly aluminous carbonaceous schists outcrops at the north end of Tsimpsean Peninsula (Area 4, in Unit 1d, Figure 9). These schists contain abundant kyanite porphyroblasts which are up to 3 centimetres in length (Snyder, 1980). Numerous other garnet and sillimanite localities are present in the Prince Rupert - Skeena area (Figure 9).

In the Douglas Channel - Kitkiata Inlet area, south of Prince Rupert, extremely garnetiferous schists and gneisses (Area 1, Units 1 and 2, Figure 10) have been reported (Padgham, 1958). Euhedral garnets 0.25 to 2 centimetres in diameter locally comprise from 10 to 50 per cent of the rocks; biotite-garnet schists from the shores of Douglas Channel often contain 50 per cent garnets (Padgham, 1958).

On Hawksbury Island, south of Prince Rupert, kyanite-staurolite-almandine schists are exposed (Area 2, in Unit 2A, Figure 10) which contain up to 20 per cent almandine garnet and up to 20 per cent kyanite (Money, 1959). The garnet is present as subhedral to euhedral grains up to 5 centimetres in diameter or as anhedral to rounded aggregates, 7.5 centimetres in size. Kyanite may be extremely coarse; blades reach 20 by 1 centimetres in size (Money, 1959). The individual kyanite-staurolite-almandine schist units vary from a metre to over 30 metres in thickness and are traceable along strike for up to 2 kilometres (Money, 1959). Sillimanite is reported from only one locality on Hawksbury Island (near Fishtrap Bay, Figure 10), where it is present as rounded knots in gneiss and comprises up to 15 per cent of the rock (Money, 1959).

Garnet and sillimanite occur in a number of other localities in the Douglas Channel - Hecate Strait area (Figure 10; Roddick, 1970). In particular, east of Kiltuish Inlet and Kiltuish River (Area 3, in Unit 2, Figure 10) schists contain abundant garnet and, commonly, sillimanite (Roddick, 1970). On the west coast of Banks Island, south of Grief Point, garnet-biotite-quartz schists crop out (Area 4, in Unit 2B, Figure 10). Some of the garnets in these schists reach up to 2.5 centimetres in length, and are strongly flattened parallel to schistosity (Roddick, 1970). In the Atan Peak area (Area 5, in Unit 2A, Figure 10) andalusite is present in quartz-biotite schists adjacent to intrusive rocks. Locally, the andalusite forms porphyroblasts up to 10 centimetres in length and comprises a major constituent of the schists (Evenchick, 1979).
Vancouver Island (928, C), Insular Belt

Aluminosilicate-rich pelitic schists of the Leech River Unit are exposed on southern Vancouver Island, outcropping between the Leech River and San Juan faults near Port Renfrew and Langford (Figure 11). The Leech River Unit, of Triassic to Cretaceous age, is largely comprised of argillites and metagreywackes, with some metavolcanics (Muller, 1981). Metamorphic grade increases from north to south across the unit; the exposed southern one-third to one-half of the unit contains staurolite and andalusite (Figure 11). Within pelitic strata, andalusite is abundant and may be present as porphyroblasts from 12 to 20 centimetres long (Rusmore, 1982; Grove, 1984). Areas of particular note are the Sombrio River and Valentine Mountain vicinities (Figure 11). Locally, retrograde alteration results in the replacement of andalusite by chlorite and muscovite (Fairchild and Cowan, 1982). Garnet may also be present in these schists in moderate abundance (Fairchild and Cowan, 1982).

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NTS: 82L (8)  
Minerals: sillimanite, garnet

NTS: 104W  
Minerals: garnet, andalusite

NTS: 82N (1)  
Minerals: kyanite

NTS: 82F (2, 3)  
Minerals: garnet, sillimanite, andalusite

NTS: 93K and 93N  
Minerals: garnet

NTS: 82L (8)  
Minerals: sillimanite, garnet

NTS: 93D  
Minerals: garnet, kyanite

NTS: 93D, 103A  
Minerals: garnet, kyanite, sillimanite

NTS: 93D, 103A  
Minerals: garnet, kyanite, sillimanite

NTS: 82E (14)  
Minerals: kyanite, garnet
NTS: 92H (11)
Minerals: garnet, sillimanite, kyanite

NTS: 92H (4), 92G (1)
Minerals: garnet

NTS: 82F (9)
Minerals: garnet

NTS: 82F (14, 15)
Minerals: garnet, sillimanite, andalusite

NTS: 92H (11)
Minerals: garnet, sillimanite

NTS: 82M (7, 10)
Minerals: kyanite, sillimanite

NTS: 82F, 82G, 82K, 82L, 82M, 92I
Minerals: garnet, kyanite, sillimanite, andalusite

NTS: 82L (3, 4, 6)
Minerals: kyanite

NTS: 82F (14)
Minerals: garnet, andalusite

NTS: 83D
Minerals: garnet, kyanite

NTS: 93A (1, 2)
Minerals: garnet, kyanite


NTS: 93A (1, 2)
Minerals: garnet, kyanite


NTS: 83D (1, 2)
Minerals: kyanite, garnet


NTS: 93H
Minerals: garnet


NTS: 92P
Minerals: garnet, sillimanite, andalusite


NTS: 82M
Minerals: kyanite


NTS: 93A (2, 7)
Minerals: garnet


NTS: 82E (3, 4, 5, 6)
Minerals: garnet, sillimanite


NTS: 92A, 92B
Minerals: kyanite, garnet


NTS: 92A
Minerals: garnet, kyanite, sillimanite, andalusite
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Minerals: kyanite andalusite

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Minerals: sillimanite, kyanite, garnet

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NTS: 82N (11, 12)
Minerals: garnet, kyanite

Minerals: kyanite, sillimanite


Minerals: garnet


Minerals: garnet, andalusite


Minerals: andalusite, garnet


Minerals: garnet


Minerals: kyanite


Minerals: garnet


Minerals: garnet, kyanite, sillimanite


Minerals: andalusite, garnet


Minerals: kyanite, garnet

Minerals: garnet, kyanite, sillimanite


Minerals: garnet, andalusite


Minerals: andalusite, garnet


Minerals: garnet, kyanite, sillimanite


Minerals: garnet, kyanite, sillimanite


Minerals: garnet, kyanite, sillimanite


Minerals: garnet, sillimanite


Minerals: kyanite, garnet


Minerals: garnet, kyanite, sillimanite

NTS 82F (3)
Minerals: garnet


NTS: 82L (5, 6, 7, 10, 11, 12, 13, 14, 15), 82M (2, 3, 4)
Minerals: sillimanite, garnet


NTS: 104P
Minerals: garnet


NTS: 94C (E1/2)
Minerals: garnet, kyanite


NTS: 104I, 104P, 104O, 104J
Minerals: garnet


NTS: 94E, 94F (W1/2), 94L
Minerals: garnet, kyanite


NTS: 104I (9, 16), 104L (12)
Minerals: andalusite


NTS: 93A (10, 11, 14, 15)
Minerals: garnet, kyanite, sillimanite


NTS: 93A (10, 11, 14, 15)
Minerals: garnet, kyanite, sillimanite


NTS: 82N (12)
Minerals: garnet, kyanite

NTS: 83D (1, 2), 82M (15, 16)
Minerals: garnet, sillimanite, kyanite


NTS: 83D
Minerals: garnet, kyanite


NTS: 83D (2), 82M (15)
Minerals: kyanite, sillimanite


NTS: 83D (1, 2, 7)
Minerals: garnet, sillimanite, kyanite


NTS: 82M (15), 83D (2)
Minerals: garnet, kyanite, sillimanite


NTS: 82F (2)
Minerals: garnet, kyanite, sillimanite, andalusite


NTS: 92H (4, 5)
Minerals: garnet, andalusite


NTS: 103P (5)
Minerals: andalusite


NTS: 928 (12W)
Minerals: andalusite, garnet


NTS: 82M (8)
Minerals: andalusite, garnet

Minerals: garnet, sillimanite


Minerals: garnet, kyanite, sillimanite


Minerals: garnet


Minerals: garnet


Minerals: garnet, kyanite, sillimanite, andalusite


Minerals: garnet (skarn)


Minerals: garnet, andalusite, sillimanite, kyanite


Minerals: garnet, andalusite, kyanite, sillimanite


Minerals: garnet, sillimanite


Minerals: garnet, kyanite, sillimanite
NTS: 1031 (W1/2) and 103E (E1/2)
Minerals: garnet, sillimanite

NTS: 1031
Minerals: kyanite, sillimanite

NTS: 103I (W1/2) and 103J (E1/2)
Minerals: garnet, sillimanite, kyanite, andalusite

NTS: 82K (4), 82F (13)
Minerals: garnet, sillimanite, kyanite

NTS: 82L
Minerals: sillimanite, garnet, kyanite

NTS: 82M (11, 12)
Minerals: garnet

NTS: 82N (11, 12)
Minerals: garnet

NTS: 82N (5)
Minerals: garnet

NTS: 82M (7)
Minerals: garnet, kyanite, sillimanite, andalusite

NTS: 82M, L
Minerals: kyanite, sillimanite
NTS: 1048, 104F, 104G
Minerals: garnet, sillimanite, kyanite, andalusite

NTS: 1031 (4)
Minerals: kyanite, sillimanite, garnet

NTS: 82M (1, 8)
Minerals: garnet

NTS: 82M (1, 8)
Minerals: garnet, andalusite, sillimanite, kyanite

NTS: 82M (10E)
Minerals: garnet, sillimanite

NTS: 82M (9, 16), 83D (1)
Minerals: garnet, kyanite, sillimanite

NTS: 82M (9, 16)
Minerals: garnet, kyanite, sillimanite

NTS: 82F (7, 10)
Minerals: garnet, kyanite, sillimanite

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Minerals: garnet

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Minerals: andalusite, garnet, (grossular)

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Minerals: garnet

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NTS: 94E (1, 2, 7, 8)
Minerals: garnet, kyanite, sillimanite

Minerals: andalusite, garnet


Minerals: sillimanite


Minerals: garnet, kyanite, andalusite, sillimanite


Minerals: kyanite


Minerals: garnet, kyanite


Minerals: sillimanite, garnet, kyanite


Minerals: garnet


Minerals: garnet


Minerals: garnet, kyanite, sillimanite, andalusite


Minerals: sillimanite, kyanite, garnet, andalusite


Minerals: garnet, kyanite, sillimanite


Minerals: garnet


Minerals: garnet


Minerals: garnet, kyanite


Minerals: garnet, kyanite


Minerals: garnet, sillimanite


Minerals: kyanite


Minerals: kyanite


Minerals: garnet, kyanite


Minerals: garnet, kyanite


Minerals: garnet, skarn, garnet-regional


Minerals: garnet


Minerals: kyanite, sillimanite


Minerals: kyanite, sillimanite


Minerals: garnet, sillimanite, kyanite

NTS: 82F (5, 12)
Minerals: sillimanite


NTS: 83D (3, 5, 6, 11, 12)
Minerals: garnet, kyanite, sillimanite


NTS: 83D (3, 6)
Minerals: garnet, kyanite, sillimanite


NTS: 83D (5, 6, 11, 12)
Minerals: garnet, kyanite, sillimanite


NTS: 83D (12)
Minerals: garnet


NTS: 82M (15, 16)
Minerals: garnet, kyanite


NTS: 92H (11, 12)
Minerals: garnet, kyanite, andalusite, sillimanite


NTS: 83D (5, 12), 93A (8, 9)
Minerals: garnet, kyanite, sillimanite


NTS: 82N (2, 5, 6)
Minerals: garnet


NTS: 82E (1)
Minerals: sillimanite
NTS: 82E (1)
Minerals: sillimanite, garnet

NTS: 82E (1) W1/2
Minerals: sillimanite, garnet

NTS: 82M (7, 8, 10)
Minerals: garnet, kyanite, sillimanite

NTS: 83D (2)
Minerals: garnet, sillimanite, kyanite, andalusite

NTS: 92H (8), 82E (5)
Minerals: garnet

NTS: 92H (6), 92H (11)
Minerals: garnet, kyanite, sillimanite

NTS: 82K (6, 11)
Minerals: garnet

NTS: 82K, 82L, 82M
Minerals: garnet, sillimanite

NTS: 82L (16), 82M (1)
Minerals: garnet, sillimanite
NTS: B2E (5), B2L (3, 5, 6)
Minerals: kyanite, sillimanite

NTS: 92H (12, 13)
Minerals: garnet, andalusite, kyanite, sillimanite

NTS: 92H (12)
Minerals: garnet, kyanite, sillimanite, andalusite

NTS: 83D (1)
Minerals: garnet

NTS: B2E (E1/2)
Minerals: garnet, kyanite, sillimanite

NTS: 82F (16)
Minerals: garnet, sillimanite

NTS: 82F (11, 12, 13, 14)
Minerals: sillimanite, garnet

NTS: B2L
Minerals: garnet, sillimanite

NTS: 82K E1/2
Minerals: garnet, kyanite, andalusite, sillimanite

NTS: 82L (8, 9)
Minerals: kyanite, andalusite, sillimanite, garnet
NTS: B2E (1, 2)
Minerals: garnet, sillimanite

NTS: B2G
Minerals: garnet, sillimanite

NTS: B2F, B2E1/2 (1, 2, 7, 8, 9, 10, 15, 16)
Minerals: garnet, sillimanite, kyanite

NTS: B3D (2)
Minerals: garnet, kyanite

NTS: 92G (6, 7)
Minerals: garnet, sillimanite

NTS: 103H and 103G (E3/8)
Minerals: garnet, sillimanite, kyanite

NTS: 92J (W1/2)
Minerals: garnet, sillimanite, andalusite

NTS: 103A, 103G, 103H, 103J, 103R and 93D
Minerals: garnet

NTS: 94C W1/2
Minerals: garnet

NTS: 94C W1/2
Minerals: garnet, sillimanite, kyanite

NTS: 94C W1/2 (3, 4, 5, 6, 11, 12, 13, 14)
Minerals: garnet, kyanite, sillimanite

Minerals: kyanite, sillimanite


Minerals: garnet, andalusite


Minerals: garnet, sillimanite


Minerals: garnet, kyanite


Minerals: garnet, sillimanite


Minerals: garnet, sillimanite


Minerals: garnet, sillimanite


Minerals: garnet, sillimanite, kyanite


Minerals: garnet, sillimanite, kyanite


Minerals: garnet, kyanite
NTS: 104K
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Minerals: garnet, kyanite, sillimanite

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NTS: 82W (W1/2)
Minerals: garnet, kyanite

NTS: 82W (W1/2)
Minerals: garnet, andalusite, kyanite, sillimanite

NTS: 82M (E1/2)
Minerals: kyanite, sillimanite, garnet

NTS: 82F (10, 15)
Minerals: garnet, sillimanite, kyanite

NTS: 82F (9, 16)
Minerals: garnet
INDUSTRIAL MINERAL POTENTIAL OF GARNET AND KYANITE IN BRITISH COLUMBIA

by Jennifer Pei

FIGURE 4
MAP 3
FIGURE 5
MAP 4

To accompany Open File 1988-28

INDUSTRIAL MINERAL POTENTIAL OF GARNET AND KYANITE IN BRITISH COLUMBIA

By Jennifer Pell

CANOE RIVER 83D
1:250 000
FIGURE 6
MAP 5

To accompany Open File 1988-26

INDUSTRIAL MINERAL POTENTIAL
OF GARNET AND KYANITE IN
BRITISH COLUMBIA

By Jennifer Pail

Compiled from Erenchik, 1985,

MESILINKA RIVER
94C
1:250 000

This project is a contribution to the Canada – British Columbia Mineral Development Agreement, 1985 – 1990
FIGURE II
MAP 10

To accompany Open File 1089-06

INDUSTRIAL MINERAL POTENTIAL OF GARNET AND KYANITE IN BRITISH COLUMBIA

By Jennifer Peti

Compiled from Fairchild and Owen, 1980; Miller, 1967; 1968; Burness, 1962.

VICTORIA (W 1/2); 92B (W 1/2) AND CAPE FLATTERY (E 1/2); 92C (E 1/2)
1:250 000