



ANDALUSITE IN BRITISH COLUMBIA - NEW EXPLORATION TARGETS

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INTRODUCTION

This paper describes new and previously reported andalusite occurrences in British Columbia. It also provides background information on currently producing andalusite mines and the andalusite market. The Leech River, Duffey Lake and Bridge River areas were the subject of reconnaissance work in 1994 and are dealt with in more detail than other regions.

Andalusite, kyanite and sillimanite are aluminosilicate 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 a volume expansion of 5, 18 and 7% for andalusite, kyanite and sillimanite, respectively (Skillen, 1993). Worldwide, andalusite is the preferred raw material because it converts to mullite at lower temperatures (1380°C) than sillimanite (1550°C). The main advantage of andalusite over kyanite is that the volume change during mullitization is negligible, therefore no calcination is required before manufacturing refractory shapes. Approximately 4.22×10^9 joules (4×10^6 BTU) are needed to mullitize one tonne of kyanite (Skillen, 1993). In North America, kyanite is the most widely used polymorph, because of its local abundance, close to markets, and availability of relatively inexpensive energy.

South Africa is by far the largest andalusite producer. Other producing countries are France, U.S.A. and China (Dickson, 1994). Most commercial andalusite concentrates from South Africa and France vary in composition from 53 to 60% Al_2O_3 and 0.8 to 1.5% Fe_2O_3 . An andalusite-pyrophyllite-sericite mixture is mined in the U.S.A for a captive market. In some cases, andalusite-pyrophyllite material has applications in ceramics. It has a substantially lower Al_2O_3 content than andalusite concentrates (<35%). Chinese concentrates commonly have higher Fe_2O_3 contents (1 to 2%) than most other commercial products. Iron is a detrimental impurity in most refractory applications. Andalusite competes with other aluminosilicate polymorphs, including high-performance synthetic mullite and high-alumina calcined products, for market share. Worldwide andalusite consumption for 1990 was estimated at 270 000 to 340 000 tonnes (Skillen, 1993). In 1993, andalusite prices varied from \$US170 to \$200/tonne f.o.b. South Africa or about DM350 per tonne in European ports. Andalusite is used primarily in

refractories for steel making and the current upswing in world steel output augurs well for the industry in 1995. Andalusite-based refractories are also used in cement kilns, incinerators, copper-roasting furnaces foundry sands and abrasion resistant materials.

ANDALUSITE GENESIS AND DEPOSITS

Andalusite deposits are typically formed by low-pressure, contact or regional thermal metamorphism of high-alumina, low-calcium pelitic rocks. There is a gradation between textbook contact metamorphism characterized by distinct aureoles surrounding a single pluton and regional, low-pressure metamorphism. The association of low-pressure metamorphic rocks with magmatic arcs is well described by Miyashiro (1961). Since that time, several theories have been proposed to explain regional low-pressure metamorphic belts. These include crustal extension (Grambling *et al.*, 1989), rapid uplift (Thompson and England, 1984), increased heat flux at the base of the crust (Oxburgh and Turcotte, 1971), thermal effects of pervasive and channelized fluid flow in the deep crust (Höisch, 1991), multiple intrusions into low-pressure metamorphic terranes (Rotstein and Höisch, 1994; Barton and Hanson, 1989) and moderate overthickening of thinned sialic crust (Thompson, 1989). The origin of the low-pressure belts in British Columbia is beyond the scope of this paper.

On the deposit scale, the thickness, chemical composition of the protolith and temperature of the low-pressure, prograde metamorphism are the main factors influencing the formation of andalusite. Typical grades of primary or 'hard rock' andalusite ores vary from 7 to 20%. Typical production capacities of individual mines vary from 25 000 to 65 000 tonnes per year. Andalusite crystals from deposits of economic interest are relatively inclusion free. In general, the coarser the crystals, the easier it is to upgrade the ore. The diameter of andalusite crystals from currently mined deposits varies from 1 millimetre to several centimetres. Primary andalusite ores are commonly crushed, and upgraded using heavy liquids; flotation may be required for the treatment of fine-grained ores. Retrograde metamorphism of andalusite deposits may result in partial or total conversion of andalusite to lower temperature phases, such as muscovite. Placer deposits account for a substantial proportion of the andalusite produced in South Africa. Garnet and staurolite commonly coexist with andalusite and where grades and textures permit, they are recovered as byproducts.

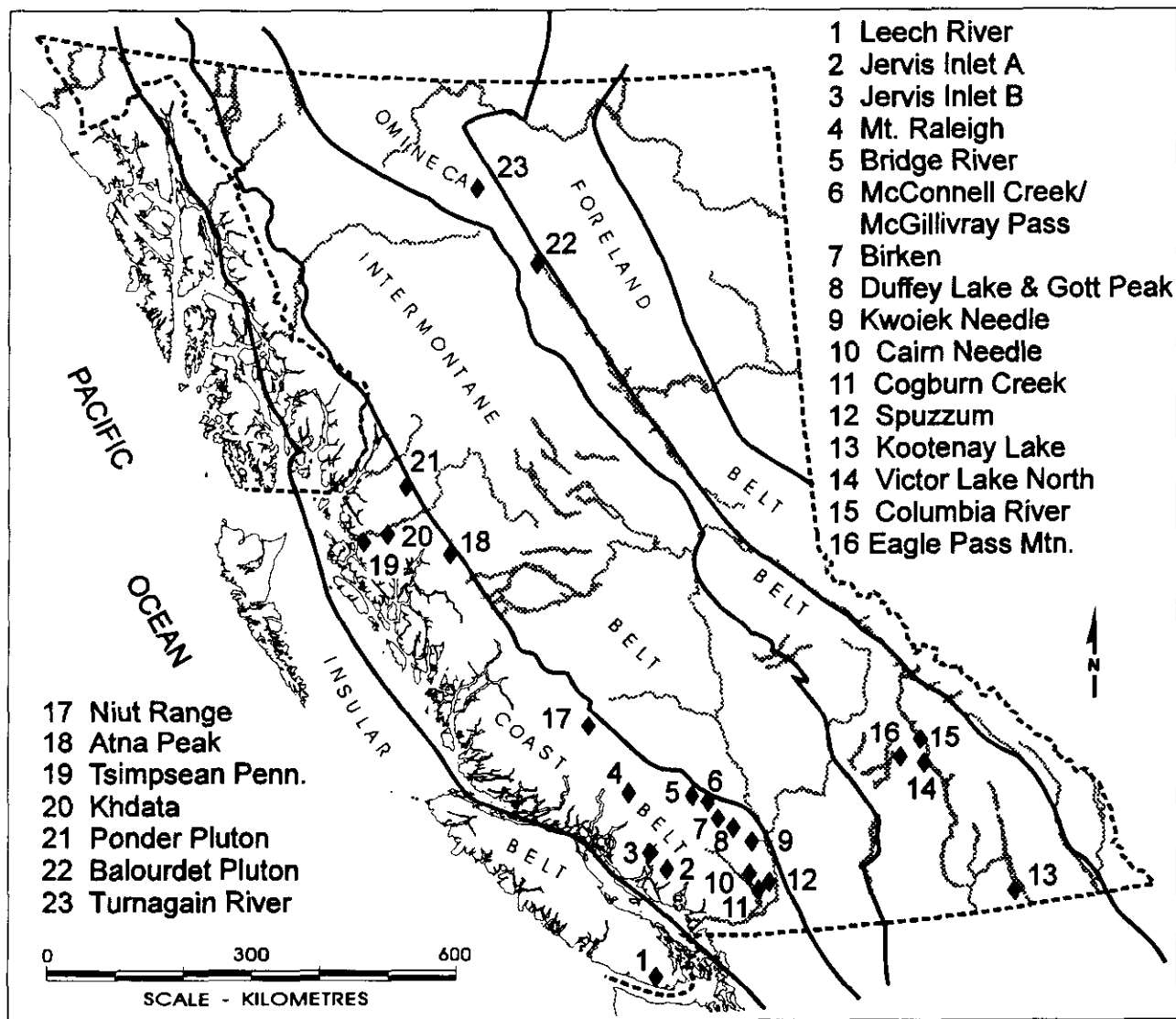


Figure 1. Andalusite occurrences in British Columbia.

ANDALUSITE IN BRITISH COLUMBIA

Information on most of the high-alumina metasilicate occurrences in British Columbia, including andalusite, was compiled by Pell (1988). Other information is available in the MINFILE database and a range of scientific literature including university theses. In most cases, literature research does not provide descriptive data sufficient to appraise the economic potential of individual showings, but it is useful for delineation of exploration areas.

The Canadian Cordillera is divided into five major tectonostratigraphic belts. The majority of andalusite occurrences are located in the Coast Plutonic Complex with a few in the Omineca and Insular belts (Figure 1). Andalusite and andalusite-pyrophyllite occurrences with sub-millimetre grain sizes, believed to be of hydrothermal origin, are not covered by this study. Examples of these include the Equity Silver mine

(Wojdak, 1974; Church and Barakso, 1990) and the Taseko property (Lambert, 1991).

OMINECA BELT

The Omineca Belt (Figure 1) consists mainly of metamorphic rocks and intrusions (Gabrielse *et al.*, 1991). During the mid-Jurassic, metamorphic rocks recorded deep structural depression followed by tectonic uplift until late Cenozoic time. Another important uplift with high geothermal gradients and associated with widespread plutonism, occurred in the Eocene. Omineca Belt andalusite occurrences are related to low-pressure, high-temperature metamorphism. In many places this forms an overprint that postdates higher pressure metamorphism. Several andalusite showings (Figure 1) are reported in the southern Omineca Belt on the west side of Kootenay Lake, near Victor Lake, Eagle Pass Mountain and north of Revelstoke along the Columbia

River (Pell, 1988). In 1994, the principal authors attempted, without success, to locate the Eagle Pass Mountain showing in the area outlined by Pell (1988). Andalusite-bearing metapelites are also known in the northern Omineca Belt, within basement gneiss, 300 metres from the contact of the undeformed, Eocene Balourdet pluton in the Sifton Range and in metapelites 30 kilometres to the north (Evenchick, 1988; Greenwood *et al.*, 1991). Another andalusite occurrence is reported near the confluence of the Turnagain and Cassiar rivers (H. Gabrielse, personal communication, 1994); andalusite porphyroblasts, 3 to 4 centimetres long, partially retrograded to muscovite, are present in metasediments along the contact of an Early Cretaceous pluton.

COAST BELT

The Coast Belt is composed mainly of granitic and greenschist to granulite facies metamorphic rocks. The western part of the belt is characterized by mid-Cretaceous or older plutons and the eastern intrusions are typically Late Cretaceous or younger (Gabrielse *et al.*, 1991). A large number of andalusite occurrences are located on the eastern edge of the Coast Belt along a northwest trend where low-pressure, high-temperature metamorphic conditions prevailed during deformation and magmatism in Middle to Late Cretaceous time. These include the Mount Raleigh, Niut Range, Bridge River, Cogburn Creek, McConnell Creek, Birken, Duffey Lake, Gott Peak, Ratchford Creek, Kwoiek Needle, Cairn Needle and Spuzzum pluton occurrences (Figure 1). The belt extends southwards into the north Cascades of Washington State (Greenwood *et al.*, 1991). During the Middle to Late Cretaceous, low-pressure metamorphism accompanied east-vergent thrusting and folding along the eastern margin of the Coast Plutonic Complex (Rusmore and Woodsworth, 1994). The peak metamorphic conditions that prevailed during deformation, believed to be responsible for andalusite formation, are estimated at less than 350 megapascals (3.5 kbars) and about 500° to 650°C. The highest metamorphic pressure within the belt was recorded in the Spuzzum area and the lowest in the Mount Raleigh area, suggesting that relative syn-metamorphic uplift decreased northwestward (Greenwood *et al.*, 1991). In several cases it is not evident if andalusite is a result of contact or regional metamorphism.

OCCURRENCES IN THE BRIDGE RIVER AND LILLOET AREAS

Among the 23 andalusite occurrences located on Figure 1, those in the Bridge River and Lilloet areas were covered by our 1994 reconnaissance study and are discussed in more detail below.

BRIDGE RIVER AREA

The Bridge River area is a well known gold mining camp, located approximately 180 kilometres north of Vancouver (Figures 1 and 2). The history and geology of the camp are summarized by Cairnes (1937), Stevenson (1958) and more recently by Church (in preparation) who recognized numerous mappable units comprised of bedded volcanic and sedimentary assemblages and a variety of intrusive rocks. Andalusite occurrences in the Bridge River area are hosted by black argillite, normally referred to as the Noel Formation (Cairnes, 1937; Stevenson, 1958; Church, in preparation). Rusmore (1985) and Roddick and Hutchison (1973) include the Noel lithofacies as part of the Hurley Formation, and Journey and Mahoney (1994) suggest that the Noel is the equivalent of units 2 and/or 3 of the newly proposed Cayoosh assemblage. Regardless of the stratigraphic nomenclature used, the metamorphic equivalents of aluminous black shales represent the most favorable protolith for andalusite exploration. The Noel lithofacies is described as a sequence of mostly thinly bedded, fine-grained turbidites. Near the confluence of Cidwalder Creek and Noel Creek, it is more than 350 metres thick and consists of siltstones and black argillites accompanied by a few lenses of dark grey limestone. It is best developed in two belts near the Hurley River, described by Church (in preparation). Metamorphism of these argillites has resulted in the development of biotite, garnet, andalusite, cordierite and staurolite. The groundmass consists mainly of quartz and biotite with some pyrite. The andalusite-bearing rocks are hard, dark grey, rusty brown weathering hornfels containing up to 12% andalusite. Andalusite is grey, idiomorphic, relatively inclusion free and fine grained (1 to 7 mm in cross-section and 1 to 40 mm long). Macroscopically, andalusite porphyroblasts from Bridge River are

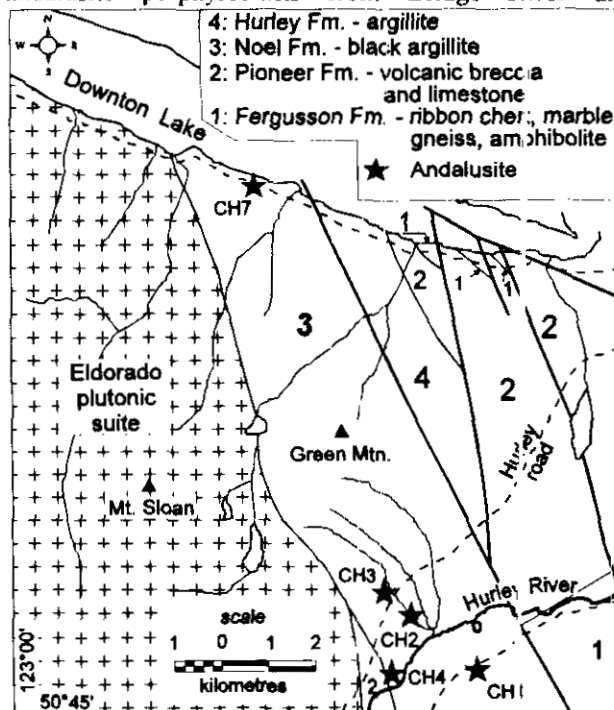


Figure 2. Andalusite occurrences in the Bridge River area.

relatively unaffected by retrograde metamorphism in comparison to those of the Leech River or Duffey Lake areas. Further microscope study will be required to quantify the degree of alteration. The individual occurrences are described below.

OCCURRENCE DESCRIPTIONS

CH-1: Andalusite-bearing layers of decimetre-scale thickness are interbedded with barren layers of hornfels striking 143/58 near the old Hurley road, approximately 6 kilometres west-southwest of Bralorne. The andalusite is unevenly distributed and the maximum grade is about 7% by volume. Pseudomorphs after andalusite prisms are 1 to 7 millimetres across, several centimetres long and characterized by typical chistolite crosses. The andalusite is almost entirely replaced by mica. Although this occurrence is not of economic interest, it demonstrates that coarse andalusite can occur in the Bridge River area if shielded from the effects of retrograde metamorphism.

CH-2: Hornfels outcrops along an old logging road, near a seasonal creek, approximately 7 kilometres west-southwest of Bralorne. The outcrop measures a few metres square and the andalusite-bearing rock is similar to that at showing CH-4, described below, which is better exposed.

CH-3: This occurrence is located on the main road connecting Pemberton and Gold Bridge, approximately 12 kilometres from Gold Bridge. The outcrop is about 45 metres long and few metres high. The hornfels is grey on fresh surfaces and breaks along heavily iron-stained fractures. Andalusite porphyroblasts are 2 to 3 millimetres across and up to 10 millimetres long. They are not uniformly distributed and soft millimetre-scale oval shaped grains, possibly altered cordierite, are also present.

CH-4: This occurrence is located approximately 8 kilometres west-southwest of Bralorne on an overgrown forestry road, about 200 metres from the Hurley River. The outcrop is approximately 30 metres long and 14 metres high (Photo 1). The hornfels is steel grey on fresh surfaces and rusty brown on weathered surfaces. Locally, weathering produces exfoliated layers several centimetres thick. Dominant compositional layering at this location is oriented 155/82 and several centimetre-scale quartz veins are oriented 147/85. Prismatic andalusite crystals are typically 5 to 20 millimetres long and 0.5 to 3.0 millimetres in cross-section. Andalusite content varies from 5 to 12% of the rock. The hornfels contains up to 1% pyrite. Several felsic dikes, several metres thick, strike approximately 120/75.

CH-6: This occurrence consists of a rounded block, 25 by 25 by 12 centimetres, containing more than 15% andalusite prisms, 2 to 3 millimetres across and 2 centimetres long. Some andalusite is partially replaced by mica. The showing is located near the main road connecting Bridge River and Pemberton.

CH-7: Andalusite crystals 1 to 3 millimetres across and 10 to 15 millimetres long (Photo 2) were observed in an outcrop along the road which follows the southern

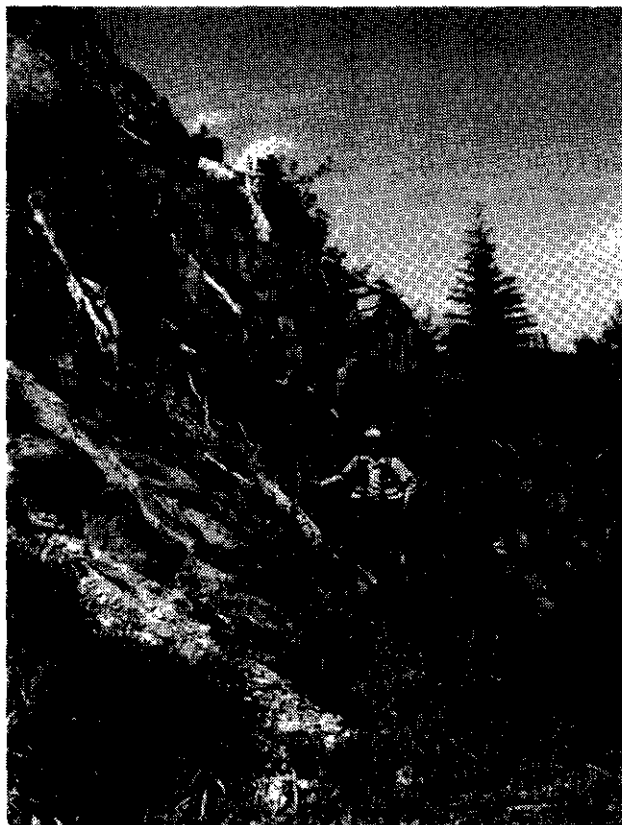


Photo 1. Well exposed andalusite occurrence CH-4, Bridge River area.

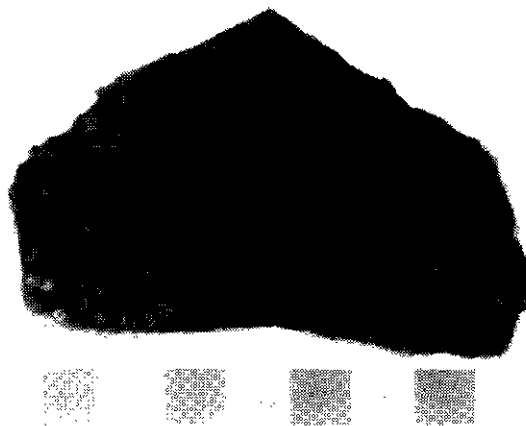


Photo 2. Andalusite porphyroblasts, CH-7 occurrence.

shore of Downton Lake. Here, andalusite is only erratically present and forms less than 5% of dark grey, heavily iron-stained phyllite. Texturally, this andalusite hornfels is similar to other occurrences in the area. Several felsic dikes cut this outcrop. A block containing pinkish andalusite up to 1 centimetre in cross-section was found along the road, possibly brought in during road construction.

LILLOOET AREA

The Lillooet area is located southeast of the Bridge River camp (Figure 1). Journey and Mahoney (1994)

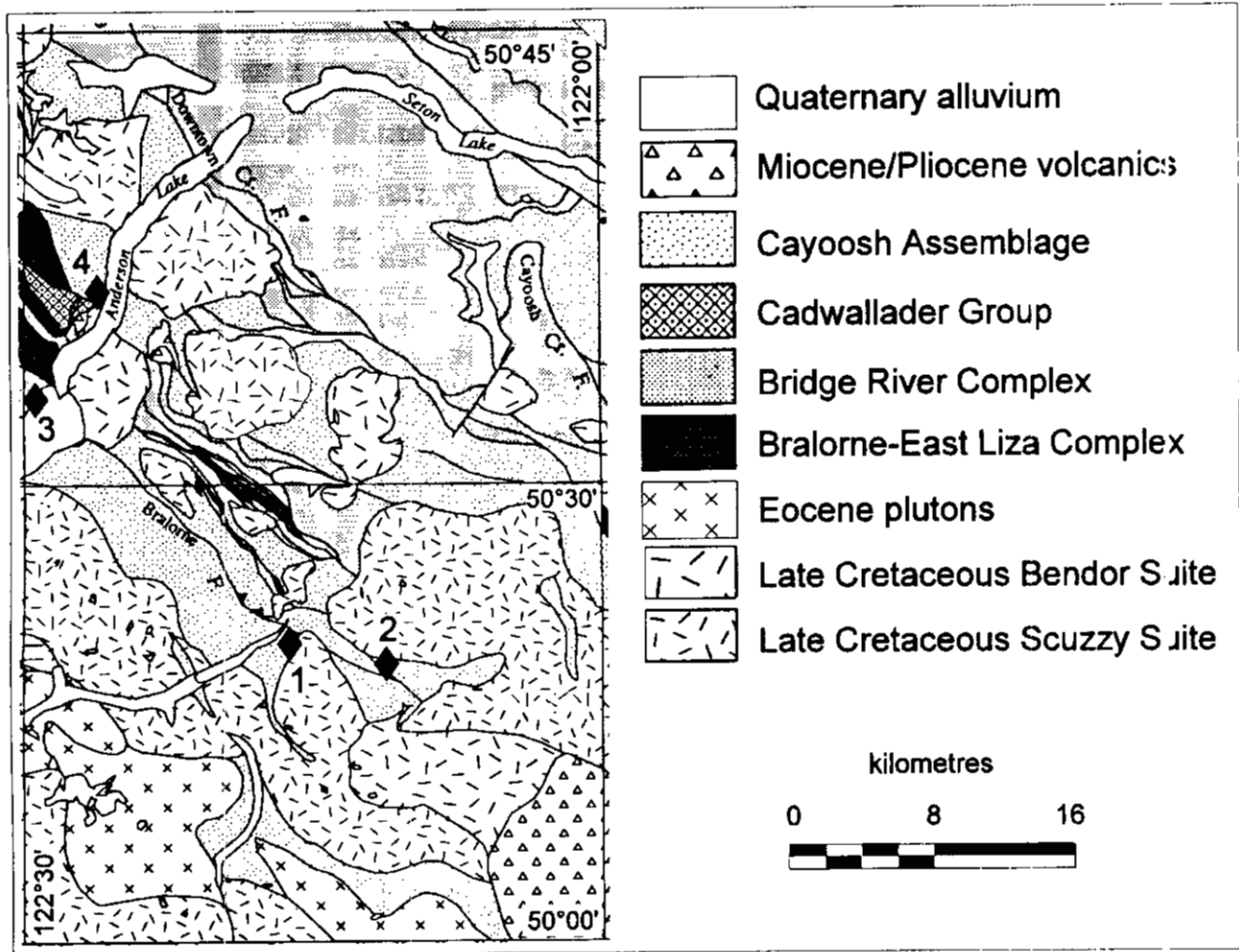


Figure 3. Andalusite occurrences in the Lillooet region (modified from Journeay and Mahoney (1994). 1 - Duffey Lake; 2 - Gott Peak; 3 - Birken (Gates), 4 - McConnell and Six Mile creeks.

describe the geology of the area in terms of the Coast Plutonic Complex, Cadwallader Terrane, Cayoosh assemblage, Harrison Terrane, Bridge River Terrane and Shulaps Complex. All the andalusite occurrences (Figure 3) are hosted by hornfels produced by a metamorphic overprint of black argillites and siltstones of the Cayoosh assemblage. The assemblage is divided into five units, all containing graphitic siltstone and phyllite beds (Journeay and Mahoney, 1994), and it is impossible to determine if all andalusite occurrences are located within units 2 and 3, without more detailed work. In any event, these phyllites are macroscopically and texturally similar to the Noel lithofacies of the Bridge River area and probably have a similar chemical composition. Coarse-grained andalusite porphyroblasts from occurrences in this area, are almost entirely retrograded to mica.

DUFFEY LAKE

The main andalusite occurrence is located in a road cut, on the west side of Highway 99 near the northern tip of Duffey Lake 0.5 to 1.5 kilometres from the nearest outcrop of granitoids of the Coast Plutonic Complex (Figure 3). The andalusite-bearing horizon is only a few

metres thick, steeply dipping and is exposed over a strike length of about 60 metres. The unit is dark grey on fresh surfaces and rusty brown when weathered. A well developed tectonic fabric has aligned most grains into the plane of deformation. The groundmass is made up of biotite, quartz and possibly feldspar. Pyrite is the main opaque mineral (<1%) present in the groundmass. Garnets, 1 millimetre in diameter or smaller, were also observed. Andalusite porphyroblasts vary from 10 to 50 millimetres long and 1 to 4 millimetres across. Although chistolite crosses are well preserved on the cross-sections of porphyroblasts, most andalusite is entirely retrograded to muscovite. Pseudomorphs after andalusite represent 2 to 15% of the rock by volume. Their concentration is strongly controlled by decimetre-scale bedding. Due to a strong retrograde overprint, the showing is not of economic interest. Nevertheless, it shows that andalusite deposits approaching economic grade and size may exist within the Cayoosh assemblage, where unaffected retrograde metamorphism.

GOTT PEAK

Andalusite occurs on the ridge north of Gott Peak in a raft of metasedimentary rocks (J.M. Journeay, personal communication, 1994) within a granitic intrusion (Figure 3). Several fresh-looking, angular boulders measuring up to 1 by 0.5 by 1 metre were found south of that area. These blocks split preferentially along a well developed fabric and contain pseudomorphs of mica after andalusite and staurolite. The pseudomorphs, measuring 3 to 8 millimetres across and several centimetres long, comprise 20% of the hostrock. These blocks may have come from the nearby Gott Peak occurrence or elsewhere.

BIRKEN (GATES)

A showing similar to Gott Peak has been documented on the eastern margin of the Mount Rohr pluton but andalusite porphyroblasts are less abundant (M. Journeay, personal communication, 1994, Figure 3). Several angular blocks containing andalusite and staurolite in a groundmass of quartz, biotite, minor iron oxide (<1%) and occasional millimetre-scale garnet were found near the contact of intercalated sedimentary and volcanic rocks with a granite intrusion near Birken. The largest block measures 20 by 5 by 25 centimetres. In some blocks, andalusite is largely retrograded to muscovite.

McCONNELL CREEK AND SIX MILE CREEK

Andalusite is reported in the McConnell Creek-Mount McGillivray area (J.M. Journeay, personal communication, 1994, Figure 3). The showing was not visited during the 1994 field season, however, rounded, dark grey hornfels boulders containing up to 15% high-alumina silicates were found in the bed of nearby Six Mile Creek. They contain 3 to 10% andalusite displaying chiasolite crosses on square cross-sections. The unusual grey colour and freshness of the porphyroblasts suggests that they may be kyanite pseudomorphs after andalusite as described by Hollister (1969a, b) and Pigage (1976). The crystals are up to 6 millimetres in cross-section and



Photo 3. Relatively unaltered andalusite porphyroblasts; Mount Raleigh occurrence. **AND** - andalusite.

are enclosed in a quartz-biotite-feldspar groundmass. Final assessment will have to be done by x-ray diffraction or detailed microscope work. This occurrence is not of economic interest, but it is an indication of low-pressure metamorphic conditions at some time. It also illustrates the dangers of misidentifying high-alumina silicates during early stages of exploration.

An andalusite-muscovite zone is also near Ratchford Creek by Journeay (personal communication, 1994).

OTHER OCCURRENCES IN THE COAST BELT

KWOIEK NEEDLE - SPUZZUM PLUTON AREA

The Spuzzum pluton occurrences were reported by Reamsbottom (1974). In the Kwoiek area, andalusite pseudomorphs replaced by sillimanite were documented by Hollister (1969a,b). He explained their existence by metastable crystallization of andalusite in the kyanite stability field. However Pigage (1976) favoured early contact metamorphism overprinted by higher pressure metamorphism.

MOUNT RALEIGH

Andalusite at Mount Raleigh occurs in a metamorphosed roof pendant of volcanic and sedimentary rocks. Metamorphic grade increases from northeast to southwest and is Late Cretaceous in age. Andalusite is confined to beds of graphitic, pelitic schist. The main andalusite-bearing unit, the Late Jurassic(?) or Early Cretaceous(?) Styx Formation, is about 400 metres thick (Woodsworth, 1979).

Andalusite porphyroblasts are up to 2 centimetres in diameter and 15 centimetres long and form up to 10% of the rock (Photo 3). They are spread over at least 10 square kilometres in Styx Formation rocks. Quartz and graphite inclusions occur in some of the andalusite porphyroblasts.

At some outcrops, the andalusite porphyroblasts are partially to entirely retrograded to fine-grained muscovite and quartz. With increasing metamorphic grade, the andalusite is more intergrown with, and replaced by, fibrolite and coarse-grained sillimanite. These factors, together with difficult access and rugged terrain, make this area less appealing for exploration than the potential grade and tonnage may suggest.

NIUT RANGE

Andalusite-bearing rocks along the east side of the Coast Range are described by Rusmore and Woodsworth (1993, 1994). As at Mount Raleigh, metamorphic grade increases across the area from northeast to southwest through a series of southwest-dipping isograds. Metamorphism is also Late Cretaceous. Andalusite, with associated garnet, staurolite and sillimanite, is confined to pelitic rocks of the Cloud Drifter formation (informal) of Early Cretaceous age.

Andalusite forms small, inclusion-filled 'spots' and porphyroblasts less than 10 millimetres across; chiastolite texture is common. Andalusite content ranges from roughly 5 to 10%. Retrogression to muscovite has affected the andalusite in some areas, particularly in the northern part of the area.

JERVIS INLET

Andalusite and biotite-bearing metasedimentary rocks of Albian(?) age are also reported near the head of Jervis Inlet and at Phantom Lake, to the east (Woodsworth, unpublished data; Greenwood *et al.*, 1991).

PRINCE RUPERT AND TERRACE AREA

The last important period of plutonism in the Coast Belt was in Eocene time (Woodsworth *et al.*, 1991). Andalusite-bearing veins of Eocene(?) age are reported to crosscut sillimanite-cordierite gneisses within the Khdata Lake Metamorphic Complex (Hollister, 1982). Although important petrologically, these veins are not of economic interest.

Andalusite is also found within the contact aureole of the Ponder pluton north of Terrace, which is of Eocene age (Hutchison, 1982; Woodsworth *et al.*, 1983; Greenwood *et al.*, 1991). The aureole extends 3 to 5 kilometres east of the pluton and is characterized by hornfels with "spots" of andalusite and cordierite (Hutchison, 1982). Prismatic andalusite, up to 1 centimetre across, is very abundant on Mount Kenney within several hundred metres of the contact of the pluton. In Maroon Creek, at the head of Kitsumkalum Lake, boulders containing coarse (2 cm diameter) chiastolite prisms are common. The source for these is

not yet known but they probably come from the contact aureole of a large pluton east of the lake.

Andalusite is reported on Tsimpsean Peninsula by Hollister (1982) and Greenwood *et al.* (1991). However this may be a mineralogical oddity as the area is affected by high pressure metamorphism.

Andalusite occurrences at Atna Peak in the Whitesail Lake area, (Evenchick, 1979) are characterized by coarse andalusite crystals. Andalusite, commonly with chiastolite cross-sections, occurs in metagreywacke and argillite over an area of several square kilometres. The occurrences are similar to those in the Mount Raleigh - Spuzzum belt (Greenwood *et al.*, 1991).

INSULAR BELT

The Insular Belt corresponds to the present Pacific margin including Vancouver Island (Figure 1). Andalusite is present in the Leech River Complex on southern Vancouver Island. The complex was affected by low-pressure metamorphism during the Late Eocene (Fairchild and Cowan, 1982).

LEECH RIVER AREA

A large number of andalusite localities are reported in the Leech River Complex on Vancouver Island (Figure 4), approximately 50 kilometres northwest of Victoria (Fairchild and Cowan, 1982). The Leech River Complex is fault bounded and consists of sedimentary and volcanic rocks intruded by a variety of igneous rocks and affected by greenschist to amphibolite facies, low-pressure metamorphism. The Late Eocene metamorphic peak is estimated to be between 150 to 350 megapascals (1.5 to 3.5 kbar) pressure and 500° to 600°C temperature.

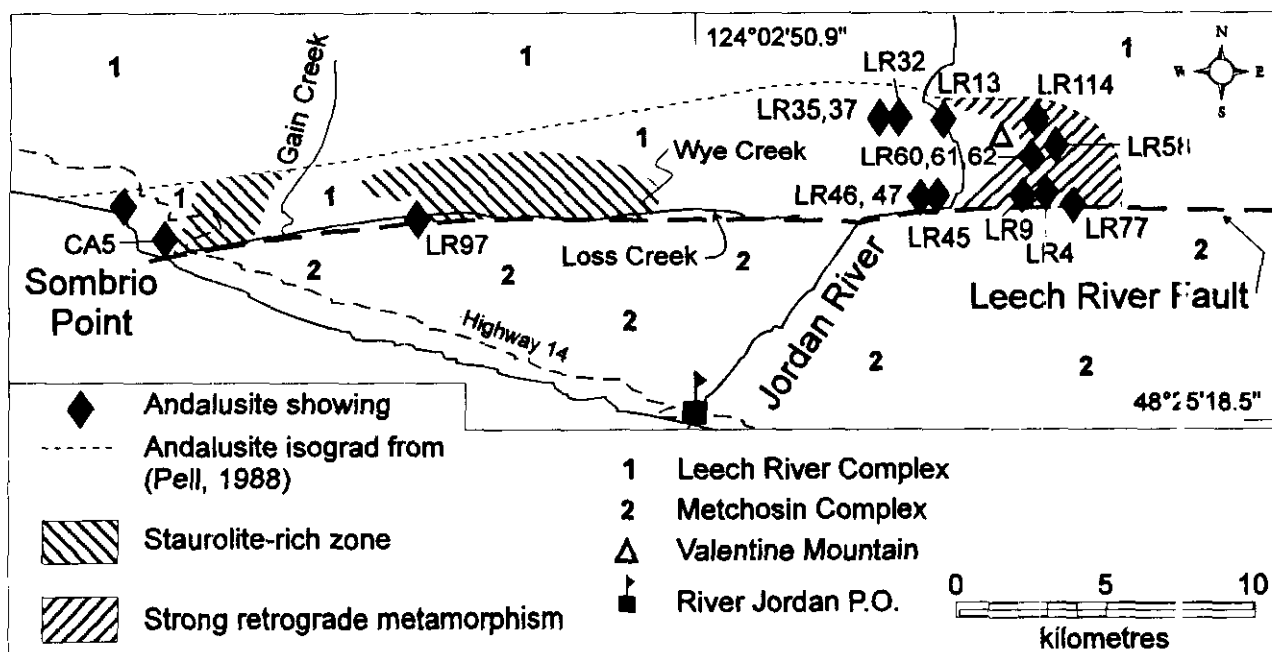


Figure 4. Andalusite occurrences in the Leech River area.

Metamorphism is believed to have continued through two episodes of deformation (Fairchild and Cowan, 1982). Isograds in the eastern and western parts of the complex are well established and truncated by the Leech River fault. The highest metamorphic grades appear to coincide with an area affected by plutonism (Fairchild and Cowan, 1982). The area prospective for andalusite of economic interest (Figure 4) was outlined by Pell (1988) from the work of Rusmore (1982), Fairchild and Cowan (1982) and Grove (1984). In most of the occurrences within the eastern part of the area delineated by Pell, and more particularly the Valentine Mountain area, andalusite is strongly or entirely retrograded to either mica and staurolite or mica and chlorite. The retrograde alteration appears to be strongest close to gold-bearing quartz veins in the nose of a large east-plunging anticline and may be genetically linked to the gold mineralization. It is possible that minerals previously identified as retrograded andalusite at some sites in the Valentine Mountain area may actually be retrograded staurolite. The degree of retrograde alteration diminishes westward from Valentine Mountain. As a result, andalusite in the showings along Jordan River and to the west is better preserved than east of the river.

This study indicates that in the western two thirds of the area of Figure 4, metapelites contain abundant staurolite porphyroblasts up to 1.5 centimetres long. However, macroscopic andalusite is lacking, considerably reducing the size of the area favourable for andalusite exploration. There are occurrences of macroscopically identifiable andalusite and others where andalusite is partially or entirely replaced by muscovite and chlorite. Variations in the degree of retrograde alteration and in the thickness of andalusite-rich zones indicate that the area delineated by Pell (1988) may contain occurrences of economic interest. An occurrence adjacent to the Leech River fault (LR-97, Figure 4), containing relatively unaltered andalusite crystals, indicates that the fault did not act as a conduit for retrograde metamorphic fluids. Rusmore (1982) identified andalusite near Sombrio Point. However this area has been designated a park and is no longer open for exploration. Individual localities where andalusite was identified are shown on Figure 4.

OCCURRENCE DESCRIPTIONS

LR-4: A zone exposed over a width of 4 metres and a length of 6 metres contains about 10% andalusite porphyroblasts almost entirely replaced by mica and chlorite. The length of the porphyroblasts occasionally exceeds 10 centimetres.

LR-9: Three small outcrops contain strongly retrograded andalusite porphyroblasts up to 2 centimetres in cross-section.

CA-5: A rounded block of hornfels, found in the bed of Loss Creek, contains up to 10% fresh, honey-coloured staurolite porphyroblasts, 0.5 to 2 centimetres long, and 5% pink, strongly retrograded andalusite porphyroblasts.

LR 13: A large zone of andalusite-bearing rocks, about 25 metres thick, outcrops in the bed of the Jordan River. Compositional layering is oriented 289/70.



Photo 4. **LR-13:** Hammer-size andalusite crystal, partially retrograded into mica, exposed in Jordan River, Leech River Complex. **AND** - andalusite.

Partially retrograded andalusite porphyroblasts measure up to 4 centimetres across and more than 20 centimetres long (Photo 4). Locally, there are some brown, euhedral staurolite crystals within the andalusite porphyroblasts.

LR 32: An andalusite-bearing zone, 5 metres thick, outcrops in a cut on the J5 road. Andalusite content varies from 2 to 8%. The zone also contains about 2% staurolite and 0.5% garnet. Some of the andalusite appears fresh and some is 50% retrograded to fine-grained muscovite.

LR-35: This is an outcrop of hornfels about 8 metres thick carrying 5% andalusite porphyroblasts that have cross-sections up to 1 centimetre and are several centimetres long.

LR-37: This is an outcrop of andalusite-staurolite-garnet-bearing rock with compositional layering oriented 286/86. It is 6 metres wide, and contains less than 7% andalusite porphyroblasts up to 10 centimetres long and 2 centimetres across, associated with dismembered, centimetre-scale quartzofeldspathic layers. The occurrence is enclosed in a felsic intrusion. Individual andalusite crystals are up to 10 centimetres long and 2 centimetres in cross-section. This andalusite occurrence is the least retrograded in the Leech River area.

LR-45: A biotite-garnet-andalusite-staurolite schist is exposed over 2 metres. Andalusite forms less than 3% of the rock and is partially retrograded.

LR-46: This is a small exposure of biotite-garnet-andalusite-staurolite schist with less than 3%, strongly retrograded andalusite.

LR-47: This zone is similar to LR-46. The andalusite-bearing layer is less than 30 centimetres thick.

LR-58, 60, 61 and 62: Outcrops of dark-coloured gneiss, interlayered with leucocratic gneiss, contain up to 8% strongly or entirely retrograded andalusite crystals, up to 2% garnet and dark, soft crystals, possibly retrograded staurolite.

STAUROLITE BYPRODUCT POTENTIAL

Currently there is no staurolite production from 'hardrock' deposits, except as a byproduct of other industrial mineral extraction. Metallurgical studies have been carried out on staurolite-bearing schists at a deposit in Ontario. Should that deposit prove to be viable, then the Leech River area staurolite zone should be re-examined in that context. The potential for producing staurolite from placer deposits within or near the Leech River Complex is not addressed by this study.

SUMMARY

The areas of the Omineca, Coast and Insular belts affected by contact metamorphism or low-pressure, high-temperature regional metamorphism have an excellent geological potential to host andalusite deposits where:

- The protolith is of favorable chemical composition and sufficient dimension.
- Andalusite was not converted to sillimanite or kyanite by a later, high-temperature metamorphic overprint.
- The andalusite did not retrograde to low-temperature, hydrated minerals such as muscovite.

The prograde metamorphic conditions favorable for the formation of andalusite were seen in all the areas selected for our current study. In the Bridge River area, several relatively fine grained, andalusite-bearing occurrences were identified. This type of deposit would be more difficult to upgrade than a coarse variety. Showings such CH-4 demonstrate that lithologies with favorable chemical composition occur over widths of tens of metres. The detrimental effect of retrograde metamorphism on the economic potential of some occurrences is seen at CH-1 where andalusite is entirely transformed into muscovite. The Bridge River area is readily accessible and could be systematically prospected for andalusite. Small-scale metallurgical tests could determine if a commercial-grade concentrate can be produced using conventional methods.

The Lillooet area occurrences have many similarities with the Bridge River area with respect to the regional geology and rock geochemistry. However, andalusite porphyroblasts from all the occurrences in the Lillooet area visited in 1994 are mostly, if not entirely retrograded to muscovite and consequently are not of economic interest.

The Leech River area has a different geological setting. A decreasing trend in the degree of retrograde metamorphism to the west is documented. The andalusite porphyroblasts in this area vary from a few centimetres to 30 centimetres long. However, most of the occurrences are of no economic interest, either because of the low

grade, narrow widths or the effects of intense retrograde metamorphism. The area of greatest potential is adjacent to and west of the Jordan River as retrograde metamorphism decreases westward. The trend formed by occurrences LR 114, 13, 32, 35 and 37 is especially interesting because it projects westward into an area less affected by retrograde metamorphism. Andalusite formed in pendants within plutonic rock have good potential as they are better protected from incursion of retrograde metamorphic fluids.

Examination of hand specimens collected by the Geological Survey of Canada from the Raleigh Mountain area and the description of occurrences in the Terrace region indicate that some of the areas not covered by our reconnaissance study have good geological potential. However, the distance of the occurrences from infrastructure and the coast must be considered in preliminary selection of exploration targets. Andalusite occurrences in the southern Omineca Belt also merit examination.

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