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Industrial Minerals Studies

FLUORSPAR IN BRITISH COLUMBIA*

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INTRODUCTION

Fluorspar is the commercial name for the mineral fluorite, CaF_2 . Fluorite is a very attractive mineral which often occurs in well-formed crystals ranging in colour from white to amber, green, blue, purple and black. It forms in a wide range of temperature and pressure conditions and therefore occurs in many geologic environments. It may be associated with calcite and barite in low-temperature, carbonate-hosted lead-zinc deposits; with quartz in granite-related silver-lead-zinc veins; with chalcedonic quartz and gold in epithermal vein systems; and with silver and lead in manto-type replacement deposits in carbonate rocks adjacent to granitic intrusions. Fluorine is also often enriched in carbonatites and related alkaline rocks, in specialized granites and complex pegmatites, and in skarns and greissens; consequently, fluorite and other fluorine-bearing minerals are often associated with the mineral deposits related to these rock types.

Fluorine is a useful pathfinder element for a wide range of deposit types; fluorite itself, has commercial importance, largely in the metallurgical and chemical industries. Mexico and China currently rank as the world's largest suppliers of fluorspar, together accounting for approximately 30 per cent of world production. The United States is the world's major consumer of fluorspar and a former significant producer. Canadian consumption of fluorspar is in the order of 170 000 tonnes per annum (Harben, 1985; Pelham, 1985).

In Canada, St. Lawrence Fluorspar Limited, at St. Lawrence, Newfoundland, is the only current producer. This mine was reopened in 1987 and produces approximately 60 000 tonnes per annum of high-purity fluorspar concentrate (Clarke, 1987). In the past, fluorspar was mined in the Madoc and Wilberforce areas of Ontario, at St. Lawrence, Newfoundland (from 1933 to 1978) and from the Rock Candy mine, north of Grand Forks, British Columbia (Dawson, 1985; Wilson, 1929). A small amount of fluorite (29.2 tonnes) was also shipped from the Gypo silica quarry, at Oliver, British Columbia (McCammon and James, 1959).

Fluorite occurrences are widespread throughout British Columbia. It has been found associated with mineral deposits in numerous geologic environments and in all tectonic belts except the Insular Belt (Figure 3-1-1). There are five major fluorite prospects and, though none are currently receiving any significant attention, one deposit, the Rock Candy mine, has a history of past production. A number of other deposits in the province also contain significant concentrations of fluorspar.

FLUORSPAR — USES AND ECONOMIC CONSIDERATIONS

Fluorspar is marketed in three major grades — acid, ceramic and metallurgical. Acid grade fluorspar (acid spar) contains no less than 97 per cent CaF_2 and limited silica, calcium carbonate, arsenic, lead, sulphide sulphur and phosphorous. Acid spar is used in the production of hydrofluoric acid, an essential feedstock in the manufacture of a wide range of chemicals, including synthetic cryolite used in aluminum smelting. Ceramic-grade fluorspar is generally marketed in two classes; No. 1 ceramic generally contains 95 to 96 per cent CaF_2 and No. 2 ceramic comprises 85 to 90 per cent CaF_2 . An intermediate grade of approximately 92 to 93 per cent CaF_2 is also produced. Impurity specifications vary, but commonly allow up to 3 per cent silica, 1.5 per cent calcite, 0.12 per cent iron oxide and traces of lead and zinc. Ceramic-grade fluorspar has widespread application in the glass and ceramics industries, in the manufacture of enamels and in the production of calcium and magnesium metal and portland cement. Metallurgical grade fluorspar contains a minimum of 60 "effective" per cent CaF_2 and less than 0.3 and 0.5 per cent of sulphide sulphur and lead, respectively. The "effective" percentage is $\% \text{CaF}_2 - 2.5 \times \% \text{SiO}_2$. Metallurgical grade fluorspar is used as a fluxing agent in steel making.

In 1983, the primary consumers of fluorspar were the chemical industry (42 per cent), the aluminum industry (21 per cent), both of which utilize acid-grade spar, and the steel industry (31 per cent), which requires metallurgical-grade fluorspar. Forecasts predict greater increases in demand for acid-grade spar than for the lower purity products (Pelham, 1985). Current fluorspar prices, as quoted in Industrial Minerals, September 1988, are approximately US\$70-77 per tonne for metallurgical-grade Mexican fluorspar, f.o.b. Tampico and US\$115-120 per tonne for acid spar, f.o.b. source (Northern Europe, Tampico or Durban, South Africa). Acid spar produced in Illinois sells for US\$168-173 per short ton.

Mineable grades vary depending on deposit type and mining method among other factors. Large, stratiform carbonate-hosted fluorite-barite-lead-zinc deposits in Illinois, Mexico, and South Africa are mined with CaF_2 grades of 15 per cent and up. Mineable vein deposits generally contain 25 to 80 per cent or more of CaF_2 . Fluorspar occurs as a major gangue mineral in many lead-zinc vein and replacement deposits and is economically recoverable, as a by-product, when fluorspar grades are 10 to 20 per cent (Pelham, 1985).

* This project is a contribution to the Canada/British Columbia Mineral Development Agreement. British Columbia Ministry of Energy, Mines and Petroleum Resources, Geological Fieldwork, 1988, Paper 1989-1.

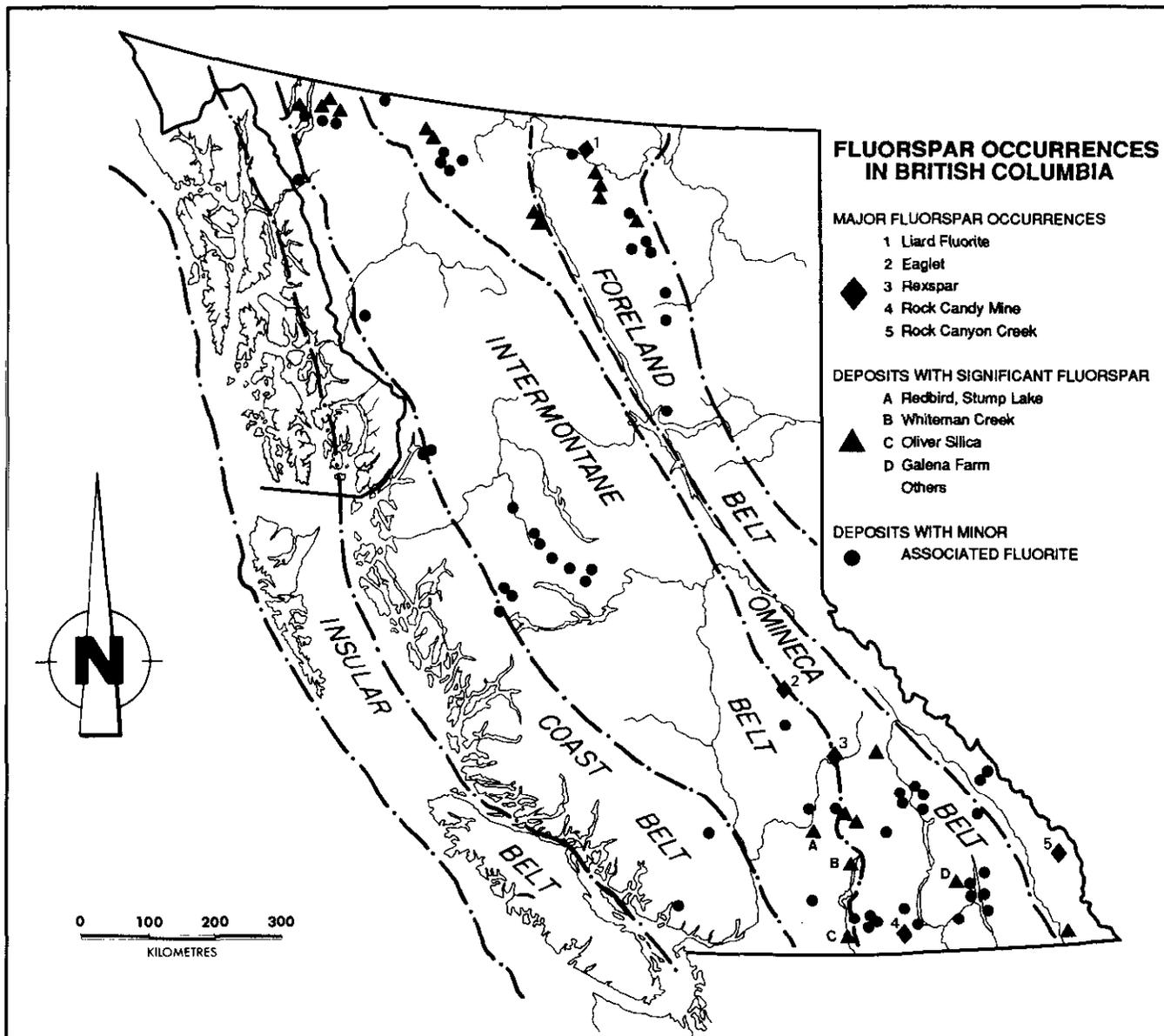


Figure 3-1-1. Location of fluor spar prospects and occurrences in B.C.

MAJOR FLUORSPAR DEPOSITS IN BRITISH COLUMBIA

ROCK CANDY MINE (MINFILE 082ESE070)

The Rock Candy fluor spar property is located on Kennedy Creek, approximately 27 kilometres north-northwest of Grand Forks, at the south end of the Omineca Belt, latitude 49°14' north and longitude 118°29' west. The main showing is exposed between 790 and 880 metres (2600 and 2900 feet) elevation.

HISTORY

The deposit was discovered in 1916 by two prospectors who mistook the green fluorite for a copper-bearing mineral (Dolmage, 1929). The property was acquired by Consolidated Mining and Smelting Company of Canada Limited

(Cominco) in 1918, once the true nature of the mineralization was realized, and immediately put into production. It was in operation intermittently between 1918 and 1929, and a total of 51 500 tonnes of ore, with an average grade of 68 per cent CaF_2 and 22 per cent SiO_2 was mined and shipped to the Trail smelter. The two mine adits remained open until the early 1980s at which time they were blasted closed. It is estimated that approximately 12 300 tonnes of broken ore remain in the stopes and that 47 800 tonnes of probable ore remains in pillars and sills (Parsch, 1973). The mine was controlled by Cominco Ltd. until its recent acquisition by a mineral collector.

GEOLOGY

The Rock Candy fluor spar deposit consists of an intricate network of subparallel veins, which vary from a few centimetres to approximately 10 metres in width, occupying a

silicified, northerly trending, moderate to steeply west-dipping fracture zone in Tertiary andesitic volcanics adjacent to a large syenitic intrusion (Figure 3-1-2). Fine-grained syenite dykes crosscut the andesites in the vicinity of the deposit (Parsch, 1973). Within the mine the veins were numerous and extremely closely spaced, with only narrow bands and isolated horses of altered country rock between them (Dolmage, 1929). The developed mineralized zone extends for approximately 200 metres north from Kennedy Creek and has a maximum width of approximately 15 metres. The vein reappears in outcrop approximately 1 kilometre north of the main developed zone (Figure 3-1-2).

Andesites which host the fluorite veins are predominantly fine to medium grained, greenish to grey in colour and contain albite, oligoclase and actinolite with minor magnetite and biotite. Quartz occurs as veinlets and as cavity fillings. Sericite, calcite and chlorite are locally developed alteration minerals. Immediately adjacent to the veins, the andesites are highly altered, weathering a pinkish buff colour, and contain abundant clay minerals (including kaolin), chlorite, sericite, quartz, calcite and pyrite (Parsch, 1973; Dolmage, 1929). These rocks are correlative with the Marron Formation of Paleocene or Eocene age. Outcropping to the east of the vein system are medium to coarse-grained, massive pink syenites which have been correlated with the Paleocene to Eocene Coryell intrusions (Dawson, 1985; Little, 1957). The syenites contain large pink and green feldspar crystals, predominantly orthoclase, with minor plagioclase. The centres of some orthoclase crystals have been identified as hyalophane, a barium-rich orthoclase (Dolmage, 1929). Biotite, hornblende, augite and magnetite, and traces of quartz, apatite, sphene and zircon are also present within the syenite. The ferromagnesian minerals are commonly altered to chlorite, and epidote is locally present (Dawson, 1985; McCammon, 1968a; Parsch, 1973). Microsyenite dykes locally crosscut the andesites and the coarse-grained intrusion. The dykes consist mainly of altered feldspars with some interstitial quartz and secondary calcite and chlorite. Fluorite has been reported from one such dyke (Dolmage, 1929). Granite and granodiorite, correlative with the Lower Cretaceous Nelson batholith, is present south of Kennedy Creek.

Excellent surface exposures of a large vein exist near the old workings (Figure 3-1-2), the eastern margin of which is covered by till. The outcrop consists of a 3 to 4-metre width of predominantly massive fluorite, bordered to the west by 1.5 to 2 metres of fluorite-matrix breccia and a thin composite-banded margin adjacent to altered volcanic country rocks. The massive portion of the vein consists of coarse-grained, pale apple to emerald-green fluorite and minor pale purple fluorite cut by numerous vuggy quartz veins. Within the mine, numerous large vugs, locally in excess of 1 metre in width, lined with crystals of barite, quartz, calcite and fluorite or containing white kaolin have been reported (Dolmage, 1929). The marginal breccia zone contains sub-angular, altered fragments of volcanic country rock in a matrix of purple and green fluorite, chalcedony, kaolin, pyrite, quartz and calcite. The banded western margin of the vein comprises both crystalline and massive banded barite with calcite, fluorite, chalcedony and quartz. Chalcopyrite, galena, chalcocite and covellite have been reported by early workers (Freeland, 1920), but are not evident in outcrop.

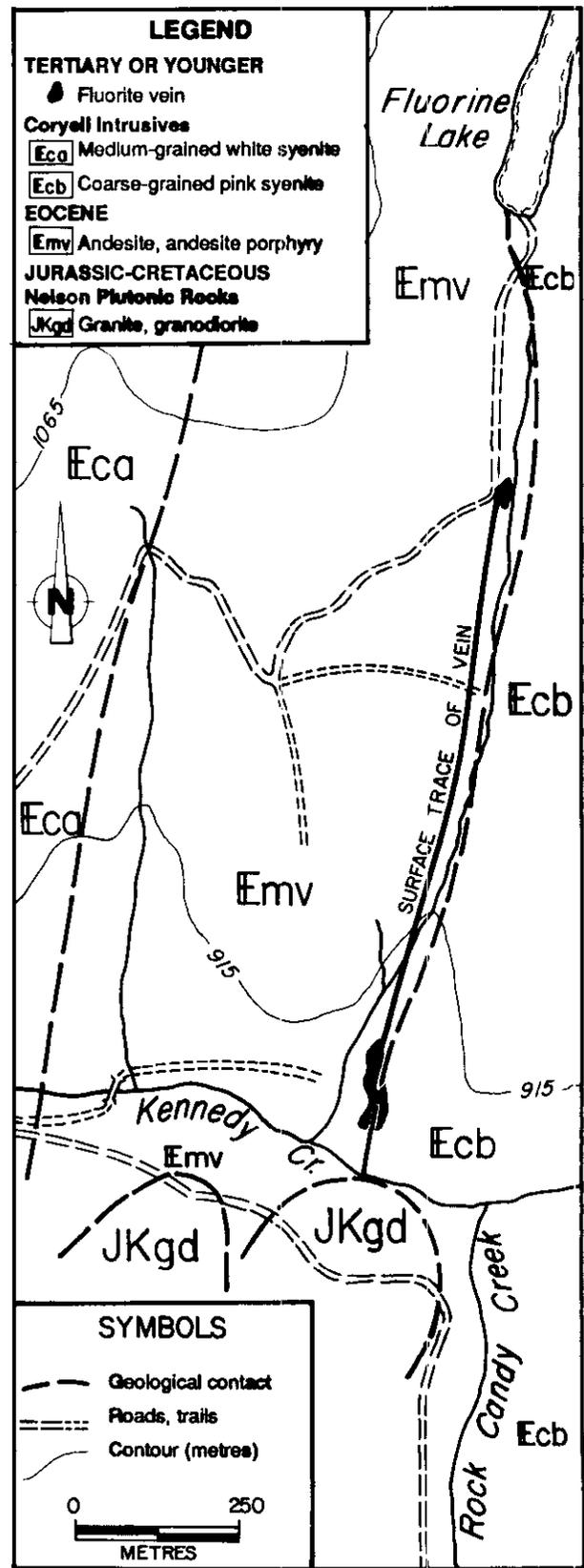


Figure 3-1-2. Geology of the Rock Candy Mine area. Compiled from field mapping by Pell, 1988.

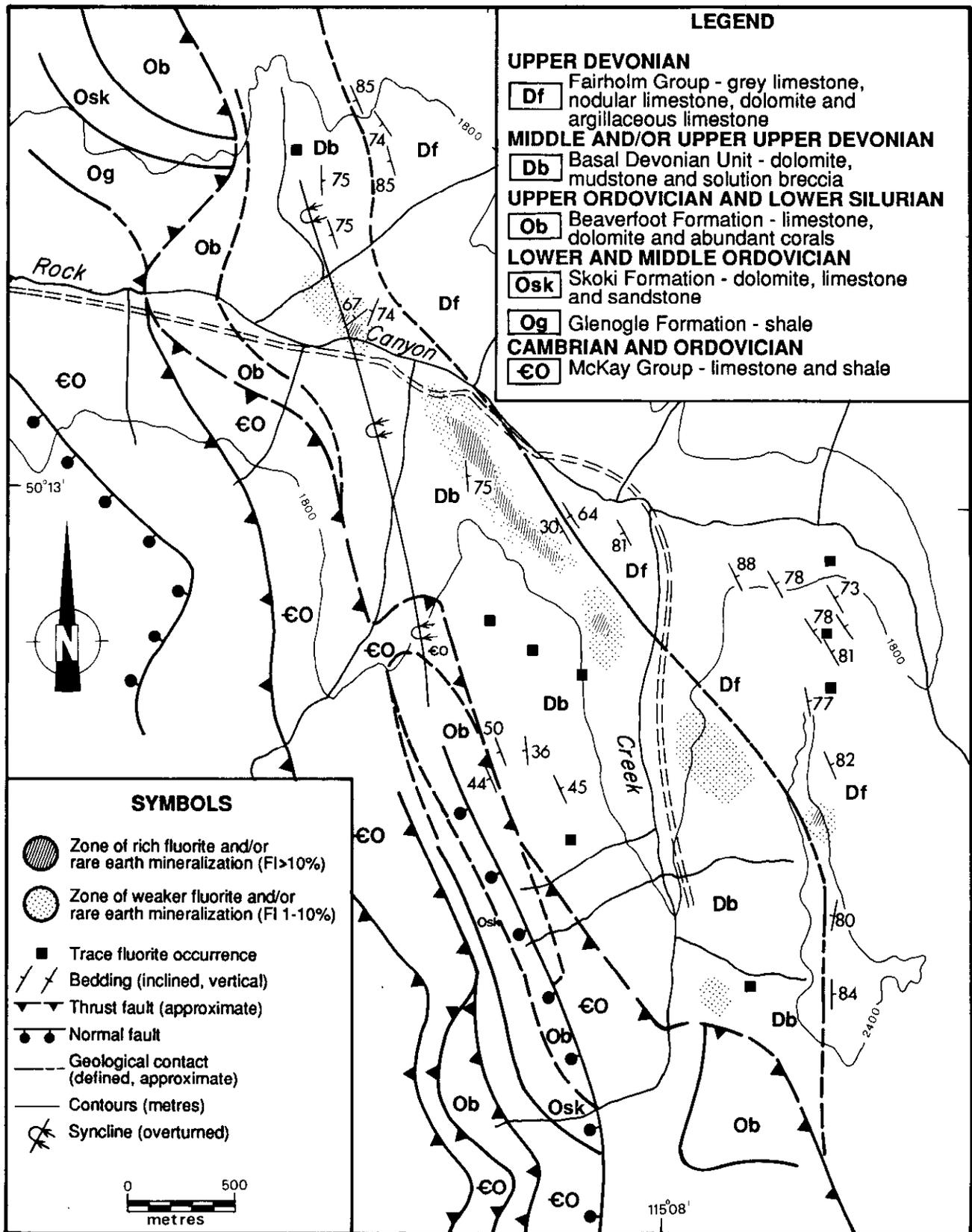


Figure 3-1-3. Geology of the Rock Canyon Creek fluorite rare-earth showing. Modified from Pell and Hora (1987) and Mott *et al.* (1986).

Numerous 4 to 5-centimetre fluorite veinlets, subparallel to the main vein, cut the altered volcanic rocks.

Approximately 1 kilometre north of the main showing, the fluorite mineralization is again exposed in outcrop. In this area a vein, 1 metre wide, cuts altered volcanics. The vein consists of massive pale purple and pale green fluorite cut by quartz veins and a breccia consisting of angular fluorite fragments, a few centimetres in size, in a matrix of small quartz crystals. Small vugs lined with quartz crystals are abundant. A significant linear structure connects this showing with the main workings and extends for some distance to the north and south. Drilling has indicated that fluorite mineralization is intermittently developed along the fracture zone; however, no economic grades were reported any distance from the main workings (Parsch, 1973).

AGE AND GENESIS

The Rock Candy deposit is an epithermal vein system occupying dilatant fissures in a north-trending fracture system. Mineralization postdates the Paleocene to Eocene volcanic rocks in which it is hosted. Based on the fact that the Coryell syenite contained barium-rich feldspars and that fluorite had been found in related dykes, Dolmage (1929) suggested that the solutions from which the fluorite veins were deposited were produced by fractionation and differentiation during the cooling and crystallization of the syenitic magma.

ROCK CANYON CREEK (DEEP PURPLE; MINFILE 082JSW018)

The Rock Canyon Creek property (Candy and Deep Purple claims) is located in the Main Ranges of the Foreland Belt, near the headwaters of Rock Canyon Creek approximately 40 kilometres east of Canal Flats, at 50°12' north, 115°08' west. It is accessible by conventional vehicles along the White River and Canyon Creek forestry roads, which join Highway 3A, 2 kilometres south of Canal Flats. The main mineralized zone lies between the 1525 and 2000-metre elevations in a valley that has been burnt-over and subsequently logged. Access is excellent, but exposure poor due to thick drift cover.

HISTORY

The prospect was discovered in 1977 during a regional exploration program carried out by Rio Tinto Canadian Exploration Limited in search of Mississippi Valley-type lead-zinc mineralization. Between 1977 and 1979, mapping, soil and rock geochemistry and trenching were done to assess the fluorite-lead-zinc potential of the property (Bending, 1978; Alonis, 1979). More recent work (Graf, 1981, 1985) attempted to establish the economic potential of the property in terms of other commodities. During this latter work it was discovered that the property also contained anomalous rare-earth element (REE) concentrations. There has been no drilling on this property and the subsurface extent of mineralization is unknown.

GEOLOGY

The Rock Canyon Creek area is underlain by a Cambro-Ordovician to Middle Devonian carbonate-dominated se-

quence (Leech, 1979). The southwestern boundary of the property is marked by a west-dipping thrust fault which places Cambrian and Ordovician strata over younger rocks (Figure 3-1-3). The remainder of the area is underlain by an overturned to upright homoclinal sequence, younging to the east. This succession comprises coral-rich limestones of the Ordovician Beaverfoot Formation in the northwest, unconformably overlain by buff-weathering dolomites and solution breccias of the basal Devonian unit which are, in turn, conformably overlain by fossiliferous and nodular grey limestones of the Fairholm Group. The fluorite and rare-earth element mineralization is stratabound, hosted mainly by the basal Devonian unit.

Four main types of fluorite mineralization are identifiable in the field (Pell and Hora, 1987). The first and most widespread consists of disseminations and fine veinlets of dark purple fluorite in a dark brown to dark orange-brown-weathering dolomitic matrix. Fluorite content generally varies from 2 to greater than 10 per cent of the rock and chemical analyses indicate CaF_2 values of 2.5 to 12.78 per cent (Graf, 1985). Bastnaesite (CeCO_3F) often occurs along the margins of fluorite veins, as does coarse crystalline dolomite. Disseminated pyrite, gorceixite [$(\text{Ba,Ca,Ce})\text{Al}_3(\text{PO}_4)_2(\text{OH})_3\text{H}_2\text{O}$], calcite, limonite, illite and barite are common accessory minerals (Hora and Kwong, 1986). Parisite [$\text{CaCe}_2(\text{CO}_3)_3\text{F}_2$] has also been identified from fluorite veins with scanning electron microscopy, and may be associated with bastnaesite. Neutron activation analyses of up to 2.3 per cent rare-earth elements and 2.7 per cent barium have been reported (Graf, 1985). Niobium, strontium and yttrium are also present in measurable amounts (Pell, 1987). Contacts between mineralized and unmineralized dolomitic rocks are gradational; the amount of fluorite veining decreases and the colour of the rocks changes gradually from dark brown to buff, the characteristic colour of unaltered dolomites in the area. This type of mineralization defines a northwest-trending zone mappable for over a kilometre, subparallel to strike (Figure 3-1-3).

The second, and highest grade type of fluorite mineralization consists of massive, fine-grained purple and white fluorite, which commonly comprises greater than 40 per cent of the rock, together with accessory prosopite [$\text{CaAl}_2(\text{F,OH})_3$], gorceixite, pyrite and minor barite, calcite, rutile and kaolinite (Hora and Kwong, 1986). Chemical analyses (Graf, 1985; Pell, 1987) indicate CaF_2 contents for this type of mineralization of between 24.6 and 70.65 per cent. The rare-earth element and pyrite contents of these rocks are relatively low. Massive fluorite mineralization has not been found in place, but abundant float occurs at the southeast end of the zone of Type 1 mineralization, near the north-flowing branch of Rock Canyon Creek (Figure 3-1-3).

Fine-grained purple fluorite disseminated in white calcite, which is locally interbedded with buff-weathering dolomite and forms the matrix of solution breccias, constitutes the third type of mineralization. Fluorite is present in concentrations from trace amounts to a few per cent. Minor rare-earth element enrichment is also reported (Graf, 1985). This type of mineralization is found randomly distributed throughout the basal Devonian unit.

The fourth type of fluorite mineralization occurs in rocks tentatively assigned to the Devonian Fairholm Group and is

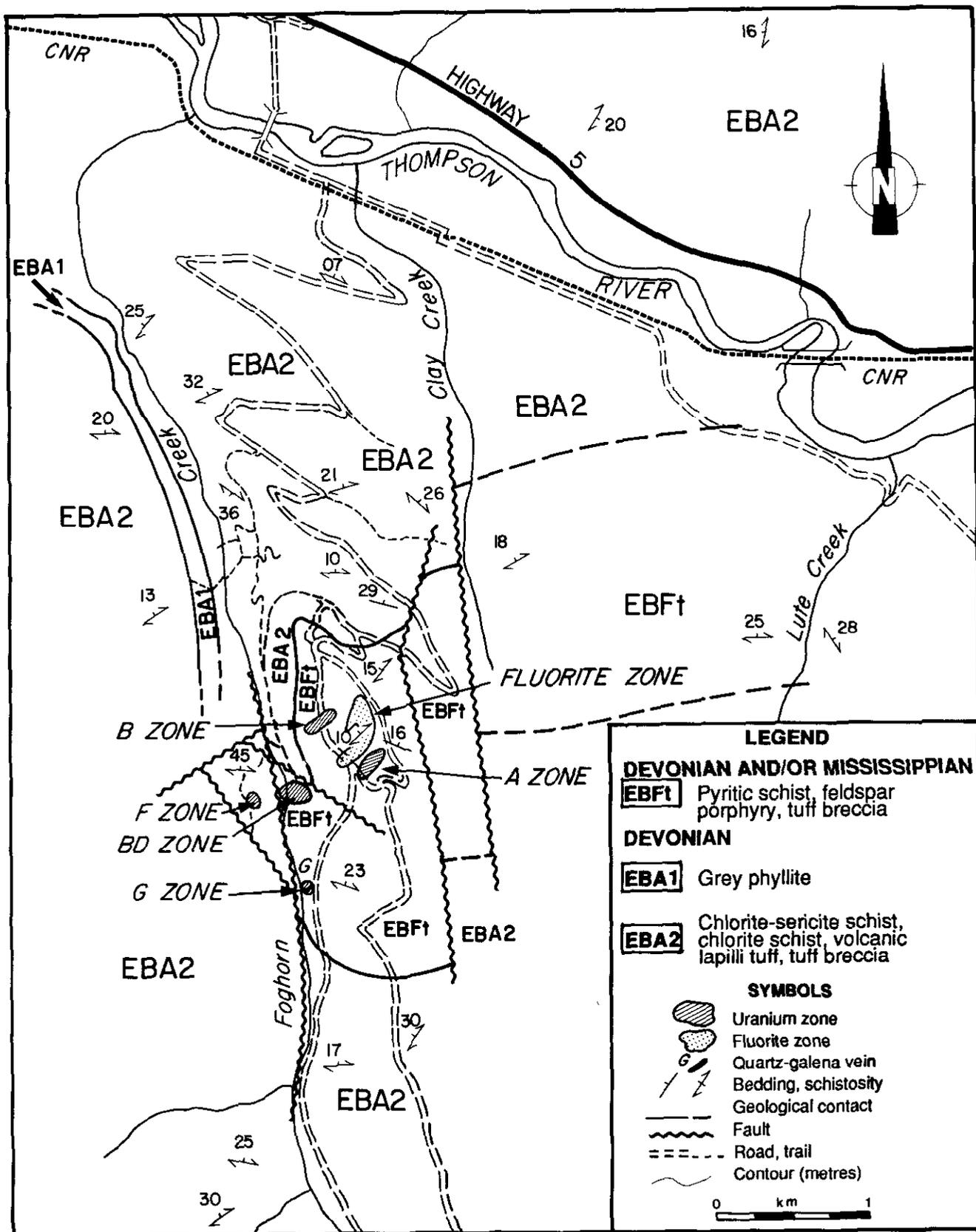


Figure 3-1-4. Generalized geology of the Rexspar property. Modified from Descarreaux, 1986, Lund, 1973; Preto, 1978 and mapping by Pell, 1988.

found in one locality, at the 2135-metre elevation on the ridge east of the headwaters of Rock Canyon Creek (Figure 3-1-3). Massive purple fluorite forms the matrix of an intraformational conglomerate and constitutes greater than 20 per cent of the rock. Minor barite, pyrite and magnetite are also associated with this type of mineralization.

AGE AND GENESIS

A carbonatite-related origin has been suggested for the Rock Canyon Creek prospect (Graf, 1985; Hora and Kwong, 1986; Pell and Hora, 1987). This interpretation appears to be consistent with preliminary geochemical data. In addition to high fluorine, rare-earth elements and barium, the rocks are enriched in Fe_2O_3 , MnO, MgO, strontium, yttrium, phosphorus and niobium, and have chondrite-normalized rare-earth element abundance patterns typical of carbonatites. Due to the lack of unequivocal igneous material and the gradational contacts of the mineralized zone with fresh carbonates, it is believed that it comprises metasomatically altered (fentitized) Devonian carbonate rocks, possibly related to a deep-seated alkaline intrusion.

Timing of metasomatism is poorly defined. Mineralization apparently occurred prior to the Jura-Cretaceous deformation, as no fluorite is observed west of the west boundary fault, and postdated at least part of the deposition of the basal Devonian unit. This broadly defines a time span of 280 Ma during which mineralization must have occurred. Some mineralization (Types 3 and 4, fluorite associated with solution breccias and intraformational conglomerate matrix) may have resulted from elemental remobilization, and therefore may postdate the Type 1 and 2 fluorite/rare-earth deposits. It has been suggested that mineralization may have been synchronous with deposition of the basal Devonian unit (Graf, 1985). A slightly younger age is favored as most other carbonatites in the province are Devonian-Mississippian to Early Mississippian (*circa* 350 to 380 Ma) in age (Pell, 1987).

REXSPAR (MINFILE 082M 007, 21, 22, 34, 43)

The Rexspar deposit is located in the Omineca Belt, approximately 130 kilometres north of Kamloops and 5 kilometres south of the town of Birch Island, latitude $51^{\circ}34'$ north, longitude $119^{\circ}54'$ west. It is reached by the Foghorn Mountain logging road, south from Birch Island. The mineral deposits occur on Red Ridge, which leads down from Granite Mountain between Foghorn and Clay creeks, at elevations of 1250 to 1370 metres (4100 to 4500 feet). The terrain is rugged and forested; however, numerous outcrops are exposed along roads, trails, trenches, creeks and cliff sections.

HISTORY

Fluorite on the Rexspar property was originally discovered and staked in 1918; lead-silver showings were found in 1926 and a bog manganese prospect was discovered north of the other showings in 1929 (Joubin and James, 1957; McCammon, 1950, 1955; Wilson, 1929). Work on the property was sporadic until the 1940s when drilling was undertaken to define the extent of fluorite mineralization. The presence of

uranium on the Rexspar property was discovered in 1949 after which extensive drilling and underground work, during the 1950s, outlined three zones of uranium mineralization, the A, B, and BD or Black Diamond zones, in addition to the original fluorite zone. From 1969 to 1976, surface work and diamond drilling was done on the property, after which time it has only received minor attention. Between 1943 and 1976, approximately 17 280 metres of drilling was completed which, together with underground work, defined combined reserves of 1 114 380 tonnes of 0.077 per cent U_3O_8 in the three uranium zones. The fluorite zone has an estimated 1 441 820 tonnes of ore averaging 23.46 per cent CaF_2 (Descarreaux, 1986; Preto, 1978).

GEOLOGY

The rocks in the vicinity of Birch Island are part of the Eagle Bay assemblage (Figure 3-1-4), which ranges in age from Lower Cambrian to Mississippian. The strata which host the Rexspar deposit are assigned to Unit EBFt of the Eagle Bay and are considered to be of Devonian-Mississippian age (Schiarizza and Preto, 1987). These rocks are correlative with the strata which host the Rea Gold volcanogenic massive sulphide-barite deposit in the Adams Plateau area to the east (Schiarizza and Preto, 1987). They comprise a shallow-dipping package of pyritic lithic tuffs and breccias of trachytic composition, locally with some rhyolite and dacite members. These rocks are light greenish to rusty weathering and have white, light grey or light green fresh surfaces and may be massive to strongly foliated; the foliated varieties are best described as sericite-albite-quartz-pyrite schists. In thin section, they comprise albite and potassium feldspar phenocrysts in a fine-grained matrix of predominantly albite and sericite. Where lithic clasts are present, they are generally of similar composition to the enclosing schists. In the vicinity of the A and BD mineralized zones polyolithic breccias with feldspar porphyry fragments and fragments of fine-grained dark rocks are present (Preto, 1978). To the south and east of G zone (Figure 3-1-4), fine to medium-grained massive rocks crop out and may represent intrusive phases. Coarse breccias are also locally present.

Underlying the trachytic tuff and breccia package (Unit EBFt) is a sequence of chlorite schists, spotted sericite schists, sericite-chlorite schists, argillaceous phyllites and sandstones (Unit EBA of Schiarizza and Preto, 1987). The schists are believed to be of metavolcanic origin; the clearly metasedimentary rocks are distinctly less abundant within this unit. No mineralization occurs within this lower package.

Uranium and fluorite mineralization are found exclusively in the upper part of the trachytic lithic tuff and breccia package (Unit EBFt). The fluorite zone measures approximately 400 metres by 50 metres, with an average true thickness of 24 metres (Descarreaux, 1986). It is hosted in a fine-grained, brecciated, tuffaceous trachyte which locally contains layers with abundant lithic fragments and is highly silicified, albitized and rich in pyrite. Fluorite occurs as dark purple, coarse-grained fragments or fine, disseminated grains, which give the rock an overall purple colour. On the weathered surface, the coarse-grained, dark purple fluorite fragments give the rock the appearance of a lithic tuff and

could be replaced rock fragments. Fluorite veins, a few centimetres to tens of centimetres wide, containing banded white to purple fluorite \pm quartz \pm barite, are locally present within this zone. Molybdenite, celestite, strontianite, chalcocopyrite, galena and bastnaesite have been identified from this zone. The fluorite deposit apparently grades laterally into a dark rock composed of mica, pyrite and 5 to 10 per cent fluorite.

The main zones of uranium mineralization loosely define a semicircular ring surrounding the fluorspar zone to the south, southwest and northwest (Figure 3-1-4). The high-grade uranium-bearing rocks are fine grained, dark grey to black and contain abundant pyrite and fluorophlogopite, up to 10 per cent fluorite and minor calcite (Preto, 1978; Descarreaux, 1986). This type of mineralization is generally conformable to layering and schistosity in the tuffs. Material from the A-zone dumps consists of strongly banded, pyrite-rich rocks that display textures not unlike those found in volcanogenic massive sulphide deposits; banded pyrite-fluorite and pyrite-fluorite-mica rocks locally show contorted bedding, fragmented sulphide layers and sulphide (rip up?) clasts. Locally fluorite veins crosscut the layered mineralization.

Low-grade uranium mineralization is characterized by coarse-grained, silver-grey fluorophlogopite in replacement zones with pyrite and minor fluorite and calcite. These replacement zones may be a few centimetres to a few metres in size, and may be either conformable or discordant, randomly oriented patches. In the G zone (Figure 3-1-4), fluorophlogopite replacements are associated with brown-weathering carbonate-filled fractures and larger carbonate pods or swells in fragmental volcanic rocks. In this area, quartz-galena veins, up to a few tens of centimetres thick, and pyrite-filled shears or fracture zones are also present.

A number of uranium-thorium minerals are reported in uranium zones, including uraninite, torbernite, metatorbernite, thorianite and thorite. These minerals are commonly found as inclusions in fluorophlogopite crystals or as discrete grains in the pyrite-fluorophlogopite matrix. Other accessory minerals include monazite, bastnaesite (a rare-earth fluorocarbonate), niobian ilmenorutile, apatite, celestite, galena, sphalerite, chalcocopyrite, molybdenite, scheelite and barite (Preto, 1978).

AGE AND GENESIS

Mineralization at Rexspar is believed to be syngenetic with the host rocks, and therefore Devonian-Mississippian in age. Preto (1978) suggests that the pyrite-mica zones and the uranium mineralization were formed by deuteric volatile-rich fluids during the late stage in the formation of the trachyte unit. The presence of related intrusive rocks, rhyolites and coarse breccias may indicate proximity to a volcanic vent. The distinct banded textures and sulphide clasts in the A zone support a volcanogenic origin. Discordant mineralization could have been produced by late fluids cutting slightly earlier formed rocks. Early workers had suggested the alternate hypothesis that mineralization was related to nearby Cretaceous granitoids.

Radiometric dating has not provided conclusive results. Potassium-argon analyses of mica from a coarse pyrite-mica rock indicated a 236 ± 8 Ma age; gas extraction during the

analysis was poor, and this is considered to be a minimum age for mineralization (Morton *et al.*, 1978). Although the data do not indicate a Middle Paleozoic age, they rule out any relationship with the Cretaceous granitic rocks. Lead-lead ages of galenas from the Rexspar deposit fall between Middle Jurassic and Tertiary (Goutier, 1986). These are considered problematic due to the highly radiogenic lead component generated by the nearby mineralization.

Studies of fluid inclusions in fluorite from the uranium zones (Morton *et al.*, 1978) indicate that two types of primary inclusions are present, one containing aqueous liquid plus vapour and one containing aqueous liquid plus liquid carbon dioxide plus vapour. It is considered likely that the uranium was transported as carbonate complexes in a weakly saline system charged with carbon dioxide of volcanic origin. As the solutions neared surface, the sudden pressure drop and concomitant effervescence and release of carbon dioxide would result in the precipitation of uranium minerals at or near the surface (Morton *et al.*, 1978), supporting the volcanogenic hypothesis.

Only one type of fluid inclusion is present in fluorite from the fluorite zone; inclusions containing aqueous liquid plus vapour. There is no evidence for the presence of a carbon dioxide rich phase. The lack of carbon dioxide in the system probably resulted in the inability of the fluids to mobilize or transport uranium and therefore the absence of uranium in the fluorite zone. This apparent difference in the composition of the fluids also suggests that the fluorite zone may have formed at a slightly different time than the uranium zones, possibly after an incursion of meteoric water into the system (Morton *et al.*, 1978).

EAGLET (MINFILE 093A 046)

The Eaglet fluorspar property is located in the Omineca Belt, on the east side of Quesnel Lake approximately 3.5 kilometres northeast of the junction of the North Arm and the main Lake, at latitude $52^{\circ}33'$ north and longitude $121^{\circ}00'$ west. Access is from Williams Lake by road, through the town of Horsefly, to the south shore of Quesnel Lake, a distance of 125 kilometres. From the south shore, a boat may be taken 8 kilometres across the lake to the mouth of Barrett Creek which is on the fluorspar property. Outcrops in the area are sparse; however, some fluorite mineralization is exposed on the slopes between Barrett Creek and Quesnel Lake, and in the Barrett Creek canyon at elevations of 760 to 915 metres (2500 to 3000 feet).

HISTORY

The fluorite showing on Barrett Creek was discovered by a prospector in 1946. Preliminary work was done on the property in the mid 1960s and from 1973 to 1983 extensive exploration involving surface work, drilling, driving of two adits and underground drilling was carried out (Ball and Boggaram, 1984; McCammon, 1966).

GEOLOGY

Fluorspar mineralization occurs in the Quesnel Lake gneiss, a granitic orthogneiss of Late Devonian to Early Mississippian age, (Mortensen *et al.*, 1987), near its contact

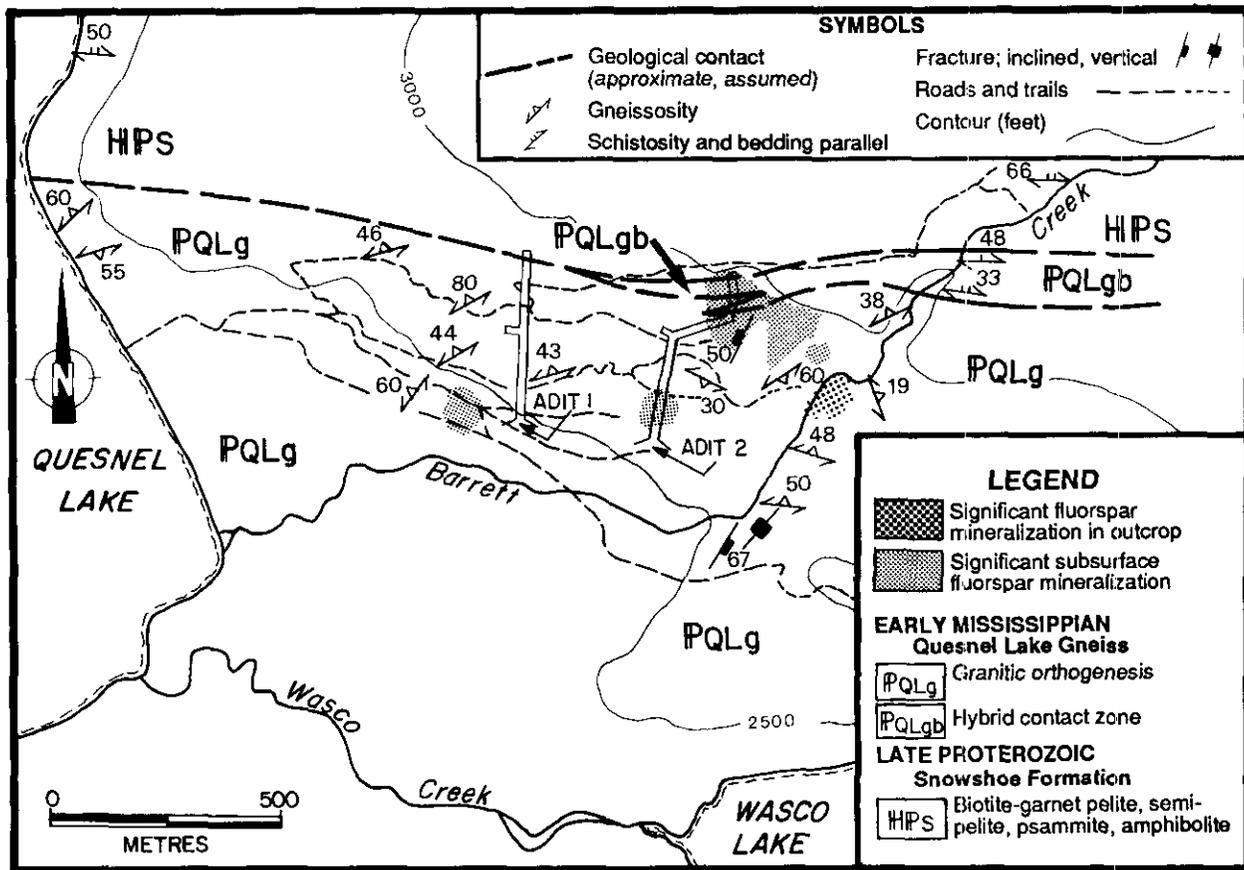


Figure 3-1-5. Geological map of the Eaglet Fluorspar Prospect. Compiled from field mapping by Pell, 1988 and drill data from Company and Assessment Reports.

with Late Proterozoic Snowshoe Group metasedimentary rocks (Figure 3-1-5). In the vicinity of the fluorite showings, the gneiss is medium grained, grey to rusty weathering, with a white to pink fresh surface. It is composed predominantly of feldspars and quartz with 5 to 10 per cent biotite and displays a weakly developed gneissosity. Biotite-rich bands, pegmatitic segregations and aplitic dykes are all locally present within the gneiss. At one locality, pink-weathering carbonate sweets were observed parallel to gneissosity. Fluorite is ubiquitous, occurring as grains disseminated throughout the gneiss in amounts from trace quantities to a few per cent, and traces of molybdenite are also locally present.

Near Barrett Creek, the Quesnel Lake gneiss is bordered to the north by biotite-garnet pelites, semipelites, garnet amphibolites and minor marbles of the Snowshoe Group. The contact of the gneiss and the metasediments strikes nearly east-west and has a shallow northerly dip, with the metasediments structurally overlying the gneiss. Relationships exposed in outcrops in the Barrett Creek canyon clearly show that this is an intrusive contact; apophyses of the granitic gneiss crosscut the metasediments and large xenoliths of metasediment are included within the gneiss near its margins.

Fluorite, in addition to disseminated grains, occurs as thin films on fractures in the gneiss, as veins up to 10 centimetres thick and as pods and irregular replacements up to 30 by 50

centimetres in size. Most fluorite exposed in outcrop varies from pale purple to black in colour. In Barrett Creek, near the contact of the gneiss and metasediments, coarse-grained calcite-fluorite-galena veins, 15 to 20 centimetres wide, are exposed. Sphalerite and tetrahedrite are reportedly associated with the calcite-fluorite-galena veins (Ball and Boggaram, 1984).

Economic concentrations of fluorspar are not evident at surface; however, drill holes and adits have encountered significant mineralization. A number of drill holes have intersections of between 9 and 21 metres of 11.5 to 19.5 per cent CaF_2 . Adit 2 (Figure 3-1-5) also intersected significant mineralized zones and reserves in the vicinity of this adit are estimated at 1.8 million tonnes of 15 per cent CaF_2 (Ball and Boggaram, 1984). The fluorspar from the adit is medium to fine grained and predominantly white to cream in colour; some pale green, pale bluish grey and light to dark purple fluorite is also present. Texturally, the fluorspar varies from massive to sugary and interspersed with quartz and potassium feldspar. Associated minerals include muscovite, pyrite, molybdenite (up to 5 per cent), calcite, chalcopyrite and possibly barite. Galena, sphalerite, wolframite, scheelite and celestite have also been reported (Ball and Boggaram, 1984; McCammon, 1966). The sugary fluorite-quartz-feldspar rock grades into altered granitic gneiss which is generally pink to rusty in colour and contains pyrite, hematite, chlorite and, locally, a few per cent molybdenite.

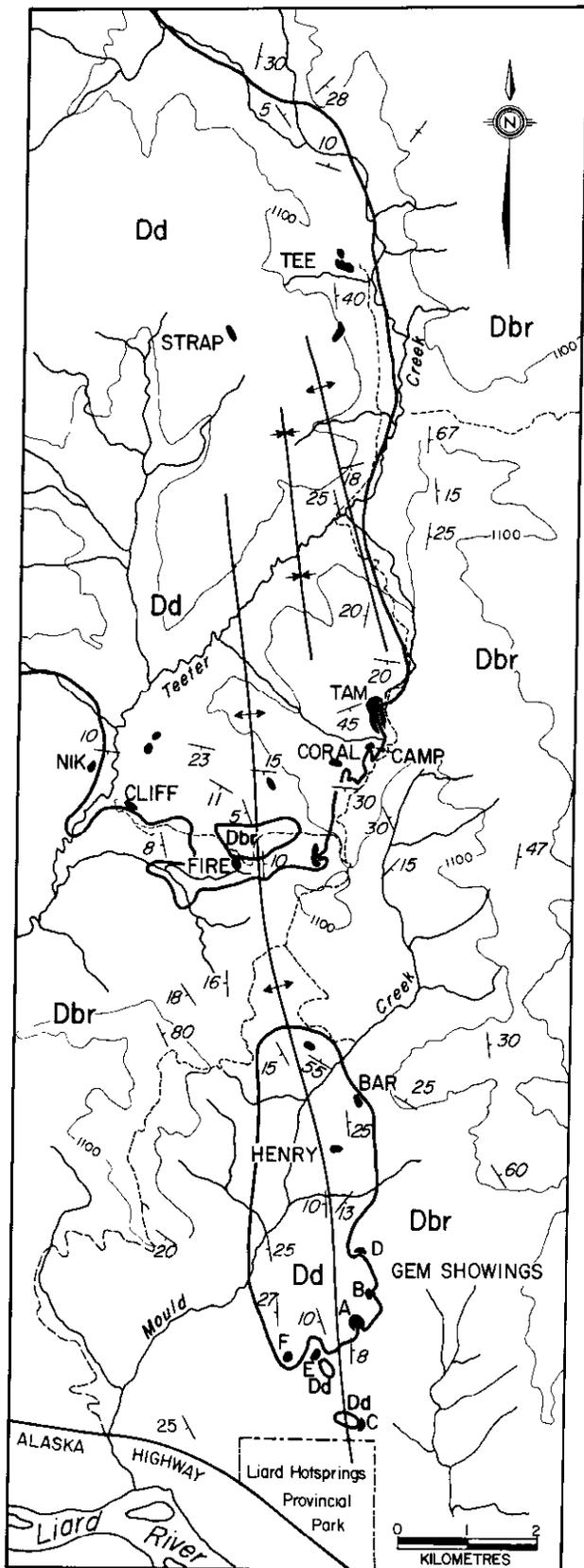


Figure 3-1-6. Generalized geology of the Liard Fluorspar showings. Modified from Woodcock, 1972 and Woodcock and Smitheringale, 1955.

AGE AND GENESIS

Fluorite mineralization is clearly superimposed on the Quesnel Lake granitic gneiss. Fluorite veins crosscut the gneiss, fluorite locally replaces the gneiss and in areas of significant fluorite mineralization, the gneiss is highly altered. The presence of molybdenum and tungsten minerals associated with the fluorite imply a granitic source for the mineralizing fluids.

Fission-track dating on fluorite from Eaglet suggests an age of formation of 104.6 ± 6 Ma (V. Harder, personal communication to Z.D. Hora, 1987). Fission-track studies in fluorite are in the very early stages of development and cannot be considered as irrefutable evidence. Preliminary potassium-argon data from muscovite separates suggest an age of 127 ± 4 Ma for the mineralizing event (J. Harakal, personal communication, 1988). Cretaceous quartz monzonite stocks with associated copper-molybdenum mineralization are known to occur in the Quesnel terrane to the west of Quesnel Lake (Bailey, 1988) and this system could be related to the mineralization at Eaglet.

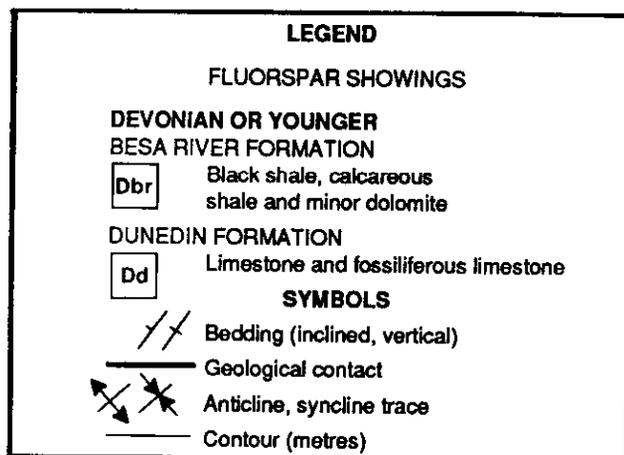
LIARD FLUORITE

(MINFILE 094M 002, 5, 6, 7, 8, 10, 11, 12, 13, 14, 15)

The Liard fluorite deposits occur within the Foreland Belt, near the British Columbia-Yukon border. They are exposed in a zone which begins approximately 3 kilometres north of Liard Hot Springs Provincial Park, Mile 497 on the Alaska Highway, and extends northwards for approximately 16 kilometres (Figure 3-1-6), from latitude $59^{\circ}27'$ to $59^{\circ}34'30''$ north at longitude $126^{\circ}05'$ west. The terrain consists of low, heavily drift-covered rolling hills of the Liard Plateau, and outcrop is sparse. Local karst topography is developed, with sink holes and isolated buttes sporadically distributed. Old roads and trails lead from the Alaska Highway to the showings which are at elevations ranging from 730 to 1100 metres (2400 to 3600 feet); however, in places the trails are so badly overgrown and covered with deadfall that they are virtually impassable, even on foot, and access to the showings is most easily gained by helicopter.

HISTORY

The Gem showings, the most southerly of the Liard Hot Spring fluorspar occurrences, were discovered in 1953 by



prospectors in search of uranium mineralization (Holland, 1955). In 1954 work was begun, which included roadbuilding, stripping, drilling and geologic mapping. Regional prospecting in 1971 resulted in the discovery of the northern showings which were drilled and extensively explored during 1971 and 1972. Grades in excess of 30 per cent CaF_2 were encountered over excellent widths and thicknesses (Northern Miner, 1972); however, high predicted production and transportation costs resulted in little work being done after the early 1970s. In 1986, the Liard fluor spar showings were restaked as the Thor claims.

GEOLOGY

The area north of Liard Hotsprings is underlain by Middle Devonian Dunedin Formation fossiliferous limestones and Middle to Upper Devonian Besa River shales (Taylor and MacKenzie, 1970). The Dunedin Formation is exposed in the core of a broad, open antiform with an approximately north-trending axis (Figure 3-1-6). It is medium to dark grey in colour and locally extremely fossiliferous, containing abundant colonial corals as well as brachiopods and gastropods. The overlying Besa River Formation consists predominantly of black shales, some calcareous shales and minor, thin buff dolomitic layers. The contact between the shales and limestones is very irregular, possibly as a result of an erosional disconformity or structural complications (Woodcock, 1972).

Mineralization, which consists predominantly of fluorite and witherite, occurs at or near the contact between the shales and the limestones. In most of the showings, the major mineralization occurs in the limestones beneath the contact; in some cases, minor amounts of fluorite and witherite are found in the shales overlying mineralized limestone; and, rarely, such as at the Gem E showings, mineralization is confined to the shales (Woodcock, 1972; Woodcock and Smitheringale, 1955). Fluorite and witherite commonly occur as infillings and replacements in limestone or shale breccias, or as fracture infilling in the surrounding limestones and shales. In some cases, such as at the Tee showing, individual replacement pods, devoid of host rock fragments, are exposed over areas in excess of 50 by 15 metres; at the Tam showing mineralization is exposed over a distance of 275 metres by 50 to 165 metres.

In addition to fluor spar and witherite, mineralized zones contain barytocalcite, minor barite and silica. In most of the deposits the fluorite is purple to black in colour and may be fine or coarse grained. In the Gem A showing (Figure 3-1-6) the fluorite has been bleached to rose and white on exposed surfaces, but is dark purple on fresh surfaces. At the Tee showing, most of the fluorite is colourless, as is reportedly the case at the Cliff prospect (Woodcock, 1972). The witherite is usually white; however, when the mineralization is shale hosted, witherite tends to be grey in colour. In some locations, witherite is more abundant than fluorite, in others, the opposite is the case. Together, they commonly comprise 60 to 75 per cent of the rock. Barite rarely makes up over 10 per cent (Woodcock and Smitheringale, 1955).

AGE AND GENESIS

Fluor spar deposits at Liard Hotsprings consist predominantly of carbonate-breccia-hosted infilling and replacement

mineralization. The breccias do not appear to be clearcut paleokarst solution breccias, they may have formed as a result of small-scale dissolution or hydraulic fracturing. In terms of stratigraphic setting and the nature of the host breccias, these showings are similar to the lead-zinc deposits in the Robb Lake-Redfern Lake belt to the south (MacQueen and Thompson, 1978). They are probably genetically similar as well, formed from solutions originating during dewatering of the sedimentary basin, but represent fluorine-barium-rich, sulphur-deficient (barium carbonate rather than barium sulphate present) end-members as opposed to the lead-zinc-sulphur end-member. If this is the case, the Liard Hotspring deposits are probably approximately the same age as the carbonate-hosted lead-zinc deposits in the Robb Lake belt. Lead isotopic evidence suggests that mineralization associated with those deposits formed near 370 ± 30 Ma (Godwin *et al.*, 1982). Fission-track studies in fluorite from the Gem showing suggests an age of formation for the deposit of 332 ± 56 Ma (V. Harder, personal communication to Z. D. Hora, 1987) which, within errors, is in agreement with the lead-lead data from Robb Lake; however, as previously stated, this must be taken with certain reservations.

OTHER FLUORSPAR OCCURRENCES IN SOUTHERN BRITISH COLUMBIA

A large number of fluor spar occurrences exist within the province (Figure 3-1-1), but due to the unfavorable economics of mining in remote areas, only those in the southern part of the province are included in this report. Fluor spar occurrences in the Atlin area should be examined in future studies as proximity to tidewater could make them economically viable. A number of the occurrences in the southern part of the province will be briefly described.

Colourless to pale green fluorite occurs as small pods near the centre of the Gypo or Oliver silica quarry (MINFILE 082ESW084), north of the town of Oliver at latitude $49^{\circ}11'40''$ north, longitude $119^{\circ}33'20''$ west. The quarry is located on a large quartz body which crosscuts quartz monzonite. It contains few impurities, other than the fluorite pods which have exposed surfaces of 0.5 to 1 metre by 1.5 to 2 metres in size. The silica quarry has operated intermittently since 1926, and in 1958 approximately 29 tonnes of fluorite were shipped from the quarry to markets in Washington (McCammon and James, 1959).

A fluorite occurrence on Whiteman Creek (MINFILE 082LSW001, latitude $50^{\circ}20'$ north, longitude $119^{\circ}20'$ west) near the west shore of Okanagan Lake across from Vernon, was explored for fluorite in the mid-1960s (McCammon, 1968b). Mineralization is exposed over an area of at least 300 by 700 metres and occurs as fracture infillings and drussy quartz-fluorite veins, 1 to 10 centimetres wide on average, in quartz monzonite. Veins are characterized by rapid pinching and swelling and rarely approach 1 metre in width. Open spaces are common and usually lined with small, well-formed fluorite crystals. The fluor spar is most commonly green in colour, although colourless, rose and pale purple varieties are sometimes intermixed with the green. Pyrite is a minor component of the veins and no other sulphides were observed or reported.

Fluorite is a common gangue mineral, together with quartz and siderite, in lead-zinc-silver veins of the Galena Farm mine at Silverton in the Slocan district (MINFILE 082FNW067, latitude 49°56' north, longitude 117°22' west). The veins occur predominantly within the Nelson granite, near its northern margin. Mineralization occurs as open-space fillings and fracture coatings. Within the gangue, quartz is present in amounts approximately equal to, or slightly greater than fluorite, and siderite is a minor constituent. The veins commonly have repeated layers of small quartz or fluorite crystals distributed parallel to vein margins; small well-formed fluorite crystals lining drussy openings; or, occasionally, botryoidal accumulations of fluorite adjacent to vein openings. The fluorspar at Galena Farm is colourless to very pale purple. Obvious sulphide minerals present are galena, sphalerite and pyrite, in that order of abundance.

Fluorite is abundant in veins cutting Triassic Nicola Group volcanics on the Redbird Claim, near Stump Lake, south of Kamloops (MINFILE 092ISE179, latitude 50°23'30" north, longitude 120°22' west), and has been exploited by mineral collectors since the mid-1960s. Veins in the area vary from a few centimetres to a few metres in width and may comprise crystalline quartz and fluorite, chalcedonic quartz and fluorite, chalcedonic quartz and fluorite breccias cemented by crystalline quartz, and banded chalcedonic quartz, pyrite and minor fluorite. Anomalous gold values have been found associated with some veins in this area (Dekker, 1983). Open spaces are common within the veins and are frequently lined with coarse, crystalline fluorspar. On the Redbird property, the fluorite is predominantly dark purple, but some dark green varieties are also present. In some veins, fluorite occurs along the vein margins adjacent to the Nicola volcanics, in others the fluorite forms the centre of veins with a vein border of chalcedonic quartz. In one vein, dark green fluorite forms a band adjacent to the vein margin, followed by purple fluorite, then banded chalcedony and the vein is cored by crystalline quartz.

A number of other occurrences where fluorspar is present in significant amounts are reported from southern British Columbia including the Tappen Creek (MINFILE 082LNW049) and To (MINFILE 082LNW034) properties near Shuswap Lake and the Howell Creek property (MINFILE 082GSE037), which is associated with syenites in the Flathead region of southeastern British Columbia. Fluorite also occurs as a minor or trace constituent in a number of areas including the Carmi molybdenum, Beaverdell silver-lead-zinc and Ainsworth silver-lead-zinc camps. Fluorite is also reported from Lower Cambrian carbonate-hosted stratiform lead-zinc deposits in the Monashee Complex near Revelstoke (the Ruddock Creek deposit) and from molybdenum deposits in the Jordan Creek-Mount Copeland area, also near Revelstoke.

CONCLUSIONS

Fluorspar mineralization in British Columbia occurs in a wide range of geologic environments, tectonic settings and ages. Fluids (volatiles) are always important in the mineralizing process. Where fluorspar deposits are associated with igneous systems, late-stage differentiated fluids released fractionated during crystallization and often enriched in in-

compatible elements (be it granitic or alkaline systems) play an important role.

In British Columbia, five significant fluorspar prospects are known. The Rock Candy orebody, a vein deposit of probable late Tertiary age associated with the Coryell intrusions, is in the southern Omineca Belt and has a history of past production. The Deep Purple prospect on Rock Canyon Creek, in the Foreland Belt, southern British Columbia, is a metasomatic replacement deposit interpreted to be related to a carbonatite-alkaline intrusive system. Mineralization at Deep Purple is probably Devonian-Mississippian to Early Mississippian in age. The Rexspar deposit, which is located along the western margin of the Omineca Belt, south-central British Columbia, comprises separate zones of fluorspar and uranium mineralization of volcanogenic origin, related to alkaline tuffs. Mineralization at Rexspar is considered to be syngenetic with the host rocks which are Devonian-Mississippian in age. The Eaglet fluorspar prospect consists of veins and replacements of Cretaceous age in the Quesnel Lake gneiss, at the western margin of the Omineca Belt in central British Columbia. The Foreland Belt of northern British Columbia contains the carbonate-hosted Liard fluorspar deposits which are apparently related to carbonate-hosted lead-zinc deposits further to the south and formed by dewatering of the sedimentary basin in the Late Devonian.

Numerous other showings occur throughout the province, but the major deposits are confined to the Omineca and Foreland belts, which suggests that these areas are most favourable for future exploration. Some deposits with abundant fluorspar are reported from the Atlin area in the Intermontane Belt; this area also warrants exploration attention. Of the known fluorspar deposits, the Rexspar property appears to have the best immediate potential. It is well located, close to the necessary infrastructure, has well-developed access and significant proven reserves of minable grades near surface. There are, however, environmental concerns due to proximity to known uranium mineralization.

In 1986, the United States imported 389 000 tonnes of fluorspar and 103 000 tonnes of hydrofluoric acid. About one half of these imports came from South Africa. Trade restrictions with South Africa may provide an opportunity for Canadian producers of low-phosphorous and low-arsenic fluorspar to penetrate the American market. Under the Free Trade agreement, the tariff on Canadian fluorspar imports to the United States will be removed in 1989 (Michel Prud'homme, personal communication to Z.D. Hora, 1988) which also will encourage new producers.

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