# KYANITE AND ANDALUSITE OCCURRENCES IN BRITISH COLUMBIA, CANADA

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## BACKGROUND INFORMATION

Andalusite, kyanite and sillimanite are alumino-silicate polymorphs of metamorphic origin with the chemical formula $Al_2SiO_5$. When calcined, these polymorphs convert to mullite, a highly refractory material. The conversion is accompanied by an irreversible volume expansion of 5%, 18% and 7% for andalusite, kyanite and sillimanite, respectively (Skillen, 1993). Worldwide, andalusite is the preferred of the three raw materials because it converts to mullite at lower temperatures (1380°C) than sillimanite (1550°C). Although kyanite converts to mullite at 1370°C, andalusite is favoured because the volume change during mullitization is negligible; therefore no calcination is required before manufacturing refractory shapes. Approximately $4.22 \times 10^9$ joules ($4 \times 10^6$ BTU) are needed to mullitize one tonne of kyanite (Skillen, 1993). Despite this, kyanite is the most widely used polymorph in North America, because of its local abundance, proximity to markets, and availability of relatively inexpensive energy. As energy costs continue to increase, this may change.

In 1998, production of kyanite was probably less than 200 000 tonnes. Prices at the time of writing were US$135 to US$165 for raw kyanite and US$238 to US$268 for calcined kyanite; both contain 54 to 60% $Al_2O_3$. The sizes of typical United States kyanite products are 28, 35, 100, 200 and 325 Tyler mesh. Concentrates are generally about 91% kyanite, less than 1% iron oxides, and the rest quartz.

South Africa is by far the world's largest andalusite producer. Other andalusite producing countries are France, the United States and China. Commercial andalusite concentrates from South Africa and France vary in composition from 53 to 60% $Al_2O_3$ and from 0.8 to 1.5% $Fe_2O_3$. An andalusite-pyrophyllite-sericite mixture is mined in the United States for a captive market. In some cases, andalusite-pyrophyllite material has applications in ceramics. Iron is a detrimental impurity in most refractory applications.

Total world production of andalusite for 1998 was estimated to be 300 000 tonnes. The bulk of this production came from Africa. In July of 2000, andalusite prices varied from US$171 to US$200/tonne for a 2 000 tonne bulk shipment FOB South Africa.

Andalusite deposits are formed by low pressure, contact or regional thermal metamorphism of high-alumina, low-calcium pelitic rocks.

Formation of andalusite deposits depends on having a mineable thickness of pre-metamorphic protolith, its chemical composition, and low pressure thermal metamorphism. Grades of currently exploited 'hard rock' andalusite ores vary from 7 to 20% andalusite. Production capacities of existing mines vary from 25 000 to 65 000 tonnes/year. Generally, andalusite crystals are nearly inclusion free, and the coarser the crystals, the easier it is to upgrade the ore. Crystals from mined deposits vary from 1 millimetre to several centimetres. Ores are commonly crushed and then upgraded using heavy liquids; flotation is required for the treatment of fine-grained ores. Placer deposits account for a substantial proportion of the andalusite produced in South Africa. In these deposits, garnet and staurolite commonly coexist with andalusite and are recovered as byproducts.

There are more than 45 kyanite and 23 andalusite occurrences known in British Columbia (http://www.em.gov.bc.ca/Mining/Geolsurv/Minfile/search/). Locations of these occurrences are presented on Figures 1 and 2. Selected occurrences are described below. Most of the occurrences have been described by Pell (1988), Simandl *et al.*, (1995), and Hancock and Simandl (1996).

## KYANITE

The Tsimpsean Peninsula and Hawkesbury Island kyanite occurrences are considered to be representative of the more than 45 occurrences reported in British Columbia. The occurrences are restricted to high-alumina, high-grade metasedimentary rocks in the Coast and Omineca tectonic belts.

### *Dudevoir Passage and Trail Bay*

At Dudevoir Passage and Trail Bay, the kyanite occurrences are probably within the same alumina-rich zone. It is possible that kyanite occurrences on the shore 13 and 29 kilometres southeast of Trail Bay (Hutchison, 1982) are part of this same zone. Where measured, the alumina-rich zone is 3 metres wide but it may thicken in fold hinges. The kyanite crystals are coarse, up to 2 centimetres long, with several coarse inclusions of quartz.

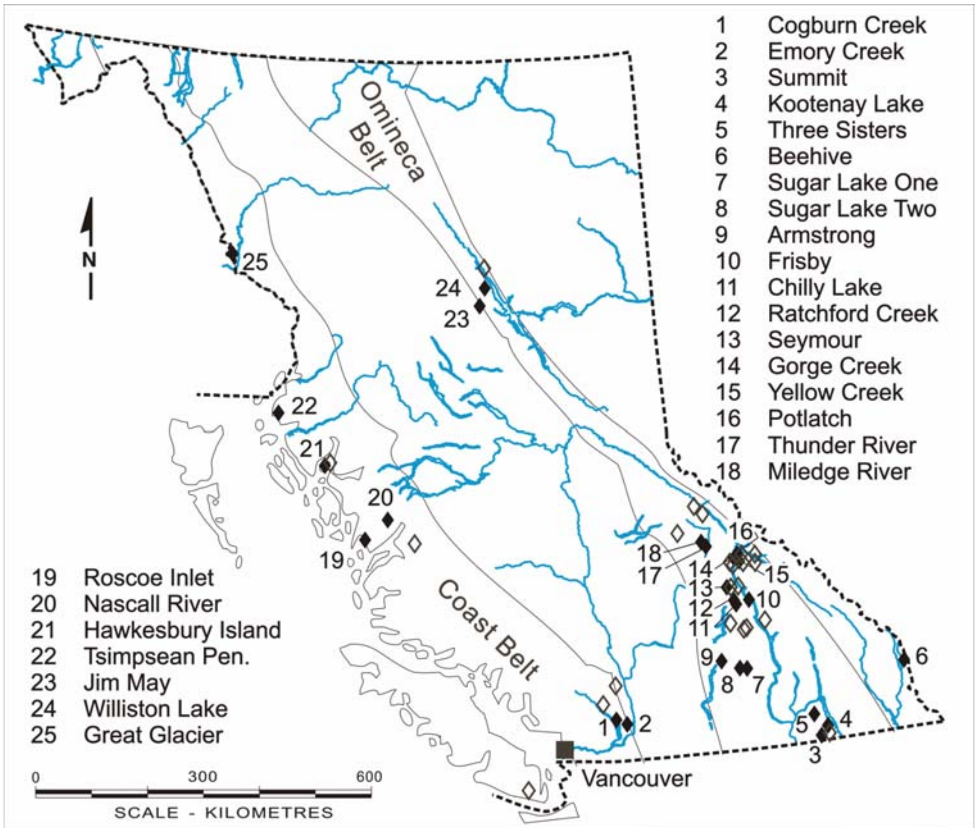


Figure 1. Location of significant kyanite occurrences in British Columbia. Major showings are named (Hancock and Simandl, 1996)

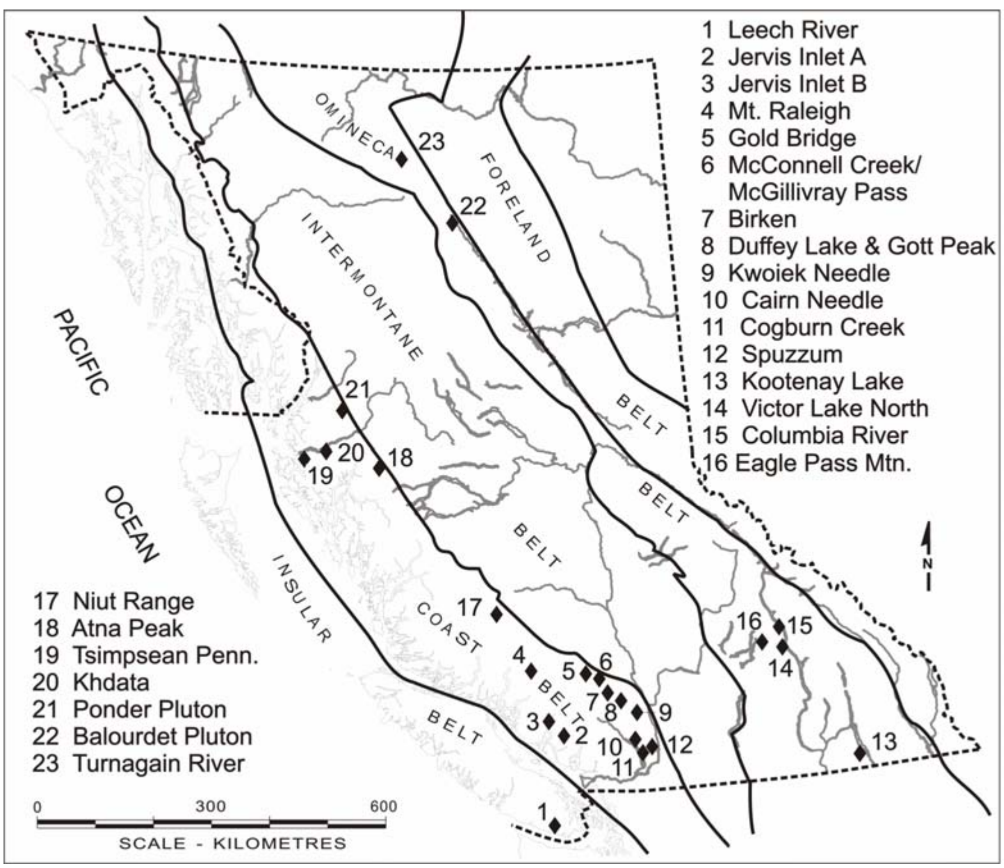


Figure 2. Andalusite occurrences in British Columbia (Simandl *et al.*, 1995)

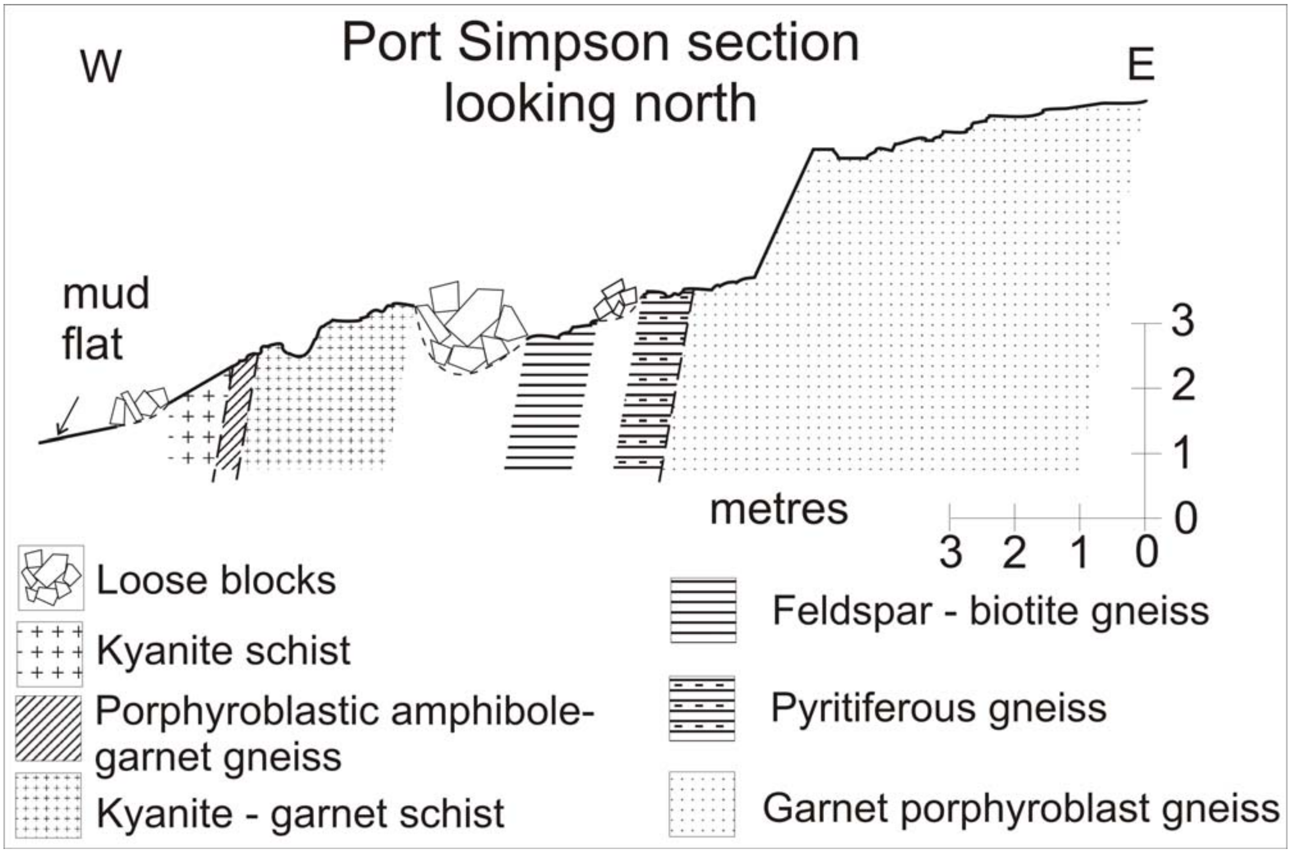


Figure 3. Section across the Dudevoir Passage kyanite showing (Hancock and Simandl, 1996)

Graphitic material within the kyanite layers could probably be removed by calcination.

At Dudevoir Passage, the kyanite outcrops form small bluffs 450 metres south of the western mouth of the passage. A vertical cross section of the Dudevoir Passage is shown on Figure 3. The section begins in medium to coarse-grained kyanite schist comprised of quartz and plagioclase with 10 to 15% each of biotite and muscovite flakes that are less than 3 millimetres across. Pyrite and magnetite are minor constituents (less than 1% each) and graphite is less than 0.5%. Kyanite content varies from 10 to 25%, and crystals measure from few millimetres to 2 centimetres in length. They contain microscopic quartz inclusions. Porphyroblastic amphibole-garnet gneiss (metabasite) is garnet-rich near the contacts and rich in feldspar and mafic minerals towards the centre of the unit. The mafic-rich center consists of amphibole and pyroxene.

At Trail Bay the kyanite-bearing gneiss contains 35 to 40% kyanite, 40% quartz, 10% biotite, which is less than 6 millimetres in size, 5% feldspar, less than 5% 1 to 2 millimetre staurolite, 2% garnet, which is less than 2 millimetres, and trace amounts of pyrite. Some kyanite crystals contain inclusions of iron oxides and graphitic material. A single kyanite zone is well exposed at the head of the bay but more than one zone may be present toward the southern limit of the exposures. The kyanite-bearing gneiss is 3 metres wide and is exposed for 50 metres along strike. It is bronze-grey on weathered surfaces. Coarse kyanite crystals, less than 5 centimetres long, generally form between 20 and 40% of the gneiss; locally, kyanite makes up 80% of the rock. Other minerals present are quartz (±40%), biotite (±10%), feldspar (±5%), staurolite (less than 1%) and trace amounts of graphite. Kyanite-bearing outcrops along the west side of the bay contain 5% of 2 to 5 centimetre long kyanite crystals; 1% garnet that is 2 to 5 millimetres in diameter, and less than 5% fine-grained graphite.

### *Hawkesbury Island*

There are 7 kyanite zones known on Hawkesbury Island. They vary in size from a few meters to several tens of meters in width and have been traced intermittently for up to 5 kilometres. Individual zones contain 10 to 70% kyanite as 0.2 to 4 centimetres long crystals. It is unlikely that kyanite alone could be economically recovered, but the rock also contains garnet, staurolite and muscovite that could be byproducts. Kyanite occurs within a number of discrete zones of high-grade metapelitic gneiss that are part of Roddick's feldspar-hornblende schist unit (Money, 1959). Kyanite-bearing zone 1, which is within a quartz-feldspar-biotite gneiss, is 3 to 25 metres across and was

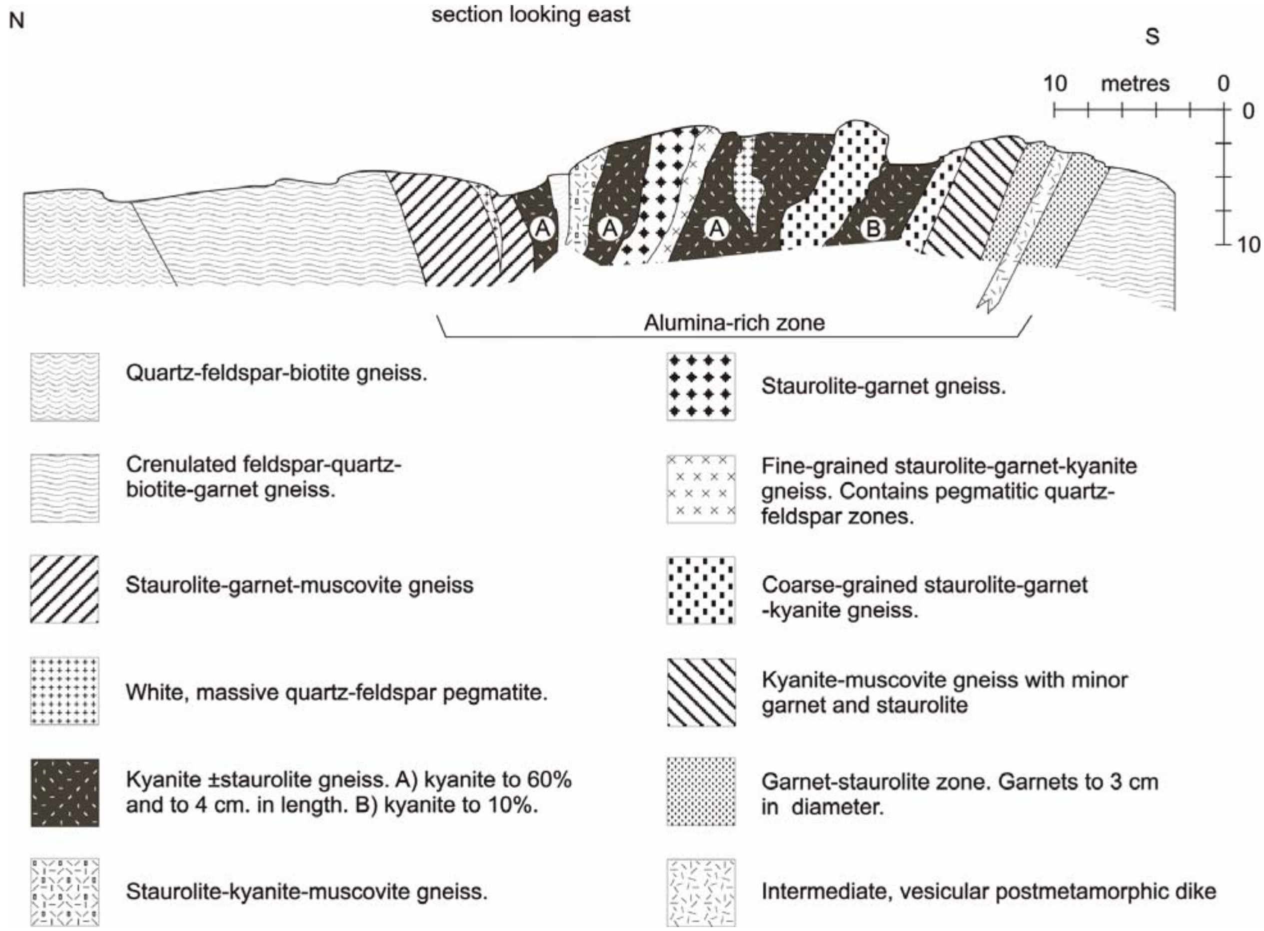


Figure 4. Section across the zone 1 kyanite showing on Hawkesbury Island (Hancock and Simandl, 1996).

traced for 900 metres along strike. Individual gneissic layers pinch and swell from 0.1 to 1 metre, and are folded. Quartz-feldspar pegmatite layers, veins and sweats exhibit ptygmatic folding. Significant mineral components include kyanite, garnet and staurolite. The mapped section (Figure 4) is 25 metres across. The kyanite zones exposed in the area may be part of a structurally repeated sequence. Selected units are described in Figure 4.

- Kyanite ± staurolite gneiss contains up to 60% kyanite crystals from 0.2 to 4 centimetres long enclosing inclusions of quartz. Staurolite is disseminated and forms 5% to 40% of the rock. Garnet may form massive lenses. The gneiss is muscovite-rich with a few percent of biotite. Remaining minerals are quartz and feldspar.
- Staurolite-kyanite-muscovite gneiss averages 7% staurolite and kyanite but locally these minerals make up to 65% of the rock. Staurolite and kyanite crystals are 2 to 10 millimetres wide and 5 to 20 millimetres long. Garnet grains are less than 1 centimetre in diameter but they comprise less than 5% of the rock.

- Staurolite-garnet gneiss contains 5% staurolite, 3% garnet and less than 10% biotite. The balance of the rock consists of feldspar and quartz.
- Fine-grained staurolite-garnet-kyanite gneiss has numerous feldspar-quartz pegmatite layers. It contains 10% staurolite, 5% garnet and 5% kyanite along with feldspar and quartz.
- Coarse-grained staurolite-garnet-kyanite gneiss is coarser than the previous unit. It contains 40% staurolite that is 4 to 20 millimetres in size, as well as 10% garnet that is from 5 to 30 millimetres in diameter and less than 10% kyanite.
- Kyanite-muscovite gneiss is distinguished by its 15% muscovite content. It also consists of 20% kyanite crystals, 1 to 5% garnet and 0 to 20% staurolite.
- Garnet-staurolite gneiss has 3 centimetre-sized garnets that form 30% of the rock. Staurolite is an accessory mineral.
- A post-metamorphic, fine-grained intermediate dike crosscuts the section.

Kyanite-bearing zone 2, which lies 450 metres south of zone 1, is 225 metres long and 10 metres wide.

It is very complexly folded. Kyanite occurs in concentrations of up to 10% in layers that are less than 25 centimetres thick. Kyanite grains are 1 to 2 centimetres long. Staurolite averages less than 5%. Grains are less than 2 centimetres long, nearly black and often form dense masses adjacent to coarse-grained quartz-feldspar lenses. Garnets occur as disseminated grains with concentrations in the 1 to 10% range. The crystals are 0.5 to 2 centimetres in diameter. In or immediately adjacent to quartz-feldspar lenses, garnets form 1 metre long masses comprised of 7 centimetre crystals (Hancock and Simandl, 1996).

## ANDALUSITE

The areas of the Omineca, Coast and Insular belts affected by contact metamorphism or low-pressure, high-temperature regional metamorphism have good geological potential for andalusite deposits wherever aluminous protoliths are present. Unfortunately, in many cases andalusite was converted to sillimanite or kyanite by a later high-temperature metamorphic overprint or to low-temperature, hydrated minerals such as muscovite.

### *Omineca Belt*

This belt (Figure 2) consists largely of metamorphic and intrusive rocks (Gabrielse *et al.*, 1991). Andalusite is related to low pressure, high temperature metamorphism that overprints an earlier higher pressure metamorphism. Several showings (Figure 2) are reported in the southern Omineca Belt on the west side of Kootenay Lake, near Victor Lake, near Eagle Pass Mountain, and north of Revelstoke along the Columbia River. Andalusite-bearing rocks are also known in the northern Omineca Belt, where they occur within basement gneiss near the Eocene Balourdet pluton in the Sifton Range, and in rocks 30 kilometres to the north (Evenchick, 1988). Another occurrence is near the confluence of the Turnagain and Cassiar rivers (Gabrielse, personal communication, 1994), where andalusite porphyroblasts, 3 to 4 centimetres long are partially retrograded to muscovite. This occurrence is hosted by metasediments along the contact of an Early Cretaceous pluton.

### *INSULAR BELT*

Andalusite is present in rocks of the Leech River complex on southern Vancouver Island (Figure 2). These rocks were affected by Late Eocene low pressure metamorphism (Fairchild and Cowan, 1982).

### *Coast Belt*

This belt is composed largely of granites, and greenschist to granulite facies metamorphic rocks. Andalusite occurs on the eastern edge of the Coast Belt along a northwest trend where low pressure, high temperature metamorphic conditions prevailed during Mid to Late Cretaceous deformation and magmatism (Rushmore and Woodsworth, 1994). Peak metamorphic conditions were estimated at 3.5 kbars and 500 to 650ºC. Examples within this belt include the Mount Raleigh, Nuit Range, Bridge River, Cogburn Creek, McConnell Creek, Birken, Duffey Lake, Gott Peak, Ratchford Creek, Kwoiek Needle, Cairn Needle and Spuzzum pluton occurrences (Figure 2).

### *Bridge River Area*

In the Bridge River area, 180 kilometres north of Vancouver (Figure 5), several fine grained, andalusite occurrences are hosted by black argillite, formally referred to as the Noel Formation (Cairnes, 1937; Stevenson, 1958; Rushmore, 1985; Roddick and Hutchison, 1973; Journeay and Mahoney, 1994). Potential ore from these occurrences would be more difficult to upgrade than coarse South African ores. Showings such as CH-4 demonstrate that lithologies with favorable chemical composition have thicknesses of tens of meters. The Bridge River area is readily accessible and could be systematically prospected for andalusite.

The Noel lithofacies is a sequence of thinly bedded, fine-grained turbidites. Near the confluence of Cadwallader Creek and Noel Creek it is more than 350 metres thick and consists mainly of siltstones and black argillites. It is best developed in 2 belts near the Hurley River. Metamorphism of these argillites resulted in development of biotite, garnet, andalusite, cordierite and staurolite within a groundmass of quartz, biotite and pyrite. The andalusite-bearing rock is a hornfels with more than 12% andalusite. The andalusite is idiomorphic, relatively inclusion free and fine grained (1 to 7 millimetres) but the porphyroblasts are partly retrograded (Simandl *et al.*, 1995). Occurrence **CH-4** is an excellent example, located 8 kilometres west-southwest of Bralorne on an overgrown forestry road and about 200 metres from the Hurley River. The outcrop is 30 metres long and 14 metres high. Weathering produces exfoliated layers several centimetres thick. The prismatic andalusite crystals (5 to 12%) are 5 to 20 millimetres long and 0.5 to 3.0 millimetres across. The hornfels also contains more than 1% pyrite (Simandl *et al.*, 1995).

### *Lillooet Area*

Occurrences known in the Lillooet area have many similarities to those of the Bridge River area but are strongly retrograded to muscovite. All known andalusite occurrences (Figure 6) are hosted by hornfels derived from black argillites and siltstones similar to those of the Noel lithofacies of the Bridge River area. Unfortunately, andalusite porphyroblasts from this area are almost entirely retrograded to mica. There are a few

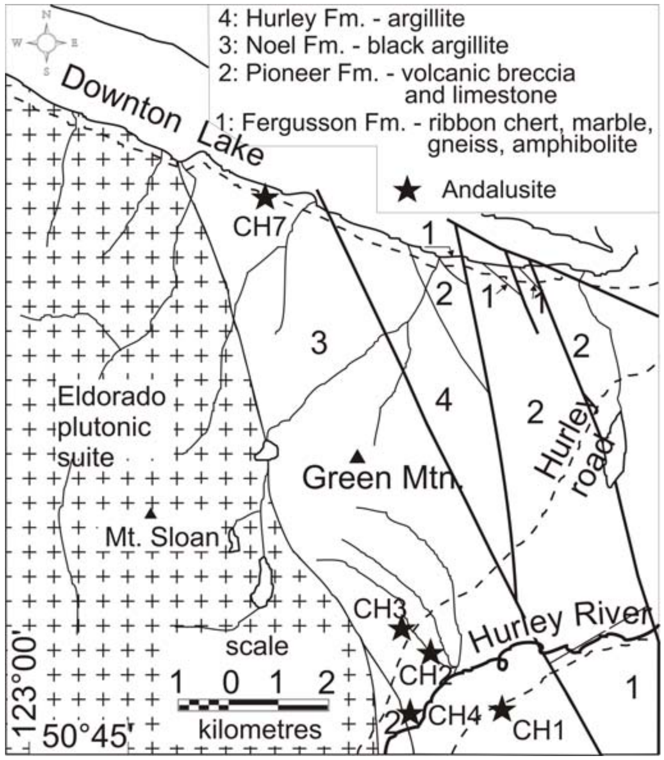


Figure 5. Andalusite occurrences in the Bridge River area (Simandl et al, 1995).

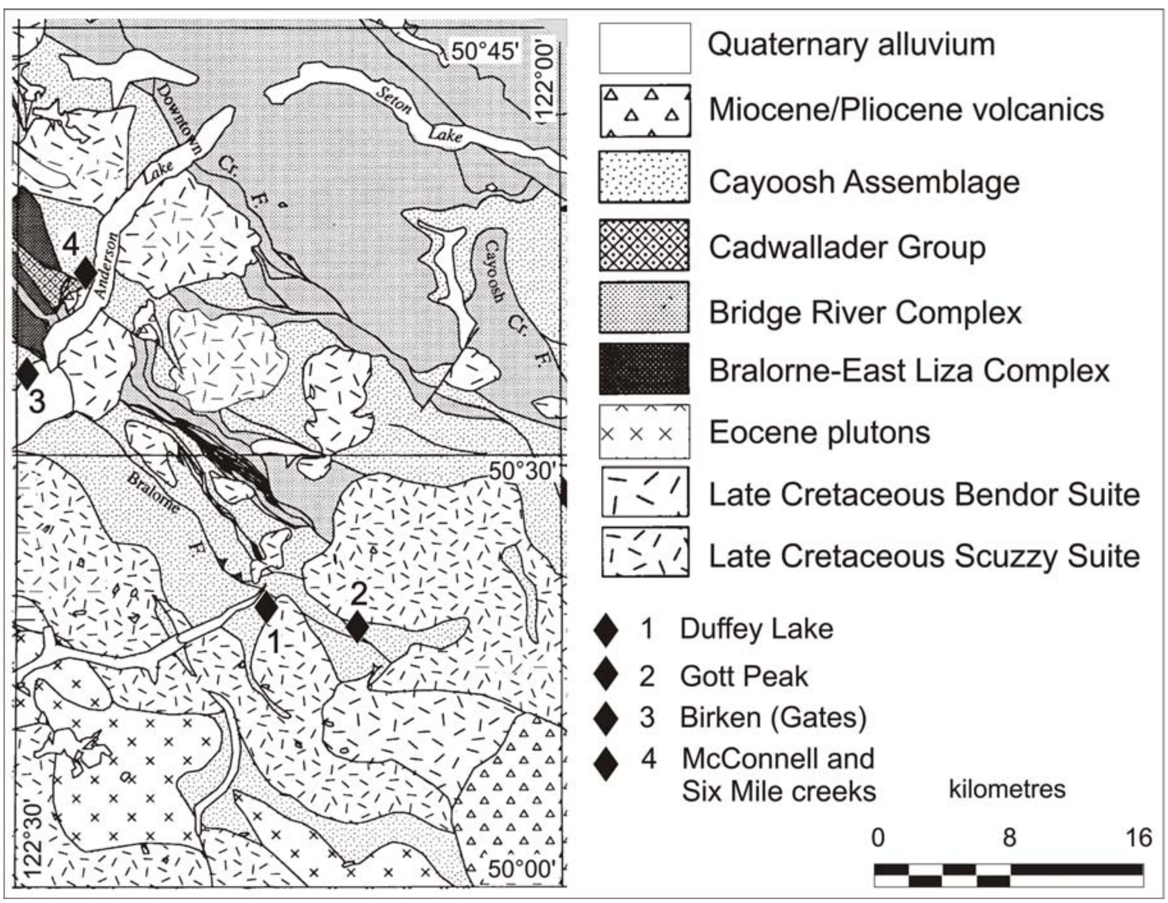


Figure 6. Andalusite occurrences in the Lillooet region (modified from Journeay and Mahoney (1994)). 1 - Duffey Lake; 2 - Gott Peak; 3 - Birken (Gates); 4 - McConnell and Six Mile creeks. (Simandl *et al.*, 1995, figure 3)

occurrences in the Duffey Lake area; the main one is west of Highway 99 near the northern tip of Duffey Lake (Figure 6). The andalusite horizon is a few meters thick and exposed over a 60 metres strike length. The groundmass is mainly biotite, quartz, possibly feldspar, pyrite (less than 1%), and garnets (less than 1 millimetre). Andalusite (2 to 15%) varies from 10 to 50 millimetres by 1 to 4 millimetres, and is retrograded to muscovite.

North of Gott Peak a raft of metasedimentary rocks (Journeay, personal communication, 1994) occurs within a granitic intrusion (Figure 6). Several fresh boulders (1 by 0.5 by 1 metres) were found south of that area. Mica pseudomorphs after andalusite, which are from 3 to 8 millimetres by several centimetres in length, comprise 20% of the rock.

The Birken (Gates) showing (Figure 6) is similar to Gott Peak but lies on the eastern margin of the Mount Rohr pluton (Journeay, personal communication, 1994). Blocks containing andalusite and staurolite in a groundmass of quartz, biotite, iron oxide (less than 1%) and millimetre-size garnets were found near the contact of sedimentary rock with the granite pluton near Birken. The largest block was 20 x 5 x 25 centimetres. Andalusite is largely retrograded to muscovite.

Hornfels boulders containing up to 15% high-alumina silicates were found in the bed of nearby Six Mile Creek (Figure 6). They contain 3 to 10% andalusite. The crystals are less than 6 millimetres in cross section and are enclosed in a quartz-biotite-feldspar groundmass.

### *Leech River Area*

Andalusite occurrences are numerous in the Leech River area. The andalusite porphyroblasts vary from a few to 30 centimetres in length. Most of the occurrences are of no economic interest because of low grades, narrow widths, or the effects of intense retrograde metamorphism. Retrograde metamorphism decreases westward, so the area of greatest potential is adjacent to and west of the Jordan River. (Simandl *et al.*, 1995)

The Leech River Complex is fault bounded and consists of sedimentary and volcanic rocks intruded by igneous rocks and affected by low-P metamorphism. At the Late Eocene metamorphic peak, pressure is estimated to have been 1.5 to 3.5 kbar, and temperature between and 500 to 600ºC. To the east, andalusite is strongly retrograded to either mica and staurolite or mica and chlorite; the degree of alteration diminishes westward from Valentine Mountain.

This study indicates that rocks in the western two-thirds of the area (Figure 7) contain abundant staurolite porphyroblasts. They are less than 1.5 centimetres long. Andalusite is limited to specific outcrops where it is partially or entirely replaced by muscovite and chlorite. Individual andalusite occurrences are described by Simandl *et al.*, (1995); most are retrograded.

### *Other Andalusite Occurrences in the Coast Belt*

Examination of hand specimens collected by the Geological Survey of Canada from the Raleigh Mountain area, and descriptions of occurrences in the Terrace region, indicate that some of the areas not covered by our reconnaissance study are prospective: In the Kwoiek area, andalusite pseudomorphs are replaced by sillimanite, (Hollister, 1969a, b).

At Mt. Raleigh, occurrences are in a roof pendant of volcanic and sedimentary rocks. Metamorphic grade increases to the southwest. Andalusite is confined to beds of graphitic, pelitic schist. The main andalusite-bearing unit, the Styx Formation, is 400 metres thick (Woodsworth, 1979). Porphyroblasts are less than 2 centimetres in cross section and 15 centimetres long. They form less than 10% of the rock. The Formation is exposed over a ten square kilometre area. Quartz and graphite inclusions occur in the porphyroblasts and the andalusite is partially retrograded to muscovite and quartz. Where metamorphism is highest, the andalusite is intergrown with fibrolite.

Andalusite-bearing rocks along the east side of the Coast Range (Nuit Range) are described by Rushmore and Woodsworth (1993, 1994). Metamorphic grade increases from northeast to southwest. Andalusite, garnet, staurolite and sillimanite are found only in pelitic rocks of the Cloud Drifter Formation where retrograded andalusite forms ‘spots’ and porphyroblasts less than 10 millimetres across. Andalusite content ranges from 5 to 10%.

Andalusite and biotite-bearing metasedimentary rocks are reported near the head of Jervis Inlet and at Phantom Lake (Greenwood *et al.*, 1991).

Although andalusite-bearing veins of Eocene age are reported to crosscut sillimanite-cordierite gneisses within the Khdata Lake Metamorphic Complex (Hollister, 1982) in the Prince Rupert and Terrace area, they are not of economic interest. North of Terrace, andalusite is found within the contact aureole of the Ponder pluton. It is very abundant within several 100 metres of the contact of the pluton on Mount Kenney. In Maroon Creek, at the head of Kitsumkalum Lake, boulders containing chiastolite prisms 2 centimetres in diameter are common. Andalusite occurrences at Atna Peak (Evenchick, 1979) are characterized by crystals with chiastolite cross-sections that occur in metagreywacke and argillite over several square kilometres.

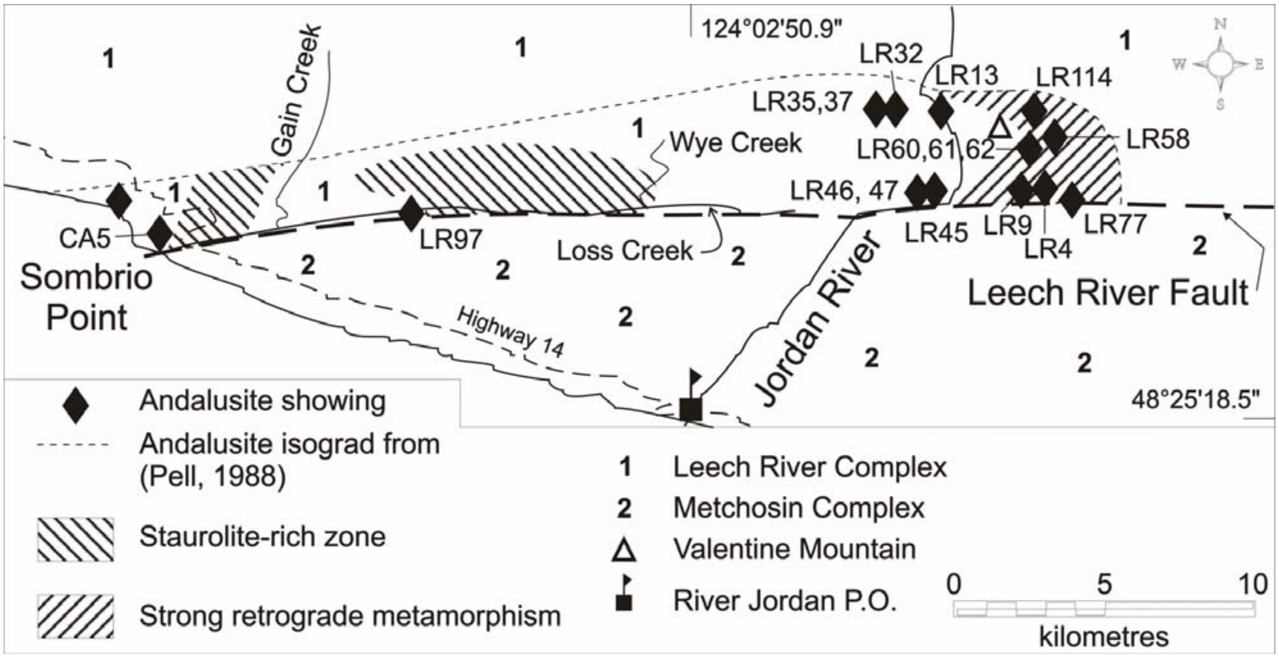


Figure 7. Andalusite occurrences in the Leech River area.

## SUMMARY

British Columbia has good geological potential to host economic kyanite and andalusite deposits. Overall, most andalusite occurrences in the province appear to be affected by metamorphism. Thus andalusite is either partially or completely replaced by sillimanite or kyanite during later, high-temperature metamorphic overprint or to hydrated minerals, such as muscovite, during a later low-temperature (retrograde) event. Kyanite is less affected by later metamorphic events than andalusite, but the need for calcination of kyanite before use, makes it less attractive exploration target. The distance of the occurrences from infrastructure and the coast must be considered in preliminary selection of exploration targets.

## REFERENCES

Cairnes, C.E. (1937): Geology and mineral deposits of the Bridge River mining camp, British Columbia; *Geological Survey of Canada,* Memoir 213, 140 pages.

Evenchick, C.A. (1979): Stratigraphy, structure and metamorphism of the Atna Peak area, British Columbia; unpublished B.Sc. thesis, *Carleton University*, 54 pages.

Evenchick, C.A. (1988): Stratigraphy, metamorphism, structure and their tectonic implications in the Sifton and Deserter Ranges, Cassiar and northern Rocky Mountains, northern British Columbia; *Geological Survey of Canada,* Bulletin 376, 90 pages.

Fairchild, L.H. and Cowan, D.S. (1982): Structure, petrology and tectonic history of the Leech River complex northwest of Victoria, Vancouver Island; *Canadian Journal of Earth Sciences,* Volume 19, pages 1817-1835.

Gabrielse, H., Monger, J.W.H., Wheeler, J.O. and Yorath C.J. (1991): Part A - Morphogeological belts, tectonic assemblages and terranes; *in* Geology of the Cordilleran Orogen in Canada; H. Gabrielse and , C.J. Yorath, Editors, *Geological Survey of Canada*, Geology of Canada, Number 4, and *Geological Society of America*, Geology of North America, Decade of North American Geology (DNAG) Volume G-2, pages 15-28.

Greenwood, H.J., Woodsworth, G.J., Reed, P.B., Ghent, E.D. and Evenchick, C.A. (1991): Metamorphism; *in* Geology of the Cordilleran Orogen in Canada; H. Gabrielse and C.J. Yorath, Editors, *Geological Survey of Canada,* Geology of Canada, Number 4, and *Geological Society of America*, Geology of North America, Decade of North American Geology (DNAG) Volume G-2, pages 533 - 570.

Hancock, K.D, and Simandl, G.J. (1996): Kyanite at Prince Rupert and Kitimat (103H, J); *in*: Geological Fieldwork 1995, *British Columbia Ministry of Energy, Mines and Petroleum Resources,* Paper 1996-1, pages 251-258.

Hollister, L.S. (1969a): Metastable paragenetic sequence of andalusite, kyanite and sillimanite, Kwoiek Area, British Columbia; *American Journal of Science,* Volume 267, pages 352-370.

Hollister, L.S. (1969b): Contact metamorphism in the Kwoiek Area of British Columbia; *Geological Society of America*, Bulletin 80, pages 2465-2494.

Hollister, L.S. (1982): Metamorphic evidence for rapid (2mm/year) uplift of a portion of the Central Gneiss Complex, Coast Mountains, British Columbia; *Canadian Mineralogist*, Volume 20, pages 319-322.

Hutchison, W.W. (1982): Geology of the Prince Rupert - Skeena map area, British Columbia; *Geological Survey of Canada,* Memoir 394, 116 pages.

Journeay, J.M. and Mahoney, J.B. (1994): Cayoosh assemblage: Regional correlations and implications for terrane linkages in the southern Coast Belt, British Columbia; *in* Current Research, Part A; *Geological Survey of Canada*, Paper 94-A, pages 165-175.

Money, P.L. (1959): Geology of Hawkesbury Island; unpublished M.Sc. thesis, *University of British Columbia,* 159 pages.

Pell, J. (1988): The Industrial Mineral Potential of Kyanite and Garnet in British Columbia; *British Columbia Ministry of Energy, Mines and Petroleum Resources*, Open File 1988-26, 43 pages.

Roddick, J.A. and Hutchinson, W.W. (1973): Pemberton (East Half) map-area, British Columbia, 92J(E1/2), *Geological Survey of Canada,* Paper 73-17, 21 pages.

Rushmore, M.E. (1985): Geology and tectonic significance of the Upper Triassic Cadwallader Group and its bounding faults, southwestern British Columbia; unpublished Ph.D. thesis, *University of Washington*, Seattle, 174 pages.

Rushmore, M.E. and Woodsworth, G.J. (1993): Geological maps of Mt. Queen Bess (92N/7) and Razorback Mountain (92N/10) map areas, British Columbia; *Geological Survey of Canada,* Open File 2586, 2 sheets.

Rushmore, M.E. and Woodsworth, G.J. (1994): Evolution of the eastern Waddington thrust belt and its relation to the Mid-Cretaceous Coast Mountains arc, western British Columbia; *Tectonics*, Volume 13, pages 1052-1067.

Simandl, G.J., Hancock, K.D., Church, B.N., and Woodworth, G.J. (1995): Andalusite in British Columbia - New exploration targets *in*: Geological Fieldwork 1994, *British Columbia Ministry of Energy, Mines and Petroleum Resources*, Paper 1995-1, pages 385- 394.

Skillen, A. (1993): Sillimanite minerals; *in* Raw Materials for the Refractory Industry, Consumer Survey, 3rd Edition, M. O'Driscoll and J.B. Griffiths, Editors, *Industrial Minerals*, pages 49-63.

Stevenson, J.S. (1958): Bridge River Area, British Columbia, *British Columbia Ministry of Energy, Mines and Petroleum Resources,* unpublished manuscript, 60 pages.

Woodsworth, G.J. (1979): Metamorphism, deformation and plutonism in the Mount Raleigh pendant, Coast Mountain, British Columbia; *Geological Survey of Canada,* Bulletin 295, 56 pages.