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METALLOGENY OF THE SLOCAN CITY MINING CAMP (82F11/14)

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INTRODUCTION

The Slocan area has had a long and illustrious mining history which has fluctuated from periods of intense exploration to inactivity (Figure 1). Prospecting in the West Kootenays dates back to the 1820's when the Bluebell deposit near Riondel on Kootenay Lake was discovered. Active exploration began around 1865. In 1883 Thomas Hammil located the Lulu and Spring claims at Ainsworth and Jim Brennan, a prospector working west of Ainsworth in the late 1880's, collected some high grade silver samples which attracted considerable attention to this new and virtually unexplored area. After initial interest at Sandon, prospectors extended their range of exploration to the south and west, discovering several deposits containing appreciable gold on Memphis Creek and locating the Dayton claim near Slocan City in 1893.

During this period, sustained mining throughout the Slocan area provided the incentive for the Canadian Pacific Railway to extend their line south and east from Nakusp to Kaslo and Cody in 1895, and connect Slocan City with the Nelson line in 1897. Slocan soon became one of the most productive mining camp in the province. The ore was shipped to smelters at Trail and Nelson from numerous local concentrating mills. Peak production in the Slocan was attained in 1918.

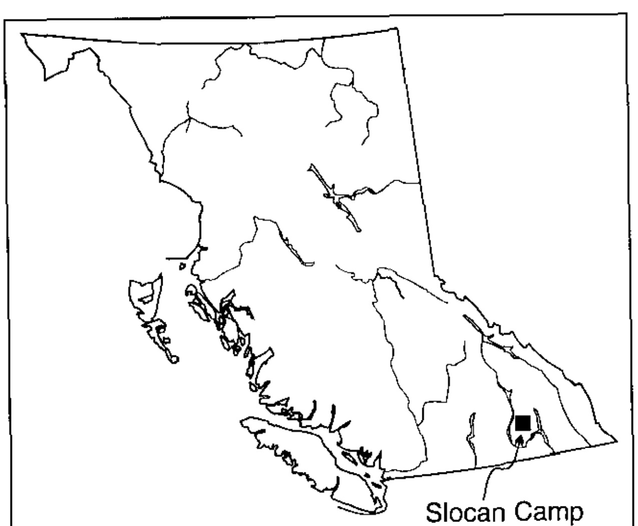

Figure 1. Location map, Slocan City mining camp.

GEOLOGICAL SETTING

The geology of the Slocan area (82FNW) comprises diverse lithological elements belonging to several tectonic terranes (Figure 2). On a regional scale, the Slocan Mining Camp is within the Kootenay Arc which lies between the Precambrian Purcell anticlinorium on the east and the Monashee and Valhalla metamorphic complexes to the west and northwest (Reesor, 1965).

The Kootenay arc is a 400 km long curving belt of early Paleozoic to Mesozoic sedimentary, volcanic and crystalline metamorphic rocks trending northeast for 160 kilometres across Washington state into British Columbia, then north along Kootenay Lake and northwest into the Revelstoke area.

In the Kootenay Lake area, the arc succession comprises the Hamill, Lardeau, Milford, Kaslo, Slocan and Rossland groups. The Hamill and Lardeau constitute the early Paleozoic pericratonic Kootenay terrane; the Milford and Kaslo belong to the accreted late Paleozoic Slide Mountain terrane. The Hamill is mostly quartzite; the Lardeau has a lower calcareous section overlain by a thick succession of schists and quartzites with lenticular masses of volcanic rock. The Milford and Kaslo groups are late Paleozoic oceanic assemblages that include phyllites, thinly bedded calc-silicate metasedimentary rocks, chert beds, basic volcanic rocks and serpentinites (Fyles, 1967).

The Mesozoic formations constitute the Quesnel terrane that lies along the western side and within the curvature of the Kootenay arc. The Rossland volcanics (Hoy and Dunne, 1997) and the Slocan argillite, slate and limestones are important units in this terrane and contain significant mineral deposits such as found in the Slocan silver-lead-zinc camp.

Granitic plutons including several small batholiths, many stocks and sill-like masses, interrupt the continuity of the older deformed stratigraphic succession throughout the Kootenay Arc. These include the Nelson batholith and many smaller stocks and sill-like masses. They are predominantly granite and granodiorite although the compositions range widely. The Nelson plutonic rocks are generally considered to be Upper Jurassic or Lower Cretaceous (Sevigny and Parrish, 1993).

The Nelson batholith and many of the granitic stocks have local zones of intense deformation around their margins. On the north and western edge of the Nelson batholith older strata are buckled downward within 1 kilometre or so of exposed granitic rock. Regional structures are deflected into near parallelism with the margins of the intrusion. It may be that the warps preceeded and controlled the emplacement of the granitic masses or, possibly, forceful intrusion deformed the wallrocks accompanied, or followed by, marginal zones of faulting.

Small Tertiary intrusions are common in the southern part of the arc and west of it. These include stocks of fresh granite and augite-biotite syenite and monzonite.

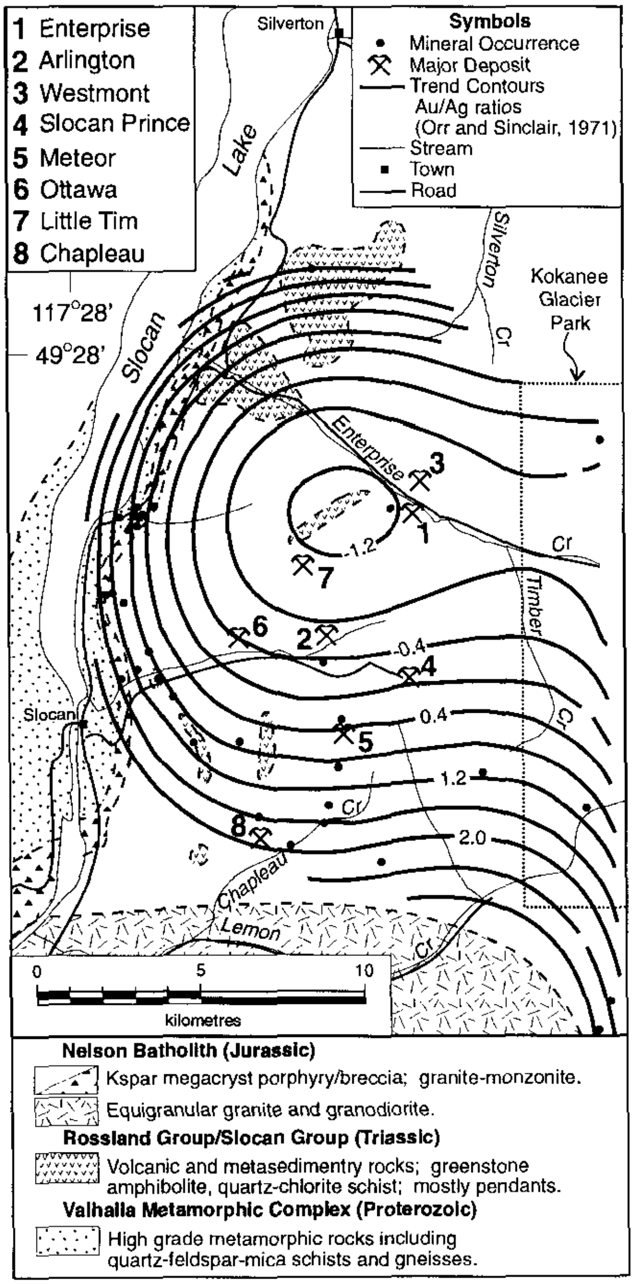

Figure 2. Geology of the Slocan City area (after Cairnes, 1934; little, 1960): contours are 3rd order polynomial fit of Au/Ag ratios (Orr and Sinclair, 1971).

All the rocks are cut by lamporphyre dikes which follow fractures, faults or prominent foliation planes and range from small discontinuous masses to bodies a few tens of metres wide and a few thousand metres long. They are dark greensih grey or brownish rocks commonly with subhedral phenocrysts of biotite, feldspar, hornblende or augite. These dikes are undeformed and mainly Tertiary age (Beaudoin, 1991).

Nelson Plutonic Rocks

The Nelson batholith underlies much of the western part of the Kootenay district where it is a complex of intrusives rocks differing in structure, texture and composition. It was first examined by Dawson (1890), and named the "Nelson granite" by McConnell and Brock (1904). The batholith is the principal rock type within the Slocan City camp and in this area it is subdivided into three phases (Cairnes, 1934) - granitic porphyry, crushed porphyry, and massive equigranular granite and granodiorite (Figure 2).

The granitic porphyry is the predominant phase and hosts most of the ore deposits (Photo 1). It is characteristically coarse-grained and distinguished by rectanglular phenocrysts (megacrysts) of K-spar, commonly several centimetres long and comprising up to 50 per cent of the rock. The K-spar megacrysts are simple or Carlsbad twins of perthitic orthoclase replaced locally by microcline. Exposed surfaces of the rock are light grey with a flesh-colour hue due to weathering of the K-spar. The megacrysts are set in a coarse grained groundmass comprising subhedral plagioclase (An_{30-50}), anhedral quartz, irregular clots of amphibole and biotite, interstitial microcline, and minor amounts of apatite, sphene, magnetite and sulphides. Thin sections and chemical analyses indicate that the rock is a silica-poor granite verging to monzonite composition, having roughly equal amounts of alkali feldspar and plagioclase and an alkali/lime index greater than 1 (Table 1). The granite facies, such as found at the Meteor, Arlington and Enterprise mines, is light coloured (colour index 5-8 per cent), compared to the monzonite facies at the Little Tim, Ottawa and Westmont mines, where the rock typically has less than 20 per cent quartz and a colour index of 9-15 per cent. Pegmatitic facies are confined to small, irregular masses in the porphyritic granite, fragments of which are seen in outcrops, the rock dumps and core samples from the Ottawa, Arlington and Chapleau mines.

The crushed porphyry forms a 100-300 metre wide band adjacent to the Slocan Lake fault along the west margin of the Nelson batholith. It is the same composition as the normal granite/monzonite porphyry and is believed to be the result of deformation caused by orogenic forces such as the intrusion of the Nelson batholith (Columbian) or detachment faulting (Laramide) associated with the development of the Valhalla metamorphic complex west of the batholith (Carr et al., 1987). The rock is commonly rust coloured as a result of alteration of ferromagnesian constituents by hydrothermal solutions moving along numerous fractures and shear planes (Parrish, 1984).

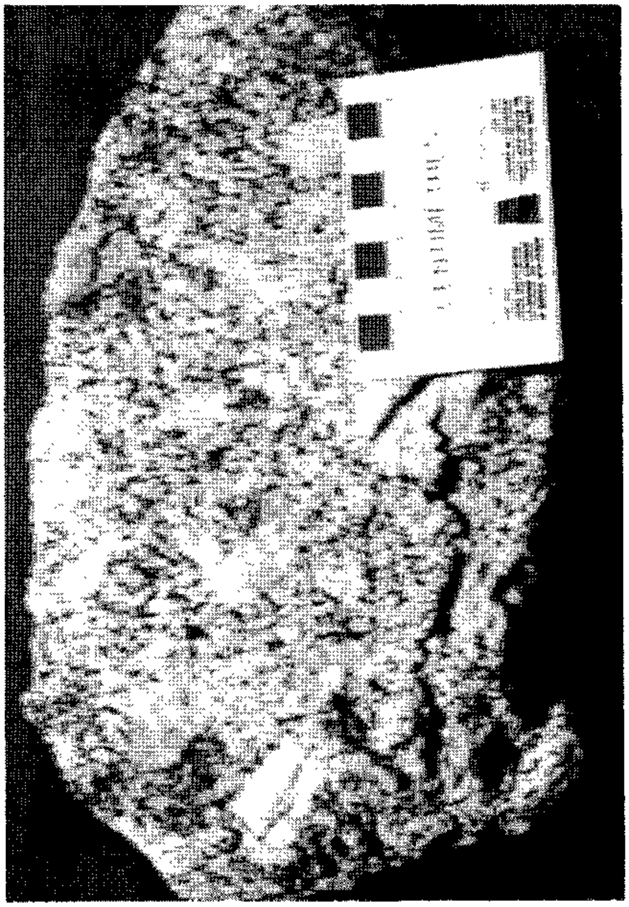

Photo 1. Nelson granitic porphyry.

Non-porphyritic facies of the Nelson batholith occur as dark coloured diorite and amphibolitic border facies and as xenoliths within the porphyry facies. Also, a large equigranular granite - granodiorite body underlies Lemon Creek and the area to the south. The dark coloured facies, containing as much as 50 per cent amphibole, may represent wholly or partially digested walls (Slocan or Rossland rocks?) of the batholith. The Lemon Creek granitic rocks may be slightly older or younger than the Nelson porphyry.

Structural Geology

The Slocan Lake fault is a 100 kilometre long, linear detachment structure exposed above the east shore of Slocan Lake (Figure 2). It dips moderately to the east and juxtaposes a ductilely deformed 'lower plate' of retrograded gneissic rocks of the Valhalla complex with an 'upper plate' of brecciated, fractured and hydrothermally altered granitic rocks of the Nelson batholith (Parrish, 1984). The lack of penetrative fabric distinguishes plutonic rocks of the Nelson batholith from the gneisses of the lower plate. Fabrics in the shear zone associated with the fault indicate easterly down dip displacement of the upper plate. Geochronological data suggest that some ductile strain exhibited in the gneisses and faulting is early Tertiary age and superimposed on considerably older deformation structures possibly related to the original emplacement of the Nelson batholith.

The fracture frequency pattern displayed by the Nelson batholith in the Slocan City area has three principal directions based on 318 measurements. These are (1) 030°/70°SE; (2) 105°/80°S and (3) 160°/85°SW (Figure 3). Fracture sets (1) and (2) are cross joints, steeply inclined to the gently dipping Slocan Lake fault and footwall gneiss complex. The northeast-striking fracture set (1) is the main direction, similar in strike and dip to the veins at the Enterprise, Arlington and Little Tim mines (Table 2). Subsidiary fractures (2) trend easterly similar to the veins at the Meteor and Chapleau mines. Fracture set (3) coincides with a sinistral fault that cuts the main vein at the Enterprise mine. It may also be related to the listric movement associated with footwall complex as shown in Figure 4.

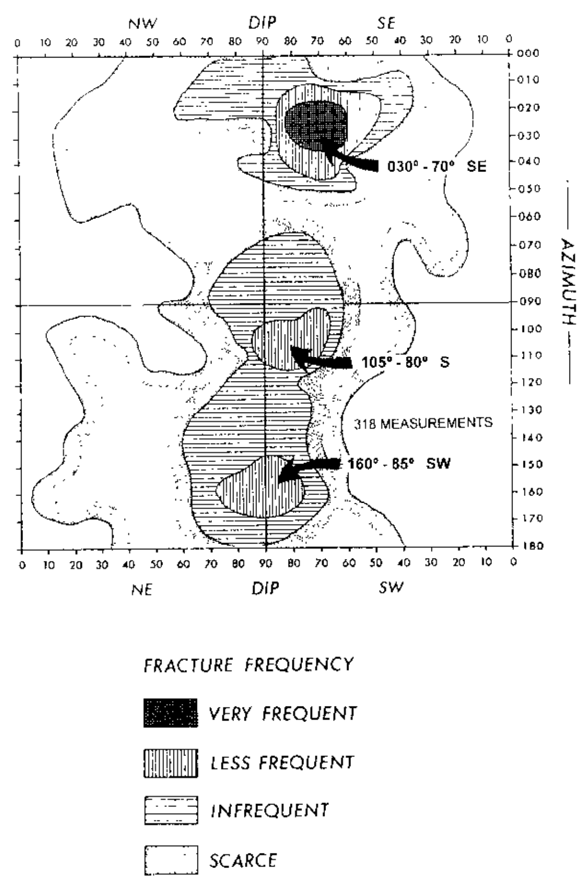

Figure 3. Fracture frequency plot.

Parrish (1984) and Carr (1985) have explained the mechanism of listric normal detachment faulting as related to the Valhalla metamorphic core complex and the overlying westerly lobe of the Nelson batholith. According to these authors, the uplift of the core complex in the early Tertiary resulted in detachment of the batholith along the lower contact of the intrusion to form the Slocan Lake fault, resulting in downward movement of the granite slab to the east. In this listric process, the gently east-dipping Slocan Lake fault was associated with the development of steeply dipping cross factures (normal faults) in the hanging wall due to the extension of the overlying granite slab. The combination of the Slocan Lake fault and the accompanying crushed zone (brecciation and shearing) and the cross factures, provided a channelway system for hydrothermal solutions.

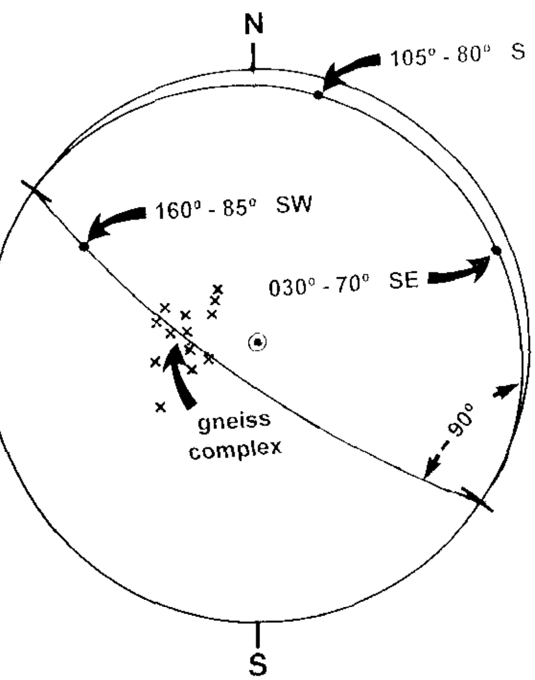

Figure 4. Stereographic projection of (lower hemisphere) of the main fracture directions related to the Nelson Batholith and adjacent gneiss complex.

It is assumed that shallow dipping contact of the Nelson batholith with the underlying Valhalla metamorphic rocks is the result of an outward and upward (ramping) movement of magma at the time of intrusion in the Jurassic. The crushed zone of granite that conforms more or less closely with the boundaries of the intrusion is probably due in part to deformation of the margins of the batholith before batholith was completely solid (Cairnes, 1934).

MINERAL DEPOSITS

The Slocan is one of the few areas in British Columbia where small scale mining remained viable for many years because of the richness of the ores. This camp and the surrounding area includes 125 documented mineral deposits of which more than half are mineral producers - 13 mines have produced more than 1 million grams of silver. The Enterprise, Arlington and Ottawa mines have each produced more than 30 million grams of silver plus significant amounts of lead and zinc.

Comprehensive descriptions of the mineral deposits of the region are by Cairnes (1934), Maconachie (1940), Little (1960) and Brown and Logan (1989). Specific details of the history and geology of the various properties are recorded in the numerous B.C. Minister of Mines reports and assessment reports covering the camp.

The following descriptions, arranged in order of production, are based on MINFILE reports and recent brief visits to the principal mines by the author. Where access to the old workings was limited, sampling of mine dumps proved successful and locations were checked by GPS equipment.

Enterprise (L. 1014; MINFILE 082FNW148)

The Enterprise mine is foremost in the quantity and total value of ore produced in the Slocan City mining camp. The property consists of the Enterprise, Slocan Queen, Rainbow, Iron Horse, Sunset, Millsite, Montezuma and Sunrise Crown granted claims and fractions. The mine is on the south side of the valley (elevation ~ 670 metres) near the confluence of Enterprise and Neepawa creeks, 11 kilometres northeast of Slocan (Photo 2). Access to the mine from the Slocan highway is via the Enterprise Creek road.

Photo 2. The headframe of No. 1 shaft, Enterprise mine.

The main vein was discovered in 1894 and mined by Enterprise (B.C.) Mines Co. Ltd. until 1901 and then by lessees. In 1928 the property was purchased by Yankee Girl Consolidated Mines Ltd. which was obliged to close operations in 1930. From 1941 to 1943 the property was leased, during which time the mine tailings and dump were re-worked. In 1944 Western Exploration Co. Ltd. purchased the property and operated it until 1953. Subsequently, until 1977, there has been intermittant production from a number of mining and salvage operations. Production from the property began in 1896 and 10,687 tonnes of ore were mined by 1977 yielding 32,676,718 g of silver, 1,674 tonnes of lead, 1,068 tonnes of zinc and ancillary gold, cadmium and copper.

The Enterprise lode has been developed by nine adits, several intermediate levels and two shafts. One shaft was sunk on the lode about 15 metres above and 90 metres southwest of the uppermost adit, and the other shaft from a point about 10 metres below and a short distance northeast of the lowest adit - the difference in elevation between the collar of the upper shaft and the bottom of the lower shaft being about 335 metres.

The rock underlying the property is a light coloured, coarse grained porphyritic granite of the Nelson batholith (Table 1, Number 2). More basic phases of the batholith, found locally in the mine workings, form irregular bodies of varying size that appear to be either digested inclusions or differentiates of the granitic magma. The Nelson rocks are intruded by a few small, hornblende porphyry and olivine-pyroxene lamprophyre dikes. Some of these dikes cut across the Enterprise lode whereas others are pre-mineral and disrupted by the same faults that cut the vein.

The main vein, averaging less than 0.3 metres wide, is continuous for more than 600 metres striking 050°, dipping 70° to 85° southeast (Table 2). On the upper levels of the mine the vein is filled with varying proportions of quartz and ore minerals, especially galena and tetrahedrite. On the lower levels, siderite and other carbonate gangue minerals are more abundant than quartz, and sphalerite is the predominant ore mineral. Most of the silver is believed to be contained in tetrahedrite and ruby silver (Photo 3).

The vein is interrupted by a major fault, or fault zone, and several minor faults and slips. The major fault intercepts the vein nearly at right angles about midway between the two shafts. The zone of faulting is 6 to 9 metres wide, strikes 160° and dips 90° to 75° northeast . The apparent displacement of the vein is about 30 metres to the left.

Aside from the extensive developments on the main Enterprise lode, some work has been done on a second lode outcropping 115 metres to the west. In 1927 it had been drifted on for about 45 metres. It is a wide shear zone composed mostly of crushed granitic rock partly cemented by quartz gangue with some calcite. It strikes 040° and dips 70° southeast. In character and width, this lode bears some resemblance to a vein developed at the Arlington mine which may be on part of a continuous structure. It seems that both lodes at the Enterprise mine and those on adjoining properties are within a single, wide zone of fissuring, shearing and brecciation, and that to the southwest this zone passes through the Arlington, Speculator and intervening properties.

Photo 3. Sulphides and quartz filling, Enterprise vein (solid circle = 1 cm.).

Arlington (L. 3648; MINFILE 082FNW152)

The Arlington property comprises the Arlington, Burlington No. 2 and Stephanite Crown granted claims and fractions situated on the north slope of the valley near the confluence of Speculator and Springer creeks, 8 kilometres east-northeast of Slocan. Access to the property from the Slocan highway is via the Spinger Creek road.

The Arlington mine was worked extensively from 1899 through 1903, then intermittently until 1971. In 1969 and 1970 Arlington Silver Mines Ltd. stoped and shipped ore, which was mainly salvaged from the old wokings, and what appears to be the northern extension of the vein system was explored by diamond drilling.

The mine was developed by eight adits over a vertical range of about 200 metres. In the early years the bulk of the ore was taken from the fifth to seventh levels and from the original discovery at surface near the shaft. In the latter years, underground work was confined to the lowest two levels.

The Arlington lode is a mineralized shear zone, about 20 metres wide, in coarse-grained hornblende granite of the Nelson batholith with basic monzonite inclusions

(Table 1, Numbers 3 and 13). The zone includes a number of parallel fissures and maintains a uniform strike of 040°, dipping 60° to 70° southeast (Table 2).

The ore is largely replacement of the country rock occurring as thin sulphide lenses on continuous fractures. The chief ore minerals are coarse to medium grained galena and sphalerite associated disseminated pyrite, chalcopyrite, stephanite, tetrahedrite and native silver (Photo 4).

Photo 4. Replacement sulphides in shear, Arlington mine (solid circle = 1 cm.).

Westmont (L. 8929; MINFILE 082FNW145)

The Westmont property, comprising the Westmont (L. 8929), Eastmont (L. 8924), Oddfellow, White Cloud, Lily G., Yankee Girl and Clipper Crown granted claims and fractions, is situated on the north slope of the valley of Enterprise Creek, 12.5 kilometres northeast of Slocan. Access to the property is from the Slocan highway via the main Enterprise Creek road. The 0.8 kilometres of old road between the main road and the mine was reopened in 1958 and a bridge was constructed over Westmont Creek.

Development work on the Westmont property began in the 1890s although production started in 1907 and continued until 1914. the property was worked continuously. Subsequent mining until 1971, mainly by lesses, was intermittent. The mine workings consist of at least four adits, located east of Westmont Creek, ranging in elevation from 150 to 400 metres above the main road along Enterprise Creek. In 1958, the No. 4 adit was retimbered from the entry to the intersection of the main vein, a distance of 60 metres. At this time caved ground was cleared west of the intersection, for about 300 metres, to provide sufficient access to the bottom of the old stope area to re-establish natural ventilation. East of the intersection, 30 metres of drifting was done on the main vein and about 400 tonnes of ore was removed from the stope above the drift. Production from the mine to 1980 totals 3,211 tonnes of ore that yielded 11,084,830 grams of silver plus 2,058 grams of gold, 199,781 kilograms lead and 65,920 kilograms of zinc.

Photo 5. Tetrahedrite-rich ore, Westmont mine (solid circle = 1 cm.).

The property is underlain chiefly by coarse grained, porphyritic Nelson monzonite (Table 1, Number 9). The granite is traversed by basic dikes along which some renewed faulting has occurred. Faulting follows two principal directions, one striking northeast and steeply dipping, the other striking northwest and dipping steeply northeast.

The main lode, as exposed in the lower No. 3 and No. 4 adits, is mostly a steeply dipping fault-fissure zone that strikes northeast, however, at about 120 metres from the portal of these two adits the lode swings to a more easterly strike and dips 70° north (Table 2). It varies up to 2.4 metres in width and averages 1.2 metres wide. The lode is composed of broken and crushed rock partly cemented by quartz which also forms veins and lenses 0.5 metres or more thick. The quartz is banded and also shows some comb structure. It carries disseminations, pockets and streaks of galena, sphalerite, pyrite, tetrahedrite, ruby silver, and native silver intimately associated with one another in varying proportions (Photo 5). The richest ore was found between No. 2 and No. 3 levels. In some places high silver is associated with galena but elsewhere combinations of tetrahedrite, sphalerite and native silver yield the best silver values.

Slocan Prince (L. 582); (MINFILE 082FNW140):

The Slocan Prince property, comprising the Slocan Prince (L. 582), Two Friends (L. 1020), Black Prince (L. 584), Bank of England (L. 2214) and Moonraker (L. 8939) Crown granted claims and fractions, is situated at the head of Crusader Creek, 10 kilometres east of Slocan. Access to the property from the Slocan highway is via the Lemon Creek and Crusader Creek roads.

This property was among the first staked in the Slocan City mining division and much work was done on it prior to 1900. The first production recorded was in 1896 from the Two Friends claim and this consisted of 36 tonnes of ore averaging 10,000 g/t silver and 50 per cent lead. The Slocan Prince and Black Prince had greater output, especially in the years 1901, 1905 and 1906 when ore shipments from these claims ranged to several hundred tonnes. Total ore production from the property up to 1970 amounts to 1,754 tonnes containing 7,045,304 grams of silver plus 128,781 kilograms of lead and 11,852 kilograms of zinc.

The property is underlain by coarse grained, porphyritic phases of the Nelson batholith. Granite and monzonite are the most common rocks but locally more basic phases of this intrusion are present (Table 1, Number 12). These granitic rocks are traversed by a few acid and basic dikes and many faults and shear zones, along which mineralization has occurred.

The workings comprise seven or more crosscut adits driven northerly to northwesterly and distributed from west to east across the claim group. The workings develop, principally, two fissure-vein systems referred to as the North and South lodes. The North lode outcrops on both the Bank of England and the Two Friends claims and has been traced for about 450 metres in an easterly direction almost parallel with the north and south boundaries of these claims. The north lode is intercepted by two adits on the Bank of England claim and, farther east, by two or three adits on the Two Friends claim. The lode strikes 060° to 070° and dips steeply northwest. In the Bank of England workings the mineralization is about 0.5 metre wide, nearly continuous for about a hundred metres, and consists of quartz with some calcite carrying galena, sphalerite and probably high-grade silver minerals. The lode intersects and slightly displaces a small basic dike. The Two Friends adits are situated about 135 metres to the east of the Bank of England workings by the west boundary of the claim. These adits are crosscuts to the North lode that is 1 to 3 metres wide containing a well defined galena-sphalerite rich ore body, varying in width from a narrow streak to 35 centimetres.

The South lode is exposed in the workings on the easterly claims of the group. A crosscut adit driven 130 metres on the Slocan Prince claim intercepts this lode which strikes 020° to 030° and dips 60° northwest. The lode, which is about 6 metres wide, has been drifted on for more than 120 metres. The ore occurs on both walls but mainly along the footwall. A second adit on Black Prince ground is a crosscut for 39 metres, beyond which it follows the lode for about 120 metres. The lode is a strongly crushed zone as much as 10 metres wide. Abundant quartz partly cements and replaces the crushed rock and forms veins in places. Ore minerals occur both as disseminations and concentrations included in and associated with quartz, some siderite, and a little calcite. They comprise argentiferous galena, sphalerite, tetrahedrite, pyrite, some native silver and possibly other silver-rich minerals. No appreciable gold occurs in the ore.

Meteor (L. 2893; MINFILE 082FNW137)

The Meteor property, comprising the Meteor, Ottawa and Cultus claims and fractions, is situated at the head of Tobin Creek on the northwesterly slope of the divide between Lemon and Springer creeks, 8 kilometres east of Slocan. Access to the property from the Slocan highway is via the Lemon Creek and Chapleau Creek roads.

The Meteor Crown granted claim was staked in 1895. The initial production of ore, amounting to about 70 tonnes, was shipped in 1897 yielding 1182 grams of gold and 466,500 grams of silver. Since this time mining continued intermittently, until 1967, achieving greatest production of 1,715 tonnes of ore in 1964. Total production from the Meteor mine is 2,659 tonnes of ore yielding 4,724,994 grams of silver, 13,177 grams of gold and a small amount of lead and zinc.

The rocks underlying the property are a light coloured, coarse-grained granite porphyry phase of the Nelson batholith (Table 1, Number 1). The granite is sheared and altered near the mine workings and intruded by felsic and basic dikes. Faults, shears and joints are oriented north and north-northeast with moderate to steep dips.

The workings of the Meteor mine consist of six adits that intersect a 5-50 centimetre wide vein that strikes 105° and dips 35° north. Vein mineralization is associated with the sheared upper contact of a 3 metre wide dike and narrow off-shoot fissures.

The vein is largely quartz carrying some sphalerite, galena, tetrahedrite, stephanite, argentite and native silver (Photo 6). Pyrite and chalcopyrite are also present and associated with significant gold values. The dike, containing up to 2 per cent disseminated pyrite, is pervasively sericitized in vicinity of the vein. Both the vein and dike are dislocated by faulting that shows dip slip downward movement to the south.

Scheelite was discovered on the Nos. 2 and 4 levels as small solitary lens-shaped bodies on the Meteor vein and on No. 6 level as disseminated grains in the granitic host rocks on a well developed fracture system striking 105°

dipping 35° northerly and 140°, dipping 80° northeast (Table 2). Also, molybdenite was discovered in a fragment of quartz stockwork hosted by sericitized granite from the Meteor mine dump.

Photo 6. Sulphides in banded quartz, Meteor mine (solid circle = 1 cm.).

Ottawa (L. 4968); (MINFILE 082FNW155):

The Ottawa mine is centred on a group of about 20 Crown granted claims and fractions on the north slope of the valley of Springer Creek (elev. ~ 1500 metres), 5 kilometres northeast of Slocan. Access to the mine site is from the Slocan highway via the Springer Creek road.

The history of the Ottawa mine dates back to 1896 when the Ottawa claim (L. 4968) was located, however, it was not until 1902 that major development work was attempted. The production of high grade silver-lead ore followed in 1903 and continued steadily through 1909. In 1913 the mine was purchased by Consolidated Mining and Smelting Co. Ltd. and in 1920 a 50-ton per day mill was constructed. In 1935 the property was obtained by the Ottawa Silver Mining and Milling Co. Ltd. who, in 1937, built a 100-ton per day floation plant. Much of the work after 1938 was done under lease or option. In 1950 and 1951, options were held by Violamac Mines (B.C.) Ltd. and subsequently by Harrison Drilling and Exploration Co. Ltd. Total recorded production between 1903 and 1984 amounts to 22,438 tonnes mined yielding 55,940,682 grams of silver plus significant amounts of gold, lead and zinc.

The property is developed on nine levels, five of which are serviced by adits driven at vertical intervals of about 30 metres. These workings explore a broad shear/ breccia zone in coarse-grained, porphyritic, Nelson quartz monzonite (Table 1, Number 8) cut by felsic and lamprophyre dikes. The zone trends nearly north and dips easterly from 25° to 45° (Table 2). The zone comprises two rather well defined lodes known as the West or Noble and East or Ottawa veins, respectively. Mining at the surface and underground indicates that these lodes are not exactly parallel, but approach each other towards the south and may join. On the No.5 level the lodes are about 10 metres apart. Most of the work has been done on the East lode that is 0.6 to 6 metres wide, composed of crushed and broken granite, gouge and vein material - the latter having been stoped in places across a width of as much as 2.4 metres. The West lode is as much as 15 metres wide in places and it is reported to have produced some good ore in the uppermost workings. On No. 8 level, the stoped vein on the West lode, strikes 025° to 040° and dips 20° southeast. The vein is up to 0.3 metres wide and bounded by a sharply defined gouge-filled slip along the footwall and an irregular hanging wall. The East lode on the No. 8 level is strong and composed of about 1 metre of gouge and beccia cemented by quartz. It strikes 170° and dips 30° to 40° east.

The ore minerals consist mostly of mixture of galena, pyrite, sphalerite and a little chalcopyrite, native silver, argentite and tetrahedrite disseminations in quartz gangue. In some high grade ore, barite is reported to be predominant gangue mineral. Beryl (aquamarine) in fragments of pink pegmatitic host rock has been found on the Ottawa mine dump.

Little Tim (MINFILE 082FNW157)

The Little Tim mine is situated east of Ottawa Hill at the head of Little Tim Creek (elev. ~2070 metres), 8 kilometres northeast of Slocan. Access is from the Slocan highway via the Springer Creek logging road system on the Memphis Creek - Ottawa Hill branch leading to the Little Tim Creek mine road.

The Little Tim claim was staked in 1918 and worked intermittently until 1947 by the owner. Hardex Mines Ltd. held an option on the property from 1951 to 1953, during which time considerable drifting and diamond drilling was done. Several individuals have held leases since the early 1950's and all shipments from the property consist of hand sorted ore. Approximately 300 metres of drifts, crosscuts and raises were developed in the original mine and by 1981 a total of 339 metres of new drifts and crosscuts were added.

The property is underlain by coarse grained porphyritic quartz monzonite of the Nelson batholith (Table 1, Number 4). These rocks are traversed by two, nearly parallel fissure vein lodes, on which considerable work has been done. The lodes are 90 metres apart and strike 055° to 070° northeast, and dip 45° to 70° southeast (Table 2).

The mine, located just southwest and downslope from an unnamed summit, is comprised of a shaft and three adits on the northwest lode, and three adits and an intermediate level on the southeast lode - the shaft being the lowest working at an elevation of approximately 2040 metres. The shaft is reported to have followed a vein to a depth of about 15 metres. The vein, about 0.3 metres wide, consists of vuggy quartz containing disseminated, galena, sphalerite, pyrite and tetrahedrite. The same vein is heavily stoped to a point about 90 metres above the shaft. On the southeast lode, the main adit is 75 metres long and follows a fissure which is well developed at the face but not mineralized. The orebody on this level, about 8 metres long, was stoped through to an intermediate level 12 metres above, where the ore was exposed for a length of 15 metres and width ranging from 10 to 30 centimetres. This ore forms a streak of nearly solid galena, sphalerite, conspicuous tetrahedrite and a little chalcopyrite. The gangue is principally quartz but some calcite and barite are also present. Some of the quartz appears to be chalcedonic. The veins are commonly flanked by a chloritic alteration envelope up to 1.2 metres wide grading into the granite.

Chapleau (L. 4963); (MINFILE 082FNW130):

The Chapleau property comprises the Chapleau and Chapleau Consolidated fraction and several other Crown granted claims centred 6 kilometres southeast of Slocan City. The Chapleau mine may be reached by a short access road about 1.5 kilometres long connected to the main road at a point about 13 kilometres from the Slocan highway.

Chapleau was one of the first properties in Lemon Creek area to receive attention. In 1896 the initial shipment of ore yielded 435 grams of gold and 11788 grams of silver. Until 1900, development was rapid and an aerial tramway and stamp mill were erected. However, in 1904 the mine was closed as a result of decreasing value of the ore and difficulties were encountered because of faulting of the vein. Until 1941 ore was shipped intermittantly by lessees. In 1946 and 1947 the workings were rehabilitated and a new road was constructed to the property, but there were no shipments of ore.

The country rock is porphyritic Nelson quartz monzonite (Table 1, Number 5) bounded a short distance to the north and northwest by a large pendant and other inclusions of argillaceous quartzite. These rocks are cut by small dikes of fine grained granite, pegmatite, and aplite. The phenocrysts of orthoclase and microcline in the porphyritic granite are up to a centimetre long. Larger feldspar phenocysts, up to 7 centimetres in length, occur in the pegmatite dikes, elongated parallel to the walls. Some pegmatites contain small crystals of garnet and magnetite but no mica or ferromagnesian minerals.

The vein strikes 110° and dips 25° northeast (Table 2). Its width ranges from 7 centimetres to 1.2 metres. The gangue is quartz that in places forms drusy cavities. Pyrite is the most abundant metallic mineral followed by sphalerite and galena. Minor chalcopyrite, free gold and ruby silver (?) are also reported.

Style of Mineralization

As can be seen from the preceeding descriptions, silver-lead-zinc ores predominate in the Slocan City camp. The ore minerals are mainly galena and sphalerite. There is a small amount of pyrite, chalcopyrite, and pyrrhotite. Silver is the most important commodity occurring in argentiferous tetrahedrite, galena and less commonly as native silver and sporadically in argentite, polybasite, ruby silver, stephanite and electrum. Gold is present in small quantities and rarely seen as native gold or electrum. Quartz is the dominant gangue mineral, but carbonates such as siderite, calcite and/or dolomite are significant gangue components in some deposits. Fluorite and barite are less common. The deposits are characterized by open-space filling, with minor evidence of replacement. In a few deposits, where replacement of wall rock has been extensive, carbonate gangue is relatively abundant.

Cairnes (1934) recognized several types of veins, the most common of which are the so-called "wet ore" composed of massive galena-sphalerite with some siderite, quartz or calcite gangue, such as found at the Enterprise mine, and "dry ore" comprising veins of quartz with galena, sphalerite and tetrahedite, characterized by high silver values, (quartz greatly exceeded the abundance of sulphides), such as found at the Little Tim, Meteor and Ottawa mines. The "dry ores" are mostly confined to the Nelson intrusion.

Discussion

Combined field and laboratory evidence indicates that the Slocan City mineral deposits formed over a long period. The mineralizing process began at time of the intrusion of the Nelson batholith dated mid-Jurassic (Armstrong, 1988). This effected the adjacent country rocks such as on Mount Alywin, where the Willa gold-silver-copper deposit (dated 165 - 184 Ma) is hosted in skarnified Rossland Group rocks (Ray and Webster, 1997; Hoy and Dunne, 1997). The mineralizing events continued during cooling of the intrusion and resulted in the development of veins within the batholith.

The Ag-Pb-Zn vein and replacement deposits of the Slocan area have long been thought to be genetically related to the Nelson batholith (Cairnes, 1934; Little, 1960). More recent work by Orr and Sinclair (1971) using Au/Ag ratios from 43 mineral occurrences in the camp supports this interpretation. Relatively high silver values are in ores hosted by a K-spar porphyry lobe of the Nelson granite at the centre of the camp, and the highest relative gold values are associated with ores from the distal parts of the porphyry and outer boundaries of the camp between Mount Aylwin and Slocan City (Figure 2). This suggests that the hydrothermal plumbing system is geographically related to the granitic body.

LeCouteur (1973) also noted a concentric zonal pattern in his study of lead isotope ratios (Pb^{206}/Pb^{240}) from the Slocan region. He attributed this pattern to leaching of lead from country rocks by rising ore fluids. Apparently the original isotope composition of lead in the fluid was progressively changed en route to depositional sites, depending on the proportions of the original and leached components. The amount of leachable lead is related simply to the volume of the rock traversed, and thus to distance from the centre of the circulation system. Accordingly, the difference in metal values (Ag-Pb-Zn, Ag-Au, Au-Ag) in the Slocan City camp (Cairnes, 1934; Little, 1960) may be the result of different proportions of the elements being scavenged by a single wide-spread ore fluid. The model is not unique, however, and other models relating compositional changes to time or to decreasing availability of leachable lead have been proposed (Austin and Slawon, 1961; and Sinclair and Walcott, 1966.

Indeed, detailed lead isotope investigations indicate that the lead in the Kootenay arc ores went through several stages of redistribution beginning with the introduction of uranium and thorium in the upper crust 1,700 million years ago (Sinclair, 1964; LeCoutier, 1973; Bevier, 1987).

Beaudoin (1991) shows that some hydrothermal activity is coeval with the Paleocene-Eocene crustal extension in the region. At this time the Valhalla metamorphic core complex was rapidly uplifted along the Slocan Lake fault - (an east dipping 'transcrustal' listric normal fault zone). Accordingly, "Pb isotopic ratios from veins display regional zonations revealing fluid flow paths of a large, fossil hydrothermal system. Regional isotopic zonations are controlled by deep fracture zones, such as the Slocan Lake fault, which channelled lower crustal and mantle Pb, and mantle CO_2 to higher crustal levels where mixing occurred with upper crustal fluids which had leached local sulphur and upper crustal Pb."

Analyses of the Nelson granitic porphyry (Table 1) shows a range of relatively low lead (2 to 22 ppm), zinc (80 to 142 ppm) and only moderate levels of barium (0.06 to 0.16 per cent). These levels appear to preclude the Nelson intrusion as a source of these elements in the Slocan City camp. However, Sangster and Vaillencourt (1990) show that trace amounts of lead, zinc , barium and iron can be leached by meteoric waters from weathered and altered granitic rocks and redistributed to form ore bodies. Fractured and crushed granitic rocks in the Slocan Lake fault zone could provide a source. The continued passage of meteoric waters through the clastic granite could result in K-spar alteration to clay releasing lead and barium from the feldspar lattice, and zinc and iron from hornblende. These elements combine with sulphur to produce pyrite, galena, spalerite and barite. (Pb and Ba are ionically substituted for K in feldspar, and Zn with Fe^{+2} in hornblende). Silica, released by the same breakdown of feldspar, may precipitate as quartz gangue.

Figure 5 shows hypothetical cross-sections of the Slocan City camp during (A) intrusion of the Nelson batholith and (B) the development of the Slocan Lake fault zone. By this model, the west margin of the Nelson batholith was broken and crushed during the process of intrusion and again during listric-normal detachment faulting/facturing associated with crustal extension. Prolonged movement in the crushed contact zone of the batholith is believed to have sustained a channelway for hydrothermal solutions.

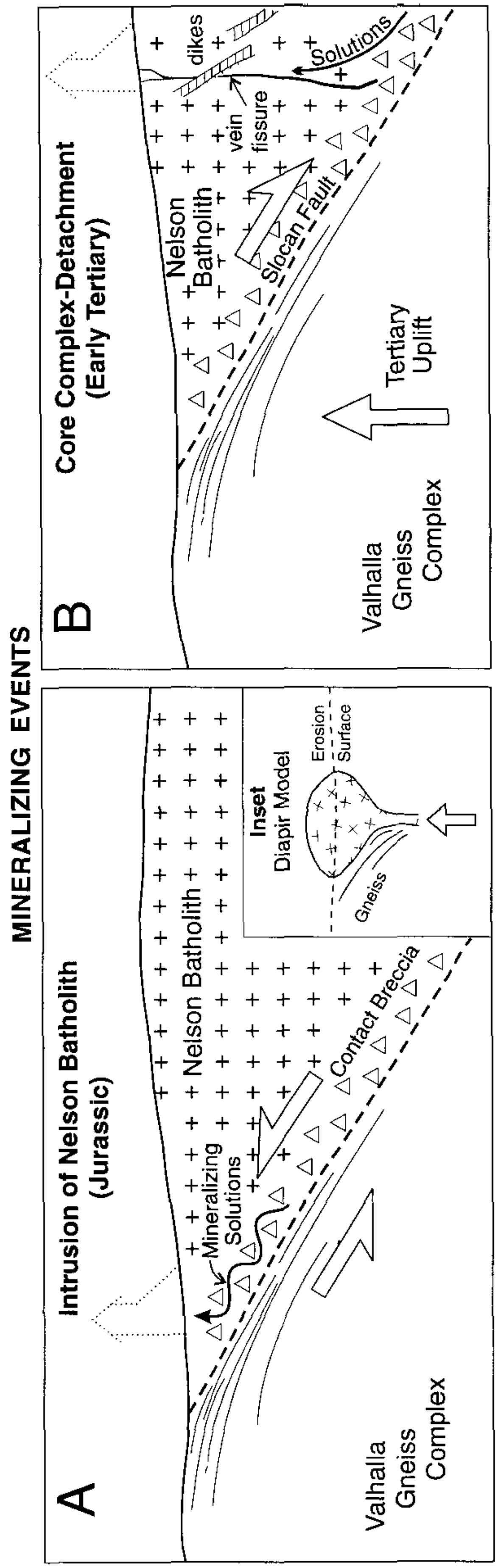

Figure 5. Hypothetical cross-sections of the Slocan City camp.

CONCLUSIONS

The silver-lead-zinc veins of the Slocan City camp are characterized by mineralogy, metal ratios and structural setting. The veins, consisting mostly of galena and sphalerite in a quartz-carbonate gangue, are hosted in the Nelson batholith. Early workers regarded these granitic rocks as the singular magmatic - hydrothermal source of lead-zinc mineralization, however, recent studies suggest a more complicated genesis. Lead isotope investigations indicate that the lead of the Kootenay arc ores went through several stages of redistribution beginning in the Proterozoic through Jurassic to early Tertiary.

The veins formed at about the time of the Nelson intrusion and subsequently. The veins are fillings and replacements in fractures that appear to be related to the Slocan Lake fault that occurs at the west boundary of the batholith. Prolonged movement on the Slocan Lake fault is believed to have sustained a channelway for hydrothermal solutions, which are the result of commingling of metamorphic and magmatic fluids and meteoric water. The main source of zinc and sulphur in the ores is believed to be the local country rocks (Nelson batholith) but, based on isotope data, a significant amount of lead in some deposits is derived from the lower crust and older rocks.

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Table 1 Chemical Analyses of Nelson Granitic Rocks

.	SiO2	TiO2	Al2O3	Fe2O3	MnO	MgO	CaO	Na2O	K2O	P2O5	Ba	LOI	SUM	Pb	Zn	Ag
Sample	%	%	%	%	%	%	%	%	%	%	%	%	%	ppm	ppm	ppm
1	68.4	0.31	15.11	2.59	0.05	0.68	2.68	3.64	4.46	0.11	0.11	1.27	99.38	16	80	<0.4
2	68.3	0.40	15.0	3.18	0.06	0.95	2.28	3.00	5.50	0.19	0.09	0.84	99.75	22	142	<0.4
3	67.4	0.43	14.74	3.68	0.06	1.07	3.25	3.66	3.54	0.18	0.08	1.25	99.29	6	86	<0.4
4	65.0	0.47	16.08	3.84	0.08	1.22	3.14	3.63	5.03	0.26	0.16	0.96	99.83	16	84	<0.4
5	63.6	0.61	16.54	4.86	0.06	1.37	3.92	3.54	3.75	0.23	0.12	0.81	99.41	12	108	<0.4
6	62.9	0.56	16.12	4.63	0.08	1.60	4.11	3.61	3.36	0.23	0.13	1.94	99.29	8	104	<0.4
7	63.5	0.55	16.23	4.64	0.10	1.57	4.09	3.75	3.66	0.27	0.13	1.16	99.68	12	108	<0.4
8	61.6	0.66	16.43	5.31	0.09	1.73	4.44	3.68	3.53	0.34	0.16	1.60	99.57	10	102	<0.4
9	62.1	0.61	16.4	5.15	0.10	1.69	4.09	3.59	3.77	0.32	0.15	1.35	99.32	10	118	<0.4
10	61.3	0.65	16.82	5.47	0.11	1.85	4.53	3.81	3.63	0.34	0.14	1.03	99.63	12	122	<0.4
11	62.0	0.65	16.67	5.56	0.09	1.79	4.36	3.99	3.70	0.32	0.14	0.61	99.87	16	104	<0.4
12	61.2	0.88	16.94	6.52	0.10	2.09	4.69	3.17	2.60	0.32	0.08	1.07	99.62	2	128	<0.4
13	57.0	0.88	17.45	7.68	0.13	2.72	5.69	4.57	2.20	0.44	0.06	0.91	99.75	6	142	<0.4

Table 2 Principal Vein Attitudes at Mines and Prospects

Occurrences (MINFILE No.)	Location Lat.	Location Long.	Vein Attitudes
Chapleau (130)	49° 44.0'	117° 23.5'	110°/25°NE
Kilo (131)	49° 44.0'	117° 22.7'	145°/35°NE
Hollinger (132)	49° 43.7'	117° 22.2'	180°/15°NE
Goldstream (134)	49° 44.4'	117° 22.2'	075°/20°NW
Tailholt (135)	49° 44.9'	117° 21.7'	135°/20°NE
Meteor (137)	49° 45.6'	117° 21.3'	105°/35°NE, 140°/80°NE
Elk (138)	49° 45.9'	117° 21.1'	115°/30°SW
Alice (139)	49°46.4'	117° 21.1'	095°/70°SW
Slocan Prince (140)	49° 46.7'	117° 19.8'	065°/60°NW
B&R (142)	49° 47.3'	117° 19.6'	065°/45°NW
Westmont (145)	49° 49.7'	117° 19.6'	045°/70°SE
Dalhousie (146)	49° 45.0'	117° 15.0'	070°/45°SE
Neepawa (147)	49° 49.3'	117° 19.9'	030°/65°SE
Enterprise (148)	49°49.3'	117° 19.5'	053°/70°SE, 040°/85°SE
Mabou (149)	49° 48.9'	117° 20.2'	055°/75°SE
Bondholder (150)	49° 48.7'	117° 21.4'	065°/58°SE
Speculator (151)	49° 48.0'	117° 21.2'	030°/65°SE
Arlington (152)	49° 47.4'	117° 21.7'	040°/58°SE, 034°/70°SE
Lily B (153)	49° 46.9	117° 21.4'	075°/55°SE, 105°/50°SW
Ottawa (155)	49° 47.1'	117° 23.7'	030°/20°SE, 170°/35°NE
Tamarak (156)	49° 47.3'	117° 24.5'	030°/25°SE
Little Tim (157)	48° 48.4'	117° 22.0'	055°/70°NE, 073°/45°SE
Molly (158)	49° 48.6'	117° 23.1'	050°/80°SE
Myrtle (159)	49° 48.6'	117° 24.7'	047°/38°SE
Coronation (162)	49° 49.2'	117° 25.4'	090°/65°N
Whitehope (165)	49°49.4'	117°26.6'	140°/50°SW
Lakeview (172)	49° 46.2'	117° 26.7	167°/80°NE
Smeralda (231)	49° 45.7'	117° 25.0'	024°/43°SE