NORTHERN SELKIRK PROJECT - GEOLOGY OF THE GOLDSTREAM RIVER MAP AREA (82M/9 AND PARTS OF 82M/10)

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KEYWORDS: Goldstream River, French Creek, Goldstream mine, Montgomery, C-1, volcanogenic massive sulphides, Besshi, Lardeau Group, Badshot Formation, Hamill Group, Horsethief Creek Group.

INTRODUCTION

The Goldstream River area, in the northern Selkirk Mountains, contains numerous volcanogenic massive sulphide (VMS) occurrences, including the producing Goldstream mine, in addition to vein and placer gold deposits. The regional stratigraphic and structural settings of these mineral occurrences is, however, problematic. Previous workers have variously assigned rocks of the Goldstream area to the Horsethief Creek, Hamill, or Lardeau groups. The main objectives of the Northern Selkirk project are to establish the stratigraphic and structural framework of known VMS deposits in the northern Selkirk Mountains, and to assess the potential for similar deposits in correlative successions elsewhere.

This report complements the reconnaissance study of Logan and Drobe (1994). It presents the results of regional mapping of a 1150 square kilometre area completed during the summer of 1994. A 1:50 000-scale bedrock map will be published as Open File 1995-2.

REGIONAL GEOLOGY

The Goldstream River area straddles the boundary between rocks assigned to the North American miogeocline and the pericratonic Kootenay Terrane (Wheeler *et al.*, 1991; Wheeler and McFeely, 1991). It lies along the western flank of the Selkirk fan structure (Wheeler, 1963; 1966; Brown and Tippett, 1978; Price *et al.*, 1979; Price, 1986; Brown and Lane, 1988), a zone of structural divergence that follows the Omineca Belt, and the suture zone between North America and Intermontane Superterrane, from northeastern Washington to east-central Alaska (Eisbacher *et al.*, 1974; Price, 1986). The area is bounded to the west by the Columbia River fault, a major extensional fault of Eocene age along the east flank of the Monashee Complex (Figure 1).

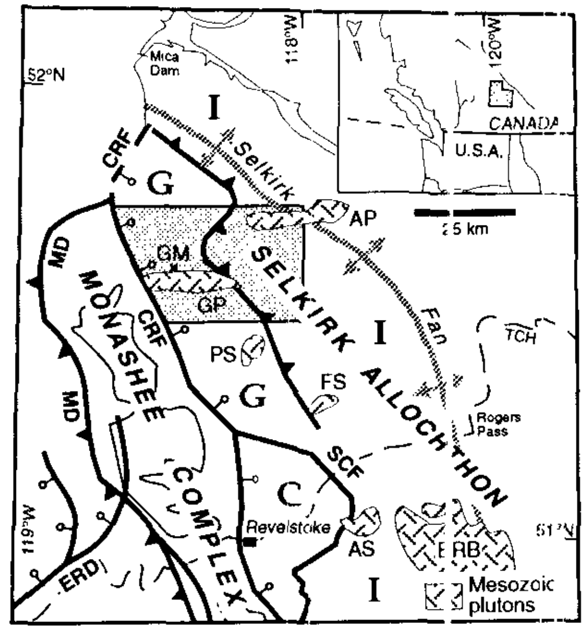


Figure 1: Location of the Goldstream River area along the western flank of the Selkirk fan structure, within the Selkirk allochthon; modified after Brown and Lane (1988). I = Illecillewaet slice, G = Goldstream slice, C = Clachnacudainn slice, CRF = Columbia River fault, DCF = Downie Creek fault, SCF = Standfast Creek fault, MD = Monashee décollement, ERD = Eagle River detachment BRB = Battle Range batholith, AS = Albert stock, FS = Fang stock, PS = Pass Creek stock, GP = Goldstream pluton, AP = Adamant pluton, GM = Goldstream mine, TCH = Trans-Canada Highway.

The northern Selkirk Mountains are underlain by a sequence of Neoproterozoic to lower Paleozoic metasedimentary and metavolcanic rocks that form part of the miogeoclinal wedge that accumulated along the western margin of ancestral North America. Wheeler (1963; 1965) has traced the stratigraphic successions defined by Walker (1926), Walker and Bancroft (1929), and Fyles and Eastwood (1962) in the Purcell anticlinorium and the Kootenay Arc, to the south, into the northern Selkirk Mountains. Wheeler assigned the various lithologic units of the northern Selkirk Mountains to the Neoproterozoic Horsethief Creek Group (Windermere Supergroup), the Eocambrian Hamill Group, the Lower Cambrian, *Archeocyathid*-bearing Badshot Formation, and the lower Paleozoic

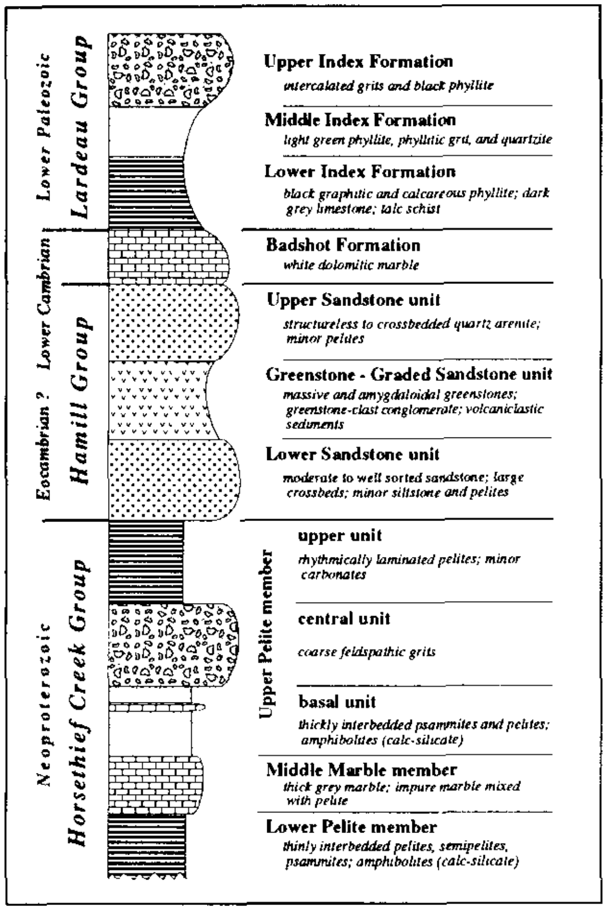


Figure 2: Schematic stratigraphic column for the northern Selkirk Mountains; compiled from data of Wheeler (1963), Brown *et al.* (1978), Devlin (1989), and Colpron and Price (1993). The lower pelite and middle marble members of the Horsethief Creek Group, and the upper sandstone unit of the Hamill Group are not exposed in the Goldstream River area.

Lardeau Group (Figure 2). To the north and east of Revelstoke, Wheeler also delineated an assemblage of higher grade gneissic and granitic rocks: the Clachnacudainn Complex (Figure 1). He suggested that rocks of the Clachnacudainn Complex form a salient of the Shuswap Metamorphic Complex into the northern Selkirk Mountains. Okulitch *et al.* (1975) and Parrish (1992) have shown that orthogneisses of the Clachnacudainn Complex are, in part, Devonian in age.

The northern Selkirk Mountains form part of a large allochthon that was displaced eastward some 200 to 300 kilometres along the Monashee décollement, between Late Jurassic and Paleocene time (Price, 1981; Brown *et al.*, 1986). As a result, the area is characterized by a complex pattern of superposed folding and faulting. The regional structural style is dominated by the northwest-trending Selkirk fan structure. The eastern flank of the fan structure is characterized by a northeast-verging imbricate thrust system which is part of the Rocky Mountain fold and thrust belt and is truncated by the Purcell thrust; a major northeast-verging out-of-sequence thrust fault (Simony and Wind, 1970). The western flank is dominated by southwest-verging fold-nappes and thrust faults (Wheeler, 1963; 1966; Raeside and Simony, 1983). Rocks along the western flank of the fan structure are generally metamorphosed to greenschist facies. Amphibolite facies rocks and migmatites occur along a west-northwest-trending metamorphic culmination that approximately follows the northwest trend of the Selkirk fan structure. It extends some 90 kilometres from near Mica dam to Rogers Pass (Figure 1).

The area has also been the locus of intermittent plutonism from Middle Jurassic to Late Cretaceous. Two main suites of granitic plutons intrude the western flank of the Selkirk fan (Gabrielse and Reesor, 1974; Armstrong, 1988): a Middle Jurassic (*ca.* 180-165 Ma) suite of granodiorite and quartz monzonite that generally cuts the regional structures, but is locally deformed by them; and a mid-Cretaceous (*ca.* 110-90 Ma) suite of quartz monzonite, diorite and two-mica granite that clearly truncates all regional structures. In addition, a less voluminous Late Cretaceous (*ca.* 70 Ma) suite of leucogranites has recently been recognized within the Clachnacudainn Complex (Parrish, 1992).

STRATIGRAPHY OF GOLDSTREAM RIVER AREA

The lithologic similarities between the Horsethief Creek, Hamill and Lardeau groups, and the intensity of deformation and metamorphism in the Goldstream River area, have complicated correlations with well established stratigraphic sequences to the south. In particular, the sequence of rocks exposed in the vicinity of the Goldstream mine have been interchangeably assigned to the Horsethief Creek, Hamill and Lardeau groups. Wheeler (1965) showed much of the area north of Goldstream River to be underlain by strata of the Horsethief Creek Group. He correlated rocks south of the river with the lower Paleozoic Lardeau Group. Brown *et al.* (1977), Lane (1977) and Höy (1979) correlated rocks of the Goldstream River area with the Horsethief Creek and Hamill groups. Brown *et al.* (1977; 1978) established a three-fold subdivision of the Horsethief Creek stratigraphy in the Goldstream area. More recently, Brown and Lane (1988) showed the western half of the area to be underlain by rocks of the lower Paleozoic Lardeau Group.

The results of our mapping show the Goldstream area to be underlain by four fault-bounded slices which comprise distinct stratigraphic assemblages (Figure 3). The structurally highest two slices underlie much of the map area. They roughly correspond with the Illecillewaet and Goldstream slices (Figure 1) defined by Brown and Lane (1988). In the Goldstream River area, the Illecillewaet slice is exclusively composed of rocks of the Horsethief Creek and Hamill groups. To the west, the Goldstream slice, which hosts the Goldstream orebody, is composed of strata correlative with the Badshot Formation and the Lardeau Group. The structurally lowest two slices are limited to the southwestern corner of the map area. They comprise higher grade metamorphic rocks which remain of uncertain correlation.

HORSETHIEF CREEK GROUP

The stratigraphy of the Horsethief Creek Group in the northern Selkirk Mountains has been subdivided into three members by Brown *et al.* (1977, 1978): the lower pelitic, middle marble, and upper pelitic members (Figure 2). Brown *et al.* (1978) further subdivided the upper pelitic member into three assemblages: a lower subdivision of thickly interbedded psammites and pelites; a central subdivision of coarse feldspathic grits with pelitic schist interbeds; and an upper subdivision of rhythmically laminated pelites (Figure 2). Brown *et al.* have suggested that the uppermost subdivision of the upper pelitic member grades westward into a sequence of calcareous pelitic schists with intercalations of marble, impure psammite and quartzite.

In the Goldstream area, the Horsethief Creek Group is predominantly exposed along two northwest-trending belts (Figure 3). The eastern belt includes exposures in the vicinity of Goldstream Mountain, between Goldstream River and the Adamant pluton. In this area, the Horsethief Creek Group can be subdivided into three mappable units, which we correlate with the three subdivisions of the upper pelitic member of Brown *et al.* (1978). The lower unit is composed of a sequence of intercalated fine-grained quartz grits, impure quartzites, garnet-biotite schist, and subordinate dolomitic marbles. Graded beds in this sequence are commonly displayed by an increase in the abundance and size of metamorphic index minerals toward the more pelitic layers. The schist layers commonly contain hornblende-rich horizons, attesting to the overall calcareous composition of this sequence. The upper part of the sequence is dominated by a package of light grey marble, dark grey argillaceous marble and limestone conglomerate. This marble sequence has a maximum thickness of about 200 metres and is overlain by more quartz grits and garnet-biotite schist.

The middle map unit of the Horsethief Creek Group consists of interbedded coarse-grained feldspathic grits and laminated phyllites. The grit beds range from 30 centimetres to 5 metres thick and are generally poorly sorted. Subangular quartz and feldspar clasts are up to 1 centimetre in size. Rip-up clasts are locally present near the base of grit beds. Phyllite interbeds are from a few centimetres to 1 to 2 metres thick and commonly display good graded beds of more silty material. This sequence grades upward into a distinct unit of light to medium grey, rhythmically laminated phyllites (upper map unit). Bedding is defined by graded siltstone and fine-grained sandstone layers. Crossbeds are locally present within the sandstone layers.

Coarse-grained amphibolites are found within the lower map unit of the Horsethief Creek Group north of Goldstream Mountain and near Hitchhike Peak (Figure 3). These amphibolites are generally concordant with layering in the grit - pelitic schist assemblage, although they locally exhibit crosscutting relationships indicating their intrusive origin. Similar amphibolites are also found within pelites of the upper map unit of the Horsethief Creek Group in upper Norman Wood Creek.

South of Goldstream River, phyllites of the upper map unit grade into an assemblage of light green phyllites, calcareous and micaceous quartzites, and white, buff and grey limestones. Coarse-grained calcareous grits and green calcareous phyllites mark the transition between the rhythmically laminated phyllite unit and this calcareous assemblage. Quartzites are progressively more mature (compositionally) toward the top of the section.

The western belt of the Horsethief Creek Group is best exposed in the alpine country between Norman Wood and French creeks, and between Goldstream River and Sorcerer Creek (Figure 3). Here, the Horsethief Creek Group consists dominantly of dark grey, green and tan calcareous phyllite and schist, intercalated with variable amounts of micaceous quartzite and grit. Light and dark grey marble horizons are present throughout the section, with the most prominent occurring near the top of the section. This marble horizon is easily identified by the presence of three beds of more resistant light grey marble within a more recessive micaceous marble. It has been traced from the headwaters of French Creek to the confluence of Sorcerer and Downie creeks (Figure 3)

Volcanogenic rocks are found locally within the western belt of Horsethief Creek Group. The most prominent exposure of volcanic rocks is along alpine ridges east of Downie Peak. Here, the rock consists primarily of a massive, dark green chlorite schist with variable amounts of epidote. Minor amounts of greenstone-clast conglomerate and light green siliceous phyllite are also associated with greenstone outcrops.

Brown *et al.* (1977) have correlated marble exposures along the flanks of Stitt Creek, and those east of French Creek, with the middle marble member of the Horsethief Creek Group. Our mapping in the Stitt Creek area shows that the marble sequence is bounded by quartzitic rocks on both sides. This association contrasts with the dominantly pelitic facies described by Brown *et al.* (1978) below the middle marble member. We suggest, therefore, that the marble sequence exposed

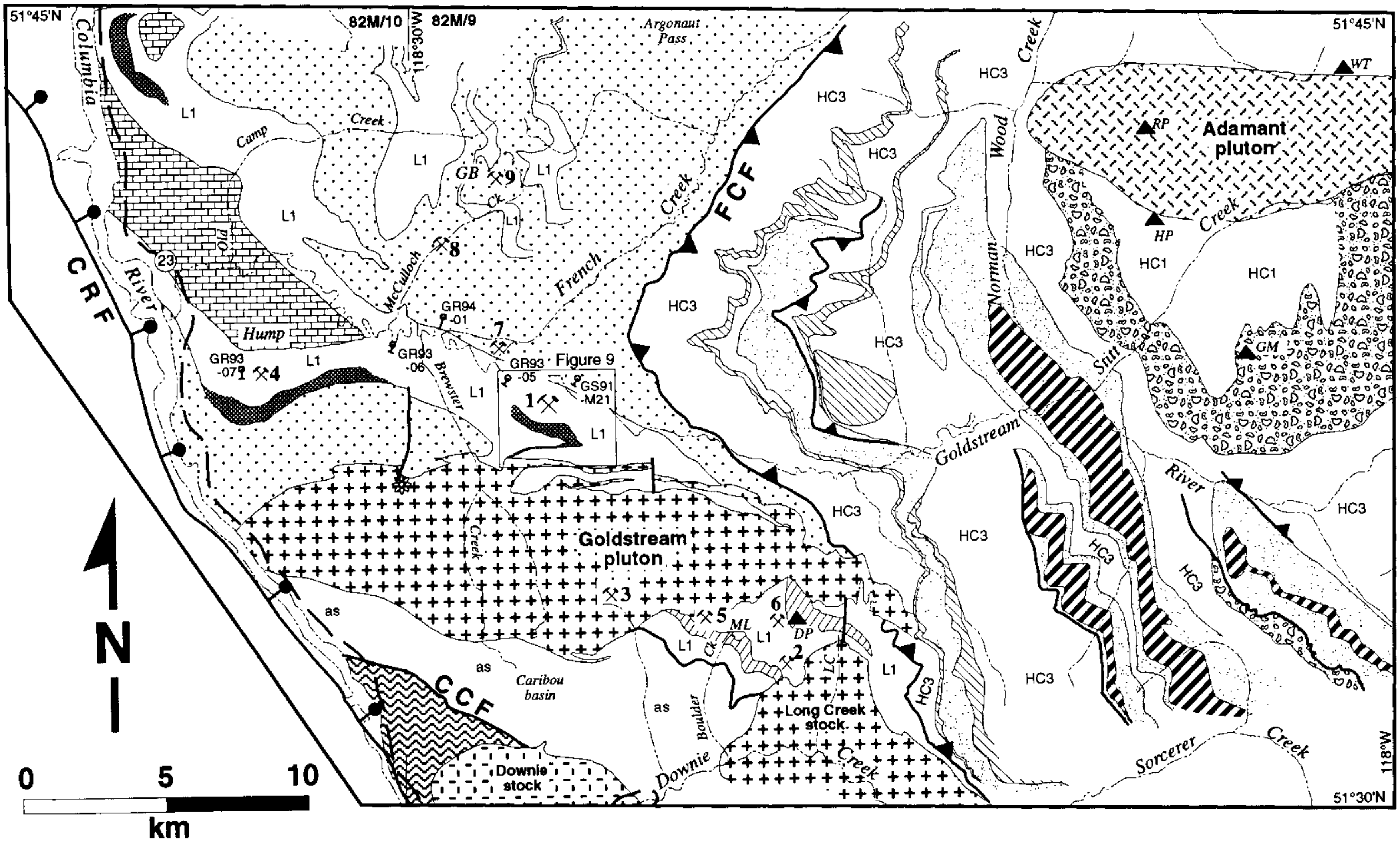
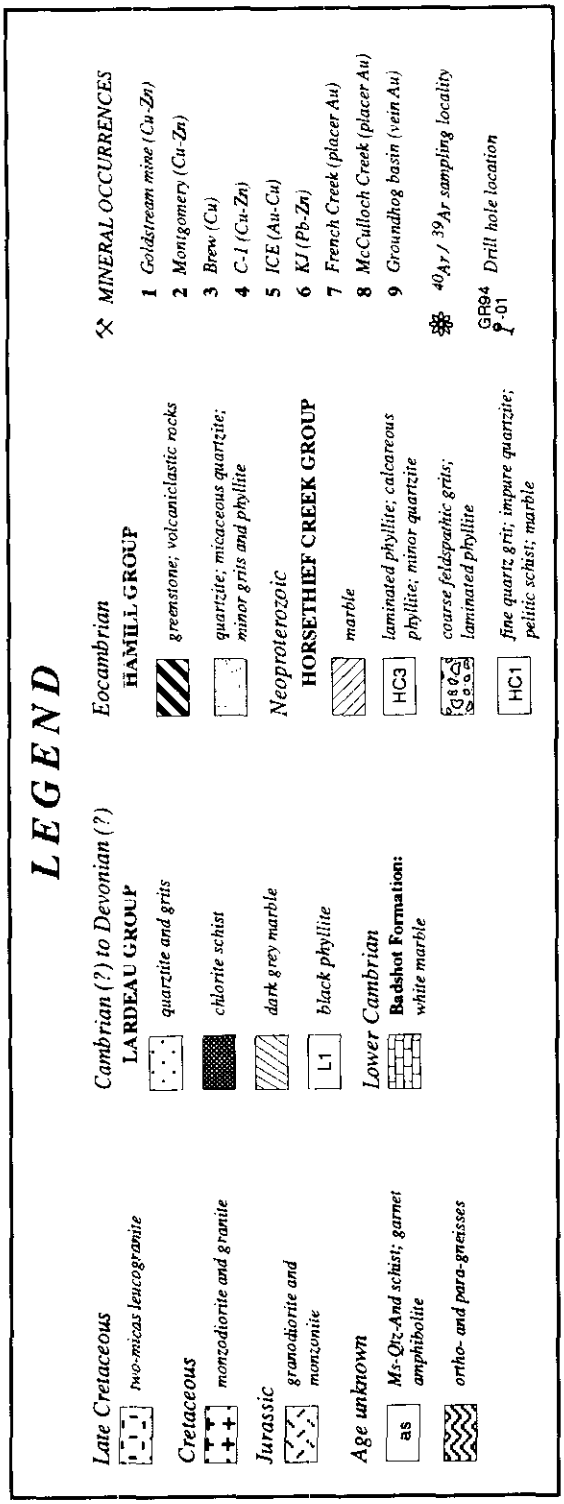


Figure 3: Geological map of the Goldstream River area compiled from our 1994 mapping and from Gibson (1982; 1989). DP = Downie Peak, ML = Montgomery Lake, LC = Long Creek, GM = Goldstream Mountain, HP = Hitchhiker Peak, RP = Remillard Peak, WT = Waldorf Towers, GB = Groundhog basin, CRF = Columbia River fault, FCF = French Creek fault, CCF = Caribou Creek fault.



along Stitt Creek corresponds to the carbonate facies described by Brown *et al.* near the top of the lower subdivision of the upper pelite member (Figure 2). Similarly, marble exposures east of French Creek occupy a higher stratigraphic level (near the contact with the Hamill Group) than the middle marble member of the Horsethief Creek Group. The main implication of these stratigraphic revisions is that only rocks of the upper pelitic member of the Horsethief Creek Group are exposed in the Goldstream River area.

HAMILL GROUP

Devlin (1989) recognizes three stratigraphic divisions within the Hamill Group in the northern Selkirk Mountains (Figure 2): a lower sandstone unit; a greenstone and graded sandstone unit; and an upper sandstone unit. Only the lower two divisions were mapped in the Goldstream River area. Rocks of the Hamill Group are exposed in the core of four southwest-verging synclines in the eastern half of the map area (Figure 3).

The basal Hamill Group corresponds to medium to coarse-grained quartzite and quartz grit, intercalated with minor grey phyllite. Quartz grains are generally well rounded and well sorted, and graded quartz grits are commonly present at the base of quartzite beds. The grits are composed almost exclusively of subangular quartz granules and pebbles (only rare feldspar clasts) in a matrix of well sorted medium sandstone. Trough crossbedding (0.3-0.5 m) is common in the basal quartzites.

The remainder of the lower sandstone unit corresponds to light grey, light green, or dark grey, fine-grained micaceous quartzites intercalated with green and/or grey phyllites. Metre-thick, clean quartzite beds are locally present within the micaceous quartzite assemblage.

The Goldstream River area comprises the largest volume of volcanic rocks within the Hamill Group. The volcanic sequence is composed, in approximately equal proportions, of massive and amygdaloidal greenstones, and volcaniclastic rocks. The greenstone is characterized by the presence of chlorite (or biotite) aggregates which are aligned along the dominant foliation. These chlorite aggregates are probably indicative of the original porphyritic texture of the basaltic flows.

Volcanic conglomerate, chloritic and feldspathic grits, mature quartzite, and lapilli tuff horizons are intercalated with the greenstone on a scale of a few metres to several decametres. The conglomerate comprises clasts of felsic volcanic rock, amygdaloidal and massive basalt, dolostone, quartzite and feldspathic grit. The clasts are subrounded to rounded (although flattened along the dominant foliation), 3 to 30 centimetres long, poorly sorted, and supported by a matrix of fine-grained chlorite schist. The grit horizons are medium to coarse grained, and are commonly graded and crossbedded. Tuffaceous rocks constitute the largest volume of material in the volcaniclastic sequence. They are differentiated from the greenstone by the widespread presence of muscovite in the matrix. Volcaniclastic horizons are locally well graded.

Felsic volcanic rocks are present at a few localities in the Goldstream River area. They occur in layers 2 to 3 metres thick which are conformable with layering in the enclosing mafic volcanic and volcaniclastic rocks. At one locality, south of Goldstream River, the felsic rocks are discordant with the underlying mafic volcanic rocks. This felsic dike may be a feeder to the overlying concordant felsic volcanics. The similarity of composition of the felsic flows (or sills) and the felsic clasts found within the volcanic conglomerate indicate that felsic and basaltic volcanism coeval.

CONTACT RELATIONS BETWEEN HORSETHIEF CREEK AND HAMILL GROUPS

The contact between the Horsethief Creek and Hamill Groups is traditionally considered to be a regional unconformity (Devlin and Bond, 1988; Devlin, 1989). Other workers have suggested that the Horsethief Creek and Hamill Groups are conformable with each other (Reesor, 1973; Warren and Price, 1993). In the Goldstream River area, (Figure 3) this contact is commonly sheared, and different levels of Horsethief Creek stratigraphy are juxtaposed against quartzites of the Hamill Group along the faulted contacts (Lane, 1977; Brown *et al.*, 1978; Devlin, 1989). In other places, the contact appears to be gradational. This gradation is marked by increasingly more mature quartzites in the upper Horsethief Creek and the presence of rhythmically laminated phyllite in the basal Hamill Group.

BADSHOT FORMATION

Massive white and grey marble, and buff dolostone exposed in the core of the Goldstream anticline, west of the Goldstream mine, are similiar to and possibly correlative with the late Lower Cambrian, *Archaeocyathid*-bearing Badshot Formation to the south (Wheeler, 1963; Read and Brown, 1979). The carbonate crops out along Highway 23 from the northern margin of the map, south to the Goldstream River. White and buff-weathering dolomite cliffs rise from the middle of the Goldstream valley at its western end and form a topographic culmination locally known as the "hump" (Figure 3). Along the highway, outcrops are brilliant white, massive and variably cut by two conjugate joint sets. Chemical analysis shows the carbonate to be a relatively pure dolomitic marble (Hurlburt *et al.*, 1988).

The unfossiliferous nature of all the limestones in the area make distinction between them difficult and correlations tenuous. Early workers mapped much of the carbonate in the Goldstream River and Downie Creek map areas as Badshot Formation, including the carbonate forming Downie Peak (*e.g.*, Wheeler, 1965). Stratigraphy and facing directions suggest that this carbonate is part of the Index Formation (Logan and Drobe, 1994).

LARDEAU GROUP

The Lardeau Group, as defined by Fyles and Eastwood (1962) in the Ferguson area, includes six formations. In ascending stratigraphic order these are: dark grey and green phyllite of the Index Formation; black siliceous argillite of the Triune Formation; grey quartzite of the Ajax Formation; grey siliceous argillite of the Sharon Creek Formation; volcanic rocks of the Jowett Formation; and grey and green quartz-feldspar grit and phyllite of the Broadview Formation. Farther north, in the Illecillewaet synclinorium, the Lardeau Group comprises a lower unit of black graphitic phyllite, a middle unit of green phyllite, quartzite and marble, and an upper unit of grit and black phyllite (Figure 2; Colpron and Price, 1993). Regional correlation of these units places them beneath the Jowett and Broadview formations and therefore within the Index Formation (Read and Wheeler, 1976; Sears, 1979; Colpron and Price, *in press*). A similiar three-fold subdivision of the Lardeau Group can be applied in the map area (Figure 4; Gibson and Höy, 1994; Logan and Drobe, 1994). Rocks of the Index Formation are exposed north of the Goldstream pluton, in the footwall (lower plate) of the French Creek fault. Similiar rocks flank the carbonate on Downie Peak at the east end of the Goldstream pluton (Figure 3).

The area extending from the mouth of the Goldstream River east to the Goldstream mine has been divided into three mappable units, each gradational one into the other and, therefore, conformable. The lower unit is predominantly a sequence of dark rocks which includes carbonaceous and calcareous phyllite and schist, dark grey carbonate and subordinate micaceous quartzite. It is correlated with the lower Index Formation and is host to the Goldstream orebody. The phyllites are strongly sheared phyllonites adjacent to marble of the Badshot Formation exposed along Highway 23. Farther east, at the mine, these rocks are referred to as the "dark banded phyllite" because of the pervasive cleavage which gives them a banded appearance. Lenticular pods of talc-magnesite schist and serpentine-antigorite schist occur near this lower contact with the Badshot Formation at the "hump". Coarsely crystalline fuchsite is associated with the talc-altered bodies which probably represent original mafic dikes and sills.

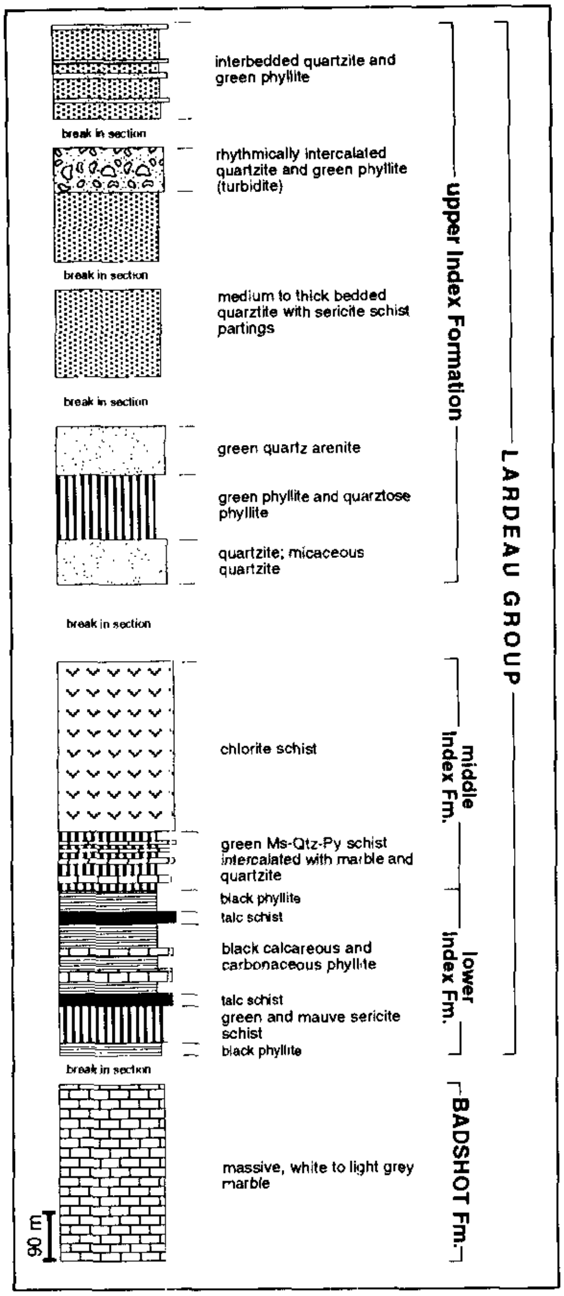


Figure 4: Schematic stratigraphic section of the Lardeau Group in the Goldstream River area (modified after Logan and Drobe, 1994). The section is a composite of measured sections along the overturned limb of the Goldstream anticline (see Logan and Drobe, 1994, for detailed description). Correlations with the Lardeau Group stratigraphy defined by Colpron and Price (1993; see Figure 2) in the Illecillewaet synclinorium, to the southeast, is shown on the right.

Green chlorite-actinolite schist, massive greenstone, thinly layered calcareous green phyllite and minor micaceous quartzite make up the middle member of the Index Formation. This sequence of volcanic rocks, subvolcanic intrusives and sedimentary rocks is the thinnest and least continuous of the three members in the Goldstream River area. The green schists are interlayered at various stratigraphic levels with the upper quartzite unit. Near the "hump" the chlorite schist is well foliated, contains white carbonate partings and several percent euhedral magnetite and pyrite crystals. Massive greenstone crops out south of the mine. Preliminary trace element chemistry indicates that the massive greenstone at the mine and the chlorite schist from the "hump" are tholeiitic basalts of mid-ocean ridge basalt (MORB) affinity, clearly different from the alkaline basalts of within-plate affinity reported for the Index and Jowett formations and possible correlatives within the Covada Group to the south (Smith and Gehrels, 1992c; M. T. Smith, personal communication, 1994). A swarm of thin mafic subvolcanic sills intrudes dark phyllites in the footwall sequence at the mine.

The upper member of the Index Formation consists of rhythmic beds of greenish micaceous quartzite, green sericite-chlorite phyllite and coarse-grained quartz grit. Micaceous quartzite predominates and the greenish hue is characteristic of this unit. The grit beds range from 10 centimetres to 3 metres thick, and are well sorted and commonly graded. Quartzites are planar bedded, ungraded and typically less than 2 metres thick. Locally the grits are interbedded with green phyllites on 2 to 5-centimetre scale.

Strata in the Groundhog basin have been divided into the lower dark phyllite and upper micaceous quartzite and grit packages (Figure 3). Calcareous, green chlorite schists of the middle member are present but do not constitute a mappable unit; they are included in the upper quartzite package. A fuchsite-bearing, talc-ankerite schist, known locally as the "spotted dog", is a characteristic unit of this area. It occurs near the contact between the quartzite and phyllite packages, usually within the latter. This rock type may represent a hydrothermal exhalation similiar to the sulphide-rich ferruginous talc sinters forming in the Guaymas Basin today (Lonsdale *et al.*, 1980). Black and brown carbonate units are interlayered with the phyllites; light grey carbonates are interlayered with the quartzites. Sections of pure, pink, pale grey and greenish quartzites occur within the predominantly micaceous quartzite package. These are planar bedded and well sorted. Graded bedding is very subtle and difficult to discern. Grey-green quartzose phyllite is interlayered with the quartz grit and quartzite.

The Lardeau Group rocks at the southeast end of the Goldstream pluton were mapped and stratigraphic sections were measured along two separate traverses; the southwest flank of Downie Peak and east of Long Creek (Logan and Drobe, 1994). The sequence west of Downie Peak is coarsening upward and includes: biotite and muscovite-quartz schists interlayered with marble (equivalent to the lower Index); and schist, quartzite and grit of the upper Index. This sequence is abruptly overlain by the white marble forming Downie Peak. The lower part of the sequence hosts the Montgomery volcanogenic massive sulphide deposit. East of Downie Peak, between the Goldstream pluton and Long Creek stock, are graphitic and sulphidic biotite hornfels, biotite and muscovite schist, marble/calcsilicate and micaceous quartzite. A siliceous spessartine-bearing graphitic phyllite within this sequence is correlated with the "garnet zone" in the Goldstream mine stratigraphy (see below). Mafic subvolcanic greenstone and green chlorite schist are interlayered with micaceous quartzites near the top of this section. These rocks are equivalent to the lower black phyllite and middle greenschist members of the Index Formation.

CONTACT RELATIONS BETWEEN BADSHOT FORMATION AND LARDEAU GROUP

Fyles and Eastwood (1962) interpreted the Lardeau Group to overlie limestones of the Badshot Formation conformably, but described the contact in the Ferguson area as strongly sheared and, therefore, of uncertain stratigraphic significance. Reinterpretation of stratigraphic relationships in the Trout Lake area and regional stratigraphic correlations with the lower Paleozoic rocks of the Covada Group, in northwestern Washington, has led Smith and Gehrels (1992a, b, c) to interpret the Lardeau Group as an inverted stratigraphic sequence that has been tectonically juxtaposed over the Badshot Formation. Alternatively, work in the Illecillewaet synclinorium (Colpron and Price, 1992; in press) indicates that the Index Formation of the Lardeau Group conformably overlies the Badshot Formation.

The contact between the Badshot Formation and the Lardeau Group is not exposed in the Goldstream River area. However, the stratigraphy intersected in drill holes west of the Goldstream mine shows that contacts between units are gradational. Despite the presence of localized shearing along main contacts, the sequence is interpreted to be conformable.

PISOLITIC DOLOSTONE

A buff-weathering, fine-grained and thinly foliated dolostone crops out east of Downie Peak along the north-trending ridge which caps Long Creek stock. Here, it is a pristine pisolitic dolostone which consists of concentric-layered, brown, ovoid pisoliths 5 millimetres in diameter, within a white to buff, cryptocrystalline dolomitic matrix (Logan and Drobe, 1994). The pisolitic dolostone is intruded along its base by a metadiorite sill. The excellent preservation of these primary sedimentary textures is uncommon for rocks of the area. This unit crops out in an area complicated by layer-parallel faulting and younger high-angle normal faults, and is not easily correlated with other marble units in the map area.

CARIBOU BASIN

The rocks exposed in the Caribou basin, south of the Goldstream pluton, were mapped by Höy (1979) as part of his "quartzite and schist" subdivision, which he correlated with the Hamill Group. Most of the area is underlain by a quartz-rich sequence of interlayered micaceous quartzite, pelitic schist and amphibolite. The micaceous quartzites form prominent ridges, whereas interlayered pelitic schists form recessive benchs. South of Downie Creek, Brown (1991) correlated similiar rocks with the Jowett and Broadview formations of the Lardeau Group.

Massive to thickly bedded quartzites predominate. They contain clean quartzite horizons interlayered with typically thinly foliated micaceous quartzite. Muscovite-andalusite-quartz schists, biotite-garnet-quartz schists, and lesser calcsilicate horizons are interlayered with the micaceous quartzites. Dark green amphibolite layers may represent primary igneous rocks, but are more likely derived from metamorphosed calcareous units. Contact metamorphism has produced garnet-biotite-actinolite-andalusite assemblages in the calcareous pelitic units. Coarse, 2 to 5-centimetre, elongate aggregates of fine-grained quartz and muscovite are interpreted as pseudomorphs of andalusite. These pseudomorphs are a major constituent of pelitic schists in the Caribou basin. Höy (1979) previously interpreted them as retrograded kyanite porphyroblasts.

GNEISSES NEAR DOWNIE CREEK

Garnet-grade paragneiss and orthogneiss crop out along Highway 23 south of the Goldstream pluton (Figure 3). Outcrop is sparse and the gneisses are intruded by leucogranite sills of the Downie Creek suite and by younger pegmatites. The gneisses include micaceous quartzite, interlayered pelitic horizons, coarse garnet amphibolite and foliated diorite. Micaceous quartzites and interlayered biotite gneisses exposed along the highway north of the Downie stock contain synkinematic garnet pophyroblasts. The garnets are commonly mantled by retrograde chlorite rims. These higher grade gneisses may be correlative with Devonian gneiss of the Clachnacudainn Complex to the south.

INTRUSIVE ROCKS

Four plutons intrude strata of the Goldstream River area. These are interpreted to represent three distinct episodes of plutonism: Middle Jurassic (Adamant pluton), mid-Cretaceous (Goldstream pluton, Long Creek stock) and Late Cretaceous (Downie Creek stock). All of the main igneous bodies have been sampled for major and trace element geochemistry, petrology and geochronology. The details of each suite follow.

ADAMANT PLUTON

The Adamant pluton is an elliptical, east-trending composite intrusion comprising hypersthene-augite monzonite cores surrounded by hornblende (± biotite) granodiorite (Fox, 1969). Only the western half of the pluton is exposed in the Goldstream River area. Our mapping was restricted to its margins.

In the Goldstream River area, exposures of the hypersthene-augite monzonite phase of the pluton are restricted to the glaciated terrain surrounding Remillard Peak, and to cirques south of Waldorf Towers (Figure 3). Here, the monzonite also contains variable amounts of hornblende and biotite (Fox, 1969). The remainder of the pluton consists of a homogeneous medium-grained hornblende granodiorite. The granodiorite locally has an orbicular texture. A narrow border of foliated biotite (± hornblende) granodiorite is present along the northeastern margin of the pluton.

Adamant pluton is discordant with the trend of regional structures to the south; along its northern margin, the regional foliation and several bands of marble strike parallel to the pluton contact. Fox (1969) and Shaw (1978) proposed that emplacement of the pluton predates the development of dominant regional structures in the area. Okulitch (*in* Stevens *et al.*, 1982) speculated that it may even be as old as Paleozoic. Fox and Shaw related the deflection of structures near the pluton to deformation around a rigid inclusion during the Middle Jurassic. Fox also proposed that the outer zone of granodiorite results from hydration of the original pyroxene monzonite during regional metamorphism. Zircon from the outer zone of the pluton yielded a concordant U-Pb age of 169±3.4 Ma (Shaw, 1980). Because of its occurrence within the hydrated outer zone, Shaw has interpreted this age to date the metamorphism of the pluton. We concur with Woodsworth *et al.* (1991) that this date may alternatively reflect a Middle Jurassic age for the pluton. The complete overprinting of regional tectonic fabrics in the contact aureole suggests that the thermal anomaly associated with emplacement of the pluton outlasted (at least in part) the development of regional structures.

GOLDSTREAM PLUTON

The Goldstream pluton is an elliptical, east-trending intrusive complex. It consists of monzodiorite and granite sills and pendants of layered country rock. The western end of the body consists of a mixture of schists, gneisses and more or less conformable sills of granitic rock (Wheeler, 1965). The pluton is a composite body consisting predominantly of an older hornblende biotite monzodiorite phase and a younger, more felsic, biotite quartz monzonite to granite phase. Textures in the felsic phase vary from equigranular to sparsely porphyritic, centimetre-scale potassium feldspar phenocrysts characterize the latter. The margins of the pluton are defined by east-trending pendants and inclusions of metamorphosed country rock inter-digitated with monzodiorite and granite sills. The abundance of inclusions and their structural continuity at the margins, as well as in the centre of the pluton, indicate passive emplacement and wallrock assimilaton, and suggest that the present erosion surface may be close to the roof of the intrusive body.

Interdigitations of concordant granitic and monzodioritic sills with pendants of country rock distinguishes the Goldstream pluton from other plutonic bodies in the northern Selkirk Mountains. This intrusive style and the presence of a foliation within the granitic rock has been interpreted to suggest that emplacement of the Goldstream pluton predates the dominant regional deformation and could be as old as Devonian (Höy, 1979).

Discordant contact relationships between the intrusive phases and the pendants, and the various degrees of assimilation of xenoliths within the Goldstream pluton indicate, however, that emplacement of the pluton postdated the development of the penetrative foliation in the xenoliths (Logan and Drobe, 1994). The biotite foliation, locally present within the granitic phase of the pluton, is interpreted as either a magmatic foliation, or a ghost foliation inherited from assimilated xenoliths.

Hornblende and biotite mineral separates from the monzodioritic phase of the Goldstream pluton both yielded $^{40}Ar/^{39}Ar$ plateau ages of 114±4.5 Ma and 100±1 Ma, respectively (Figure 5). Metamorphic mineral assemblages in the aureole of the Goldstream pluton (*cf.* Metamorphism below) indicate that it was emplaced at high level. The hornblende age of 114 Ma is therefore interpreted to be the best estimate of the crystallization age. The younger biotite age (100 Ma) suggests slow cooling. Such a slow cooling rate (~14 °C/Ma) is somewhat unexpected in a high-level intrusion. Further geochronological studies of the Goldstream pluton are required in order to elucidate its emplacement history.

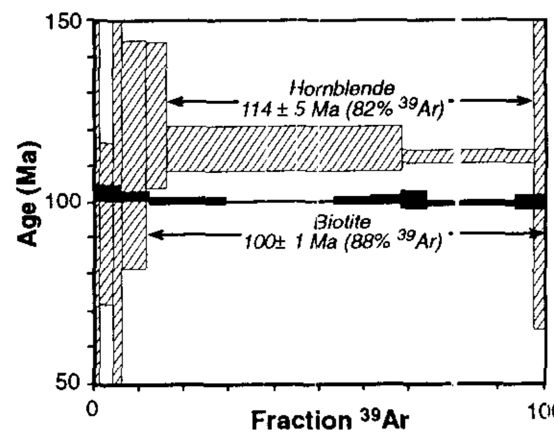


Figure 5: $^{40}Ar/^{39}Ar$ age spectra for monzodioritic phase of Goldstream pluton. Sampling locality is shown in Figure 3.

LONG CREEK STOCK

The Long Creek stock is a 5 by 8-kilometre body centred on Long Creek. It extends from south of Downie Peak across Downie Creek (Figure 3) and south of the map area to the mouth of Standard Creek (Brown, 1991). A 1370-metre vertical section of the stock, capped by marbles and phyllites of the Lardeau Group, can be viewed to the east, from the highway at Downie Creek. The eastern contact dips northeasterly and is subconcordant to strata. Along its western margin the stock clearly truncates regional structures. The stock consists of medium-grained biotite quartz monzonite similar to the felsic phase of the Goldstream pluton, but, in contrast, is generally free of inclusions of country rock. The margin of the intrusion is characterised by a zone of massive quartz and quartz-feldspar segregations, and sericite alteration 50 metres wide (Vanderpoll, 1982) and is associated with tungsten-bearing skarns developed in calcareous country rocks.

DOWNIE CREEK STOCK

The Downie Creek stock is a roughly circular body exposed north of Downie Creek at its confluence with the Columbia River. Fresh exposures of the stock are rare, but it forms a prominent talus slope along the north flank of Downie Creek. The stock is a medium to fine-grained, equigranular two-mica leucogranite, composed of plagioclase, potassium feldspar, quartz, biotite and muscovite in the proportions of a quartz monzonite to a granite. Fine-grained garnet is locally present. Country rocks are garnet-grade biotite-quartz paragneiss and dioritic orthogneiss of the lowest structural slice along Highway 23, and garnet-andalusite schist and micaceous quartzite in the Caribou basin to the northeast (Figure 3). The Downie Creek stock is interpreted to truncate the Caribou Creek fault (Figure 3). It is crosscut by brittle fault zones and chloritic breccias associated with the Columbia River fault at its western end.

ARGONAUT PEGMATITE COMPLEX

Abundant sills and dikes of pegmatite (1-5 m wide) intrude the psammitic schist exposed east of Argonaut Pass and along the flanks of French Creek (Figure 3). The sills are concordant with the north-trending, east-dipping attitude of the dominant foliation in the area. Dikes are subvertical and trend east-west; they are most abundant along the ridgetop east of Argonaut Pass and along the western flank of French Creek, where they comprise approximately 50% of the outcrops. The Argonaut pegmatites are composed of quartz, plagioclase and muscovite with minor amounts of biotite and garnet. A peculiarity is the presence of pods of sillimanite(?) 30 to 40 centimetres long.

STRUCTURE

The complex structure in the northern Selkirk Mountains is the result of polyphase folding and faulting associated with the Mesozoic accretion of allochthonous terranes at the western edge of the North American plate (Monger *et al.*, 1982, 1994). The earliest structures were postulated by Read and Wheeler (1976) to predate a middle to late Paleozoic erosional unconformity, but large-scale major folds and faults are generally accepted to be related to polyphase deformation during Mesozoic orogenesis (*e.g.*, Brown *et al.*, 1986; Price, 1986). These structures were transported eastward 200 to 300 kilometres together with the migrating deformational front above a diachronous décollement (Monashee décollement; Brown *et al.*, 1986, 1993), prior to Eocene extension (Brown and Journeay, 1987).

The Goldstream area is dominated by southwest-verging fold-nappes and thrust faults characteristic of the western flank of the Selkirk fan structure (Wheeler, 1963, 1966; Brown and Tippet, 1978; Raeside and Simony, 1983; Brown and Lane, 1988). The origin of the Selkirk fan has been ascribed to "the superposition of two distinct phases of deformation upon strata previously involved in nappe formation" (Brown and Tippett, 1978) or to "one protracted phase of deformation" (Price *et al.*, 1979). Earlier workers (Lane, 1977; Brown and Tippett, 1978; Höy, 1979; Brown and Lane, 1988) have suggested that dominant, southwest-verging folds in the area deform a previously inverted stratigraphic sequence and that strata of the Goldstream slice occupy the overturned limb of an early southwest-verging nappe (Carnes nappe; Brown *et al.*, 1983; Brown and Lane, 1988). Our stratigraphic revisions, and proposed correlations for rocks exposed in the western part of the Goldstream area, indicate that the stratigraphic sequence was not inverted prior to development of the regional southwest-verging folds.

Two generations of structures (and associated tectonic fabrics) are recognized throughout the Goldstream area. They correspond to the second and third phase structures of Lane (1977), Brown and Tippett (1978), and Höy (1979). The earlier generation of structures correspond to northwest-trending, southwest-verging folds and thrust faults which define the map pattern (Figure 6). These structures locally deform an older schistosity which is subparallel to bedding. They are also interpreted to deform a set of older contraction faults between Goldstream River and Sorcerer Creek. Regional relationships indicate a Middle Jurassic age for this generation of structures (*e.g.*, Parrish and Wheeler, 1983; Brown *et al.*, 1992;). The southwest-verging structures are deformed by younger, easterly trending, gently plunging folds. These structures predate the emplacement of the mid-Cretaceous intrusive suite. These two generations of structures are readily recognized by their overprinting relationships with respect to one another and to regional metamorphic events. North-trending fractures, normal faults and gentle open warps are the youngest structures and are interpreted to be associated with Eocene crustal extension along the Columbia River fault.

The Goldstream River area is subdivided into two structural domains bounded by the French Creek fault (Figure 6). In the eastern domain, dominant folds are tight isoclines with north-trending axial traces; in the western domain, the axial trace of dominant folds trend more northwesterly. Younger, east-trending cross-folds are present in both domains. The eastern and western domains correspond, respectively, to the Illecillewaet and the Goldstream slices of Brown and Lane (1988).

NORTHWEST-TRENDING STRUCTURES

The structural style of the Goldstream River area is dominated by north and northwesterly trending, southwest-verging structures. Folds are tight to isoclinal, overturned to recumbent, and characterized by axial plane schistosity which dips either east, northeast or, where refolded by later cross-folds, northerly. Fold axes plunge moderately to the northeast. The superposition of younger, easterly trending cross-folds has produced type 3 interference patterns (Ramsay, 1962).

In the eastern structural domain, the competent quartzites and volcanic rocks of the Hamill Group are deformed into a series of four west-verging synclines between Sorcerer Creek and the Goldstream River (Figure 6). These parallel folds are locally truncated by thrust faults (Photo 1).

The French Creek fault is the major north-trending thrust fault that separates the eastern and western structural domains (FCF; Figure 6). It places the older rocks of the Horsethief Creek and Hamill groups, to the east, over rocks of the Lardeau Group in the Goldstream slice. The French Creek fault is exposed in marbles along the French Creek road north of the Goldstream River. Shear sense indicators from a grey, thinly foliated marble mylonite in the footwall of the fault consistently show tops-to-the-west sense of motion. North of this exposure, the fault continues into the French Creek valley maintaning its east dip, but probably warped about the east-trending synclinal cross-fold. East of the Long Creek stock, the fault separates strongly foliated, mylonitic greenstones, dolostone and dark phyllite of the Horsethief Creek Group from Lardeau Group phyllite and carbonate (Figure 3). The fault is traced to the south into the Downie Creek fault (Brown, 1991), a major northwesterly-trending, southwest-verging thrust fault. At its southern end, the fault dies out in the core of a southwest-verging anticline which forms part of the Illecillewaet synclinorium (Colpron and Price, 1993).

The Goldstream anticline is a west-northwesterly trending structure cored by dolostone of the Badshot Formation in the western structural domain (Figure 6). Its axial trace follows the Goldstream River southeasterly, where it swings into near parallelism with the northern margin of the Goldstream pluton (Figure 6). Minor folds associated with the Goldstream anticline plunge to the east. Parasitic minor folds in green micaceous quartzites and grits of the upper Index Formation, north of the Goldstream River, are Z-shaped; minor folds in phyllite of the lower Index at the open pit, south of the Goldstream mine, are S-shaped. A north-trending anticline-syncline pair, cored by Badshot dolostone, occurs to the north, in the vicinity of Nicols Creek, and probably reflects the northward continuation of the Goldstream anticline. The strongly sheared nature of the enclosing phyllites has been interpreted by earlier workers (*e.g.*, Read and Brown, 1981; Gibson and Höy, 1994) to be associated with the Goldstream River fault: a major northwesterly trending structure linking the

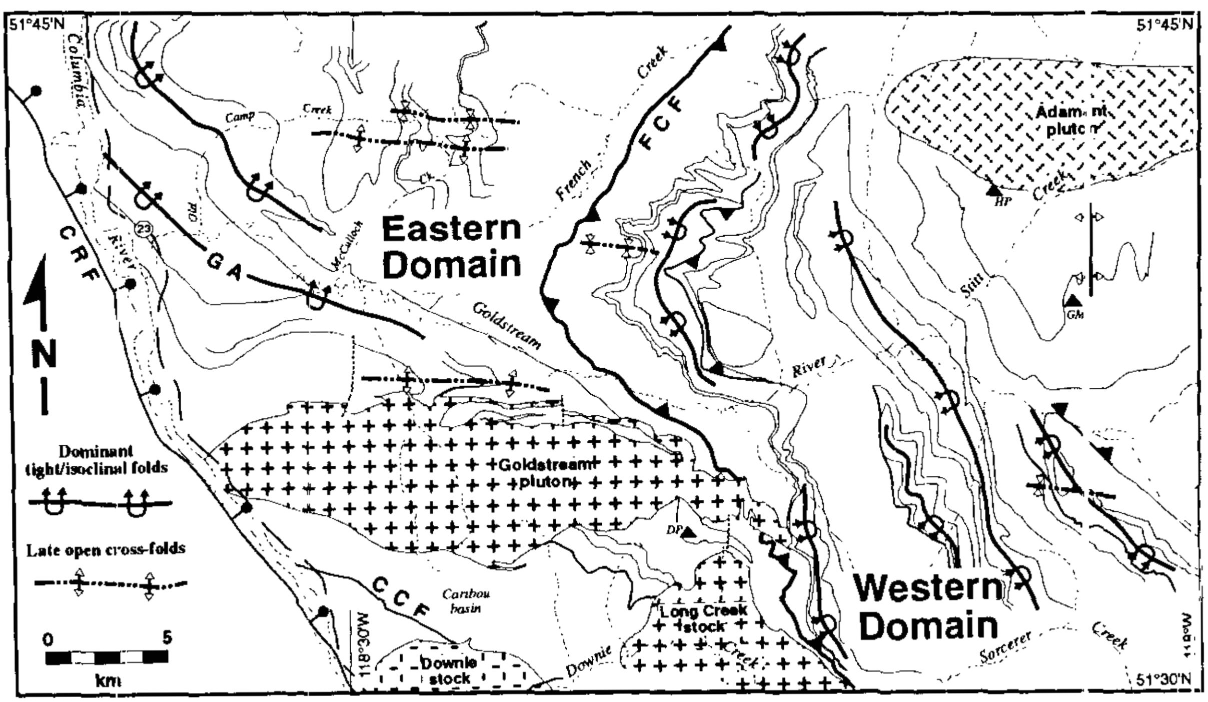


Figure 6: Structural map of the Goldstream River area showing the location of major folds. Major faults: CRF = Columbia River fault, CCF = Caribou Creek fault, FCF = French Creek fault; GA = Goldstream anticline.

Photo 1: Southwest-verging parallel folds and thrust faults in Hamill Group quartzites; view is towards the northwest. Outcrops are located between the headwaters of Sorcerer Creek and Goldstream River.

Photo 2: Early recumbent isoclinal folds (in centre) of micaceous quartzites of the Horsethief Creek Group refolded about open, upright east-trending cross-folds; view is to the east.

Downie Creek fault to the Columbia River fault zone. However, the stratigraphic continuity in drill holes both north and south of the Goldstream River does not support the existence of such a structure.

A poorly understood, northwesterly trending structure separates rocks of the Index Formation on the southwest flank of Downie Peak from the quartz-rich sequence of interlayered micaceous quartzite, pelitic schist and amphibolite of the Caribou basin. It is conformable with the dominant foliation and truncated by the Goldstream pluton at its northern end and the Long Creek stock at its southern end. This structure is probably correlative with the southwest-verging Standard thrust fault to the south (Brown, 1991).

The Caribou Creek fault (CCF; Figure 6) is northwest-trending structure that is inferred to separate higher grade metamorphic orthogneiss and paragneisses, possibly correlative with the Clachnacudainn gneiss, from the mixed package of micaceous quartzites, pelitic schist and amphibolites of the Caribou basin. It is truncated by the Downie Creek stock to the south.

EAST-TRENDING STRUCTURES

Young, east-trending, steeply dipping crenulation cleavage and open folds are superposed on the northwest-trending structures. Deformation of the earlier schistosity produced a pervasive crenulation cleavage in the phyllite and calcareous chlorite schist of the Index Formation. These cross structures are best developed north of the Goldstream River, in the Groundhog basin, and north of the Goldstream pluton. In the Groundhog basin the folds are upright, open chevron and kink folds. East of French Creek, rocks of the Horsethief Creek and Hamill groups are gently folded about an easterly trending synformal axis (Figure 6).

South of the Goldstream River, the Index Formation is folded into an upright antiform about an east-trending axis. The strata at the mine dip moderately north, on the north limb of this cross-fold; the south limb is intruded by the Goldstream pluton and offset by high-angle reverse faults (G. Gibson, personal communication, 1994).

EARLY CONTRACTION FAULTS

The earliest fault structures recognized in the Goldstream area are north-trending, east-dipping faults between Sorcerer Creek and Goldstream River (Figures 3 and 6). These structures are illustrated in Brown and Tippet (1978, Figure 3), who described the Hamill Group as "preserved in synclinal keels that are generally faulted against sheared limbs of anticlines in the Horsethief Creek Group". Fold vergence and bedding truncations indicate that these structures are east-verging imbricate contractional faults which placed the Horsethief Creek Group onto Hamill Group rocks. Continued deformation overturned these structures which now appear to have a normal sense of displacement. Similar overturned, east-verging thrust faults were recognized by Zwanzig (1973) in the Illecillewaet synclinorium to the south.

COLUMBIA RIVER FAULT

The Columbia River fault zone separates the hangingwall Selkirk allochthon from the footwall rocks of the Monashee Complex (Figure 1). The Columbia River fault is a normal fault which dips 20° to 30° to the east. Motion is dip slip and of sufficient magnitude to juxtapose greenschist facies rocks of the Goldstream slice against upper amphibolite facies rocks in the footwall (Read and Brown, 1981). The fault is responsible for the development of cataclasite and chloritic breccias in the Goldstream pluton and Downie Creek stock. Discreet brittle fault zones less than a metre wide, and characterised by anastomosing slip planes and angular centimetre-scale breccia fragments. are visible in weathered exposures of the Badshot Formation along Highway 23. The late-stage brittle-ductile deformation of the carbonates here overprints earlier ductile fabrics. Internal structures visible on weathered surfaces include anastamosing alternating dark and light wispy foliation which wraps around angular, rotated and stretched carbonate breccia fragments.

Additional late-stage, brittle deformation includes east-trending, north-side-down normal faults which are exposed in the Goldstream River valley and in the Goldstream mine workings. These are generally foliation-parallel shear zones.

RELATIONSHIPS BETWEEN PLUTON EMPLACEMENT AND DEFORMATION

The temporal relations of Middle Jurassic granitic intrusion to regional deformation in the northern Selkirk Mountains, and particularly the deflection of dominant structures around these bodies, has been addressed by various authors. The debate has mostly focused on the relationships around Fang stock, south of the Goldstream River area (Figure 1). Wheeler (1963) originally concluded that the deflection of structures reflects the forceful emplacement of the Fang stock after development of the regional structures. Reesor (1963) suggested that the pluton was emplaced early in the tectonic history and was subsequently deformed. Recent work by Brown *et al.* (1992) suggests that Fang and Pass Creek stocks were emplaced after the development of the regional southwest-verging structures and that the deflection of structures is related to later "rigid-body rotation of the plutons". Colpron and Price (1993) argue that emplacement, consolidation and rigid-body behaviour of the Fang stock all occurred during progressive development of the regional southwest-verging structures.

A similar deflection of the regional structures occurs around the Adamant pluton (Fox 1969; Shaw, 1978). Fox and Shaw concluded that this deflection of structures resulted from deformation around a pretectonic intrusion. However, relationships along the southern margin of the Adamant pluton suggest that the pluton was emplaced late in the defomation history.

In a detailed section across the aureole northwest of Hitchhiker Peak, the metamorphic assemblages overprint the dominant foliation in the wallrocks and granitic leucosomes are common within an 800-metre radius from the pluton. Porphyroblasts increase in size (up to several centimetres) as the pluton is approached. Within 500 metres of the contact, the country rocks are completely devoid of foliation, and dismembered calcsilicate and amphibolite boudins are "floating" within a quartzite matrix. Deformational features are limited to disharmonic, ptygmatic folds and boudinaged calcsilicate and amphibolite layers. Because the style and orientation of folding in the aureole of the Adamant pluton differ from that of regional structures in the area, we relate this deformation to the emplacement of the pluton rather than to regional deformation. These relationships imply that intrusion of the Middle Jurassic Adamant pluton occurred after the development of the dominant structures in this area. However, large-scale deflection of the regional structures to the north and east of the pluton suggests that deformation continued after its emplacement (Fox, 1969; Shaw, 1978). We therefore suggest that perhaps Adamant pluton had a similar emplacement history to Fang stock.

A chiefly retrograded, contact metamorphic aureole surrounds the Goldstream pluton. It overprints the dominant foliation and the younger east-trending cross-folds. This implies that emplacement of the mid-Cretaceous Goldstream pluton postdates the development of the east-trending cross-folds. Numerous zones of brittle-ductile deformation associated with the Columbia River fault crosscut the pluton at its western edge, along Highway 23. The eastern edge of the pluton truncates the French Creek fault (Figure 3).

METAMORPHISM

Rocks of the Goldstream River area contain mineral assemblages characteristic of greenschist to amphibolite facies metamorphism. Figure 7 shows the distribution of isograds as defined by first occurrence of index minerals mapped in the field. Assemblages characteristic of the chlorite zone are found within a west-northwest-trending metamorphic depression which approximately follows the Goldstream River (Figure 7). Chlorite-kgrade mineral assemblages define the dominant foliation throughout the Goldstream area. Synkinematic biotite-grade assemblages are present in the northern part of Groundhog basin.

The low-grade depression is flanked to the northeast and southwest by two metamorphic culminations (Figure 7). The southwest culmination surrounds the Goldstream, Downie and Long Creek intrusive bodies, and is ascribed, for the most part, to

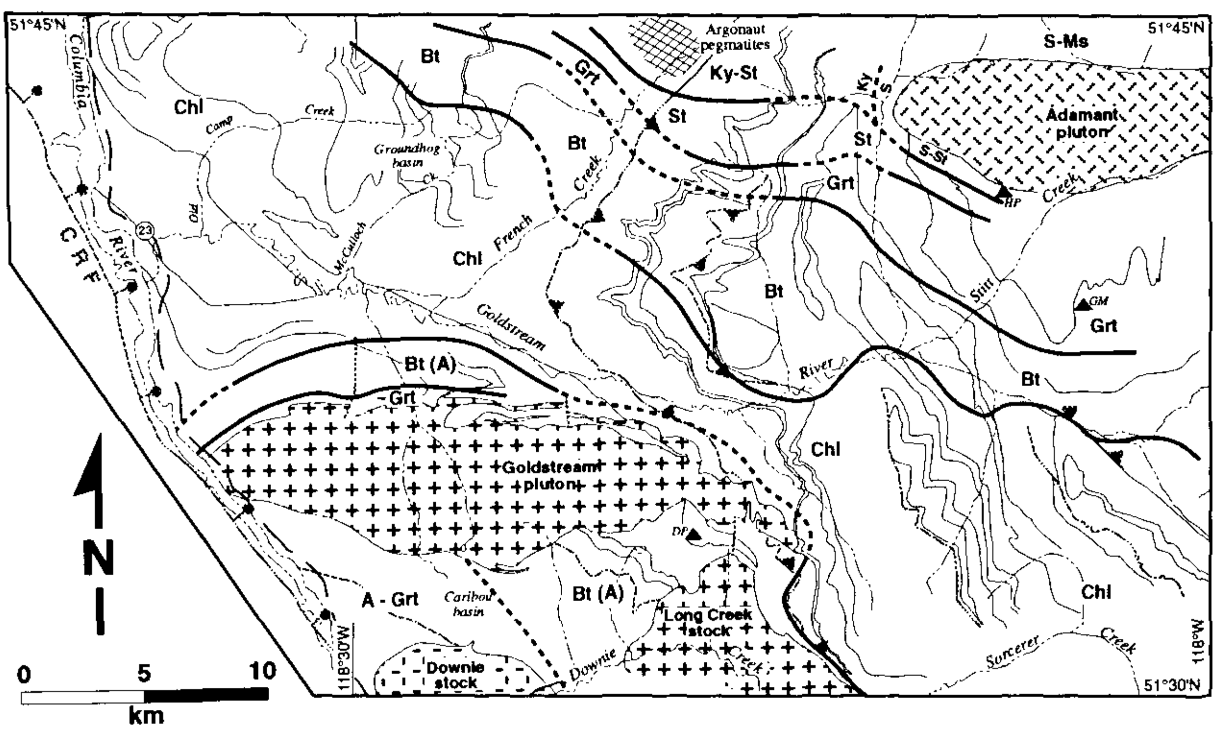


Figure 7: Metamorphic map of the Goldstream River area. Isograds are defined on basis of the first occurrence of index minerals mapped in the field. Metamorphic zones: Chl = chlorite, Bt = biotite, Grt = garnet, St = staurolite, Ky-St = kyanite-staurolite, S-St = sillimanite-staurolite, S-Ms = sillimanite-muscovite, A-Grt = garnet-andalusite. (A) denotes the presence of retrograded andalusite pseudomorphs. Cross-hatched pattern shows distribution of pegmatites. See Figure 3 for other abbreviations

contact metamorphism imposed by these plutons. Assemblages of the biotite and garnet zones define this metamorphic culmination (Figure 7). Psammitic and pelitic rocks in this culmination commonly contain andalusite pseudomorphs up to 5 centimetres long. Calcareous rocks along the northern flank of the Goldstream pluton contain fine radiating clusters of actinolite. Occurrences of fresh andalusite are restricted to the immediate vicinity of the Downie pluton. Coexisting biotite, garnet and andalusite constrain emplacement of the Downie pluton to bathozone 2 (or less) of Carmichael (1978), corresponding to a pressure of less than 350 MPa (3.5 kbar). Similarly, andalusite pseudomorphs in the aureole of the Goldstream pluton constrain its emplacement to bathozone 3 or less (less than 375 MPa (3 75 kbar)). The southwest metamorphic culmination is most likely a composite contact aureole of Cretaceous age. A notable exception is the presence of synkinematic garnet-grade assemblages in gneissic rocks exposed along Highway 23. We believe that these gneisses may preserve a pre-Cretaceous (?) garnet grade regional metamorphism.

The culmination in the northeastern part of the Goldstream area is a segment of a regional west-northwest-trending metamorphic culmination extending for more than 90 kilometres between Mica dam and Rogers Pass (Windy Range culmination; Read and Brown, 1981; Greenwood *et al.*, 1991; Read *et al.*, 1991). This culmination was first outlined by Wheeler (1965) and has subsequently been the subject of studies by Ghent (1975), Ghent *et al.* (1979) and Leatherbarrow (1981). Nathalie Marchildon (University of British Columbia) has recently initiated a detailed study of the southwest flank of the Windy Range culmination in the area northwest of French creek.

Regionally, the Windy Range culmination grades from biotite zone in the southwest, to sillimanite - potassium feldspar zone in the core of the culmination (Leatherbarrow, 1981; Read *et al.*, 1991). To the northeast, metamorphic grade decreases to kyanite-staurolite zone along the southwest flank of the Rocky Mountain Trench. In the Goldstream River area, assemblages characteristic of the biotite, garnet, staurolite and kyanite-staurolite zones are present along the southwest flank of the culmination. Sillimanite-staurolite grade assemblages in the contact aureole of the Adamant pluton may (or may not) be part of the culmination.

The west-northwest trend of the isograds is discordant with the more northerly trend of the regional structures north of Goldstream River (Figure 7). Porphyroblast growth in the Windy Range culmination appears to postdate the development of the dominant regional fabric. However, N. Marchildon (personal communication, 1994) reports synkinematic to post-kinematic prophyroblasts in the area northwest of French Creek. Locally, biotite porphyroblasts define a weak alignment which parallels the trend of late crenulations in the area. Calcareous psammites metamorphosed to garnet grade (and higher) commonly contain large aggregates of hornblende arranged in a characteristic "bow-tie" texture. Kyanite porphyroblasts, locally as large as 15 centimetres long, are randomly oriented along the surface of the dominant regional fabric. These relationships indicate that high-grade metamorphism along the Windy Range culmination is late to postkinematic with respect to the development of the dominant regional structures in the area (Brown and Tippett, 1978; Leatherbarrow, 1981). Mineral alignments which parallel the trend of late crenulations suggest that metamorphism was locally contemporaneous with the development of late open folds.

The assemblage biotite-garnet-kyanite constrains metamorphic conditions to at least bathozone 5 (pressures in excess of 500 MPa (5 kbar ; Carmichael, 1978). Leatherbarrow (1981) reported pressures of about 500 MPa (5 kbar) and temperatures up to about 500°C for the southwest flank of the Windy Range culmination. West of Argonaut Pass, kyanite porphyroblasts are partially (to completely) replaced by andalusite. Kyanite is still preserved in the core of larger andalusite porphyroblasts. This relationship indicates decompression to bathozone 3-4 (*ca.* 375 MPa, (3.75 kbar)).

The contact aureole of the Adamant pluton contains assemblages of the garnet-staurolite sillimanite-staurolite, and sillimanite-muscovite zones (Figure 7). Sillimanite occurs in large bladed pseudomorphs after kyanite; relict kyanite is still present in thin sections. Coexisting sillimanite, staurolite, garnet, biotite, muscovite and kyanite constrain emplacement of the Adamant pluton to the transition between bathozones 4 and 5, corresponding to pressures of about 500 MPa (5 kbar; Carmichael, 1978). Similarities of mineral assemblages and pressures suggest that contact metamorphism in the aureole of the Adamant pluton may be related to the Windy Range metamorphic culmination. Replacement texture of kyanite by sillimanite may even indicate that the pluton is somewhat younger than the culmination, and is consistent with the indications of late decompression observed in the Argonaut Pass area.

MINERAL OCCURRENCES

MASSIVE SULPHIDE DEPOSITS

A number of volcanogenic massive sulphide deposits occur within the polydeformed, and metamorphosed terrigenous sediments and interlayered mafic volcanic flows and sills of the Lardeau Group. The Goldstream orebody and the Standard, Brew and Montgomery copper-zinc prospects have characteristics of Besshi-type deposits (Höy *et al.*, 1984). Zinc-lead±copper deposits at the Rift and C-1 prospects have characteristics of both distal volcanogenic massive sulphide deposits (Large, 1977) and clastic-hosted deposits. Besshi-type deposits occur within either mafic volcanic rocks or terriginous clastic rocks interlayered with mafic flows or sills. Clastic-hosted deposits occur within well layered successions of dominantly calcareous schists, carbonate and quartzite, generally free of volcanic influence.

Additional mineral deposits in the map area include lead-zinc carbonate replacements, tungsten-copper skarns, base and precious metal quartz veins and placer gold concentrations.

GOLDSTREAM MINE

In conjunction with the regional mapping, 4 weeks were spent studying the Goldstream deposit. Surface and underground mapping and sampling of hangingwall, massive sulphide and footwall lithologies of the mine sequence were completed. In addition, drill core from some of the 1991, 1993 and early 1994 diamond drilling programs was logged and sampled. Major and trace element analyses will be used to characterize the alteration assemblages, element mobility and possible vectors towards the ore horizon. The data from this alteration study form one aspect of a larger regional lithogeochemical study.

The Goldstream mine is located on the south side of the Goldstream valley, approximately 14 kilometres east of Highway 23 (Figure 3). Copper-zinc mineralization was discovered at Goldstream during construction of logging roads in 1972. Noranda Mines Ltd. acquired the property in 1975 and completed 8912 metres of diamond drilling, outlining 3.175 million tonnes of ore grading 4.49% Cu, 3.24% Zn and 20 g/t Ag. A production decision was made in 1980 and the mine opened in 1983. Depressed metal prices forced the mine to close less than a year later. Production during this period totalled 11 850 tonnes of copper and 505 tonnes of zinc from 428 000 tonnes milled.

Bethlehem Resources Corporation and Goldnev Resources Inc. acquired the Goldstream property from Noranda in 1989. Production resumed in May 1991. The mine is currently producing at a rate of 1150 tonnes per day. Production from May 1991 to Oct 1, 1994 totals 55 838 tonnes of copper and 39 343 tonnes of zinc from 1.35 million tonnes milled.

During the past year, exploration and development work at the Goldstream mine was supplemented by provincial funding provided under the Mineral Exploration Incentive and Accelerated Mine Exploration programs. Exploration work targeted the C-1 zone and the western strike extension of the mine horizon in the area between Brewster Creek and the C-1 zone (Figure 3). Development work tested the down-plunge extension, grade and thickness of the orebody below the 350-metre elevation. Eleven diamond-drill holes drilled from the north side of the Goldstream River have been completed totalling 5226.5 metres. The deepest exceeded 670 metres (Wild, 1994). Reserves as of October 1, 1994 include: drill indicated to the 150-metre level, 455,000 tonnes at 4.10% Cu and 3.24% Zn; and geologically inferred to the 0-metre level, 300,000 tonnes of 4.20% Cu and 3.24% Zn (C. J. Wild, personal communication, 1994). These are equivalent to two years of current production.

Goldstream is a Besshi-type volcanogenic massive sulphide deposit of early Paleozoic age. The orebody is hosted by a structurally complex, inverted package of fine-grained calcareous and carbonaceous clastic rocks, and mafic volcanic rocks of the Index Formation, which has been intruded and metamorphosed by the mid-Cretaceous Goldstream pluton. The mine sequence is best exposed along the east wall of the open pit (Figure 8). A detailed description of this section is given in Logan and Drobe (1994). In general, the mine sequence consists of a lower dark pelite, including an iron-silica-manganese-enriched unit (garnet zone), a massive sulphide layer enveloped by a micaceous and calcareous quartzite unit, a carbonate unit and an upper mafic metavolcanic unit (Figure 8). The mine sequence is distinguished from the lower Index Formation elsewhere by the presence of iron-manganese and boron-rich sedimentary units which are associated with the massive sulphide layer. These chemically distinctive units extend laterally beyond the sulphide horizon and provide better exploration targets than the smaller alteration envelope of chlorite-biotite-sericite schist that encloses the massive sulphide layer at the mine.

The garnet zone at the mine is a complex unit consisting of: graphitic phyllite with or without garnet; very thinly layered chert; siliceous iron carbonate and garnet-bearing horizons; and siliceous iron sulphide and garnet-bearing horizons. It extends laterally 1.5 kilometres northwest and 3 kilometres southeast from the mine. Drill hole GR93-5, northwest of the mine and apparently distant from the Goldstream pluton (Figure 3), intersected 15 metres of weak garnet zone, consisting of coarse garnets (1 cm) mantled by retrograde chlorite rims. Correlative horizons south of the mine are very siliceous, grey chert-like layers mineralized with several percent pyrrhotite. The garnet horizon occupies the stratigraphic footwall of the deposit (Figure 8). Typically, iron-manganese and silica-rich horizons are found in the stratigraphic hangingwall, and as distal facies to Besshi-type deposits. The garnet zone at Goldstream may reflect an early low-temperature hydrothermal exhalation unrelated to the deposit-forming event. Alternatively, it may have formed by selective replacement of permeable sediments in the upper part of the hydrothermal system (Slack *et al.*, 1993) at the same time the sulphide layer was forming. Ore consists of intermixed pyrrhotite, chalcopyrite and sphalerite and numerous rounded inclusions. The inclusions comprise various wallrock lithologies, several generations of metamorphic quartz and clasts of massive sulphide, floating in a matrix of swirled fine-grained sulphides (*durchbewegung texture)*, a texture common in metamorphosed massive sulphide deposits. Sulphides within the ore layer are fine grained, often folded, recrystallized gneissic bands; commonly, they are remobilized into discordant fracture fillings and pressure shadows. Disseminated sulphides extend into the hangingwall and, less often, the footwall rocks. The quartzite adjacent to the massive sulphide layer contains up to several percent disseminated pyrrhotite, chalcopyrite and sphalerite. The distribution of the sulphides appears to be related to replacement of calcite matrix cement in the quartzites.

Surface mapping on recent logging roads (Gibson, 1994; this study) has traced the mine stratigraphy around an east-trending cross-fold south of the open pit (Figure 9). Manganese-garnet units occur along the southern limb of this fold; siliceous/chert(?) horizons and massive sulphides (East Creek showing) occur structurally below it. Four drill holes (GR93-1 to 4) tested the extension of the mine horizon on the south limb of the fold. All holes were collared in rocks below the footwall marble and drilled south, ending in hangingwall rocks (Figure 9). No significant base metal mineralization was intersected. Up to five chert horizons were recognized in drill core; two are located below the footwall limestone and one of these, in hole GR93-3, contains 1.9 metres of semimassive pyrrhotite and chalcopyrite (G. Gibson, personal communication, 1994). This mineralized horizon is stratigraphically equivalent to the East Creek zone, discovered in 1974. Mineralization consists of coarsely crystalline, massive pyrrhotite, veined with chalcopyrite. This high-grade pod (20 centimetres by 1 metre) of recrystallized sulphides lies along the lower contact of the footwall marble and is interpreted to be skarn mineralization (G. Gibson, personal communication, 1994). The stratigraphy can be correlated between GR94-1 and GR94-3. However, in hole GR94-1 the chert-garnet zone is barren of sulphides. Strata at the collar of GR93-1 dip steeply south and are cut by a vertical fault zone. The three chert-garnet zones intersected in hole GR93-1 may reflect fold duplication on tight parasitic Z-shaped folds. The Goldstream pluton was intersected in the bottom of drill hole GR93-1 (Figure 10). The pluton leaves little room for continuation of the mine sequence around the south limb of the fold or for undiscovered orebodies, except possibly in inliers in the pluton, and current exploration (1994) is again focused on the north limb of the fold at its western end.

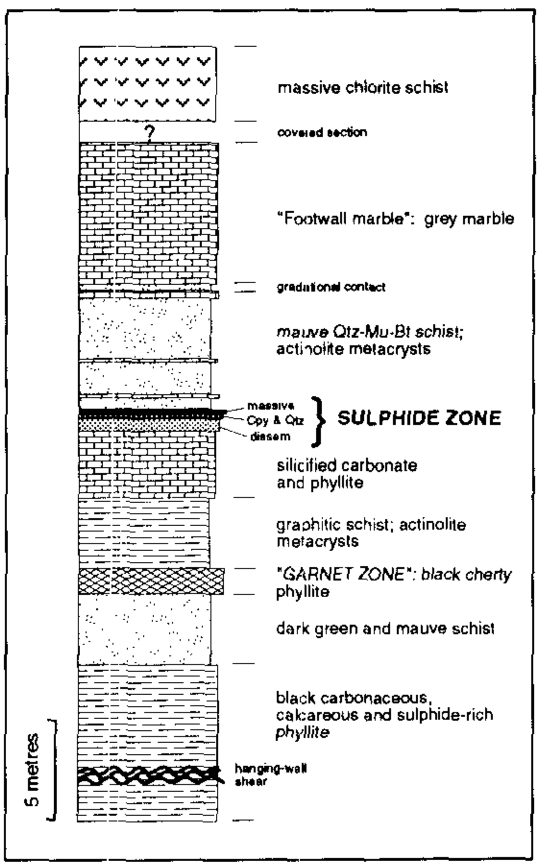


Figure 8: Measured stratigraphic section of the east wall of the Goldstream mine open pit. Modified after Logan and Drobe (1994).

Preliminary conclusions from underground mapping and sampling follow those of earlier workers (Höy *et al.*, 1984) that sulphide textures and morphology of the orebody reflect Middle Jurassic deformation and metamorphism. The orebody is a northeast-plunging ruler-shaped body. The mineable section of ore is approximately 300 metres long and 1 to 3 metres thick with a down-plunge extension exceeding 2000 metres. The orebody is developed by sublevels spaced at 8 metre vertical intervals and mined by long hole stoping.

The southern boundary of the orebody crops out along the east wall of the open pit at 845 metres elevation. It is hosted by tight, isoclinally folded and sheared calcareous and quartzose pelitic rocks. The northeast plunge of the orebody parallels stretching lineations and fold axes of the dominant, northwest-trending structures. Structures along the length of the sulphide body vary from northwest to southeast and across it, from footwall to hangingwall. The generally competent footwall marbles and lesser phyllites exhibit moderate to tight northeast-plunging folds, but the micaceous carbonate and schists of the hangingwall, together with the sulphide body, are typically ptygmatically folded and faulted into southwesterly verging structures. The intensity of deformation increases northward towards the hangingwall.

The northwestern boundary of the orebody plunges northeasterly (Figure 9). It coincides with structural disruption along high-angle faults and tight upright folds. Low-angle, east-trending faults occur at the boundary. They generally follow the hangingwall, but locally cross to the footwall, faulting-out complete sections of the sulphide layer. Rocks at the northwestern end of the orebody are generally less competent, with relatively more biotite, sericite, chlorite and talc, and less silica alteration (C. J. Wild, personal communication, 1994). As the sulphide layer is traced to the east, the orebody tapers in thickness and copper grade drops off. Thick, white quartz sweats and large quartz augen are present in the massive ore along both footwall and hangingwall sections at the southeastern end of the orebody. A steep, northeast-trending, east-side-down, normal fault offsets the ore horizon along the east wall of the open pit; displacement is on the order of 10 metres.

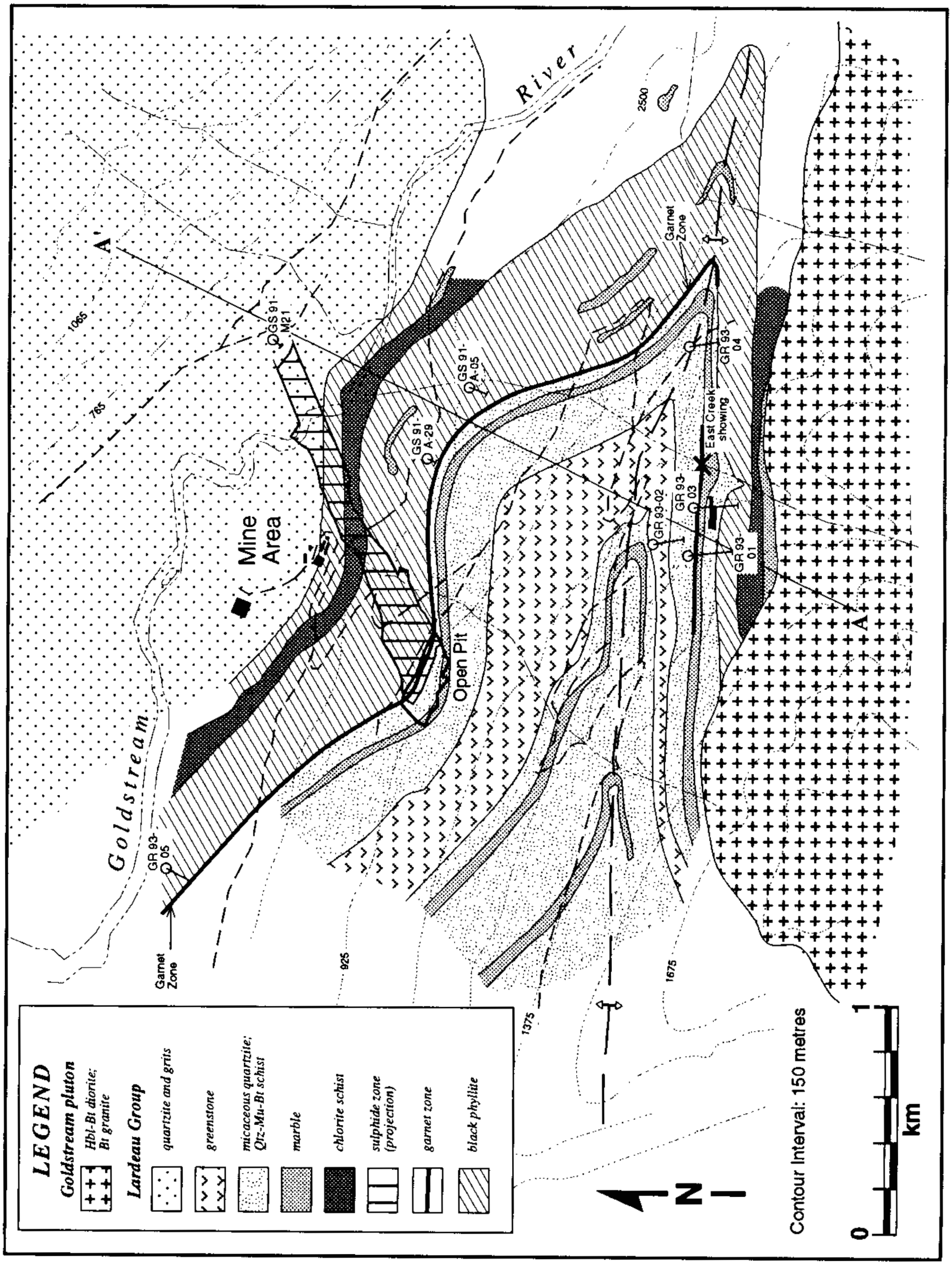


Figure 9: Detailed geological map of the Goldstream mine area compiled from our 1994 mapping and from Gibson (1994).

Foliation-parallel brittle fault zones follow incompetent layers in the footwall and hangingwall rocks. The footwall shear is a west-trending reverse fault, dipping 30° north. It follows the footwall of a narrow section of sulphidic phyllite and mafic sills within the footwall marble, approximately 60 metres below the orebody. The hangingwall shear is an anastamosing structure that in general follows the garnet zone. It comprises a number of foliation-parallel shears, dipping 30° or less to the north, resulting from the competency contrast between siliceous and carbonaceous units of the garnet zone. The hangingwall shear has a top-to-the-southwest sense of shear, similiar to the regional sense of motion.

The orebody varies in thickness along its length, where isoclinal folding and shearing have stacked fold hinges along low-angle faults. Locally, it consists of northeast-plunging rootless-fold hinges of massive sulphide ± disseminated layers. These flat fault structures are folded about younger east-trending folds. This configuration is overprinted by contact metamorphism of the mid-Cretaceous Goldstream pluton. The youngest deformation event has produced north-trending broad open folds and minor strike and dip deviations in the massive sulphide layer.

South of the mine, the lower greenschist facies rocks are overprinted by the contact aureole of the Goldstream pluton. Metamorphic assemblages include biotite, muscovite, garnet, andalusite, actinolite and cordierite(?). For the most part, the calcareous strata have been metamorphosed to a calcsilicate sequence. These minerals have been retrograded by late-stage fluids and in most cases only relict porphyroblasts of chlorite or sericite remain. Greenish-brown tourmaline, probably magnesium-rich dravite or schorl-dravite, is present in concentrations up to 10 modal percent in quartz-muscovite schists and impure carbonates of the footwall section. In the carbonates, coarse tourmaline crystals up to 3 centimetres long are intergrown with actinolite on foliation planes. Both minerals define a mineral lineation parallel to the elongation of the orebody.

Wallrocks adjacent to the massive sulphide layer include a pale silver weathering, thinly interlayered calcareous muscovite schist and quartzite. Very fine grained secondary biotite, and more rarely, actinolite occur in the hangingwall and immediate footwall. It has been suggested that this envelope to the massive sulphide layer is in part an exhalative unit (Höy, 1991). The rhythmic layering of quartzose units with calcareous and micaceous partings suggests to us that most of this unit is clastic in origin.

Black to dark green, lustrous chlorite zones are locally present, but rare. Most often they are associated with either disseminated chalcopyrite zones or inclusions in massive sulphide rocks. Chlorite alteration appears to be late stage and to be associated with crosscutting fractures and fault zones. Pale yellow quartz-muscovite-chlorite-andalusite-cordierite(?)-tourmaline schists are interlayered with calcsilicate assemblages and black phyllite south of the mine. The rocks outcrop close to the northern edge of the Goldstream pluton and, as a result, are retrograded to quartz, chlorite and muscovite. These coarse, porphyroblastic schists may be equivalent to the spotted cordierite-anthophyllite rocks (dalmatianite) which

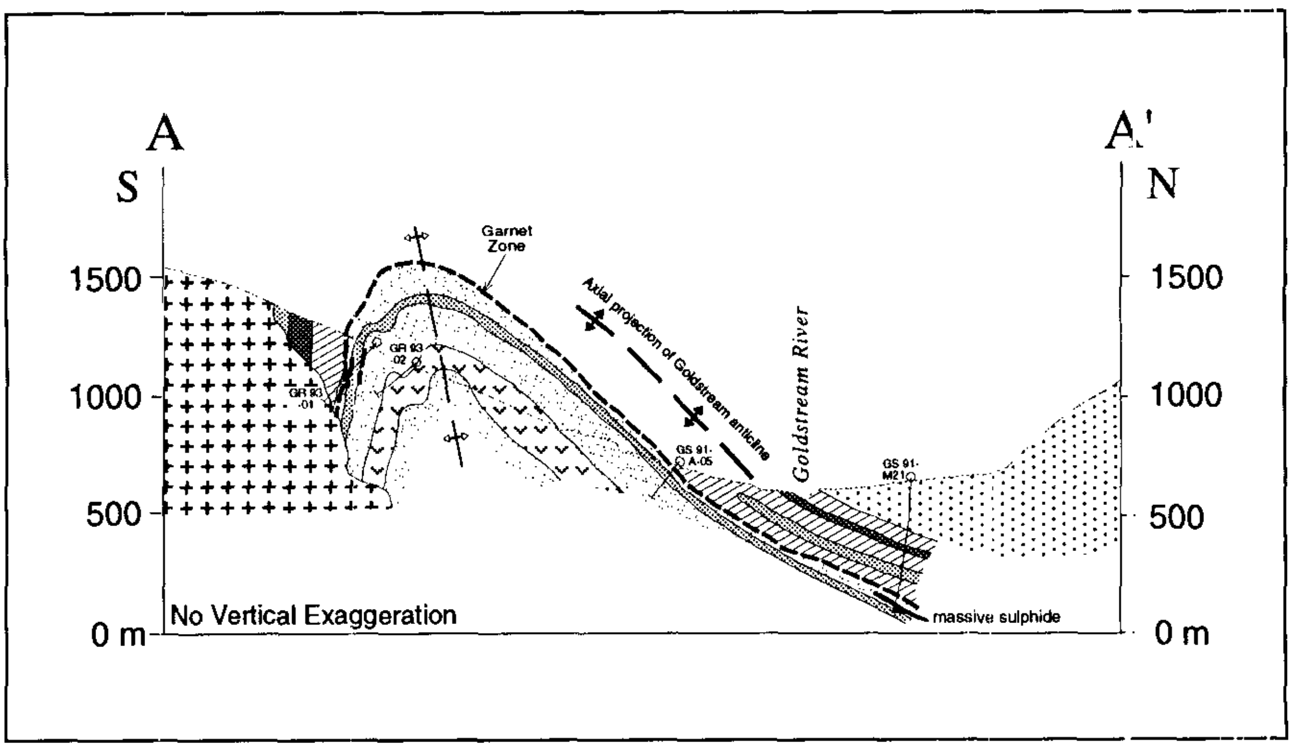


Figure 10: Cross-section of the Goldstream mine area. See Figure 9 for location of the line of section and for the legend.

surround Archean copper-zinc deposits in the Rouyn-Noranda district. At this stage, it is difficult to determine whether these assemblages are related to syndepositional alteration related to ore formation, the regional metamorphism or later contact metamorphism (prograde followed by retrograde metamorphism), or the combined affects of all these processes.

C-1

The C-1 zone was discovered in 1991 by diamond drilling coincident geochemical and geophysical anomalies on the south-facing slope of the 'hump', approximately 9 kilometres west of the Goldstream mine (Figure 3). The zone is comprised of one or more layers of disseminated and banded to locally semimassive pyrrhotite and sphalerite, with trace amounts of chalocopyrite and galena (McArthur *et al.,* 1991). Ten drill holes tested the zone over a strike length of 400 metres and down dip for up to 75 metres (McArthur *et al.,* 1991). The best intersection returned 3.94 % Zn, 1.54 % Pb, 0.04 % Cu and 31.19 g/t Ag over 2 metres. The sulphides are hosted by strongly fractured and faulted dark chlorite phyllite, carbonate and black graphitic phyllite, and minor quartz stockwork zones within these units. The thinly foliated calcareous green chlorite schists and carbonates are probably equivalent to the middle Index Formation, or the uppermost lower Index Formation, and are correlated with footwall rocks at the Goldstream mine. Talc-altered ultramafic rocks and dark graphitic phyllite crop out in a soapstone quarry 2 kilometres east of the C-1 zone. Drill hole stratigraphy (McArthur *et al.,* 1991) eastward towards the mine, shows an interlayered sequence of graphitic phyllites, chloritic phyllites, talc-altered ultramafic rocks and lesser carbonate as far east as the tailings pond (approximately 4 km east of the C-1 zone). Northwest of the C-1 showing, asbestos-bearing serpentinite occurs in graphitic schists of the lower Index Formation at the Monarch showing (Wheeler, 1965), now submerged by the Columbia River. Thinly foliated talc-altered greenschists and ankeritic talc schist may represent zones of hydrothermal exhalation (Fox, 1984) rather than altered ultramafic rock.

The mineralogy and host stratigraphy of the C-1 showing are similiar to the stratiform Rift lead-zinc deposit located approximately 22 kilometres north. The Rift consists of a number of layers of massive sphalerite, pyrite, pyrrhotite and galena, up to 2 metres thick. Sulphides are hosted by a predominantly schistose package of staurolite-grade quartz-garnet pelitic schist and layered calcsilicate with lesser psammite and marble (Gibson and Höy, 1985). A sheared and metamorphosed ultramafic body, 15 metres thick, intrudes the metasediments above the massive sulphide layer. It consists of magnesite, antigorite, talc and magnetite. Similiar ultramafic rocks occur in the Keystone area and are intimately associated with massive sulphides at the Standard deposit farther south.

MONTGOMERY

The Montgomery showings are located approximately 12 kilometres southeast of the Goldstream mine, below Downie Peak. They comprise a series of massive and disseminated sulphide lenses in micaceous quartzose schist, marble and carbonaceous sericite-chlorite phyllite. The hostrocks are similiar to those at the Goldstream mine, although metamorphosed to higher grade, and include siliceous garnetiferous hornfels, biotite and muscovite schist (± andalusite), and impure marble containing tremolite.

Sulphides have been traced intermittently by trenching for 770 metres along the Downie Creek slope (Schindler, 1982). This horizon extends across the divide between Long Creek and Boulder Creek at an elevation of about 1825 metres and then north along the Boulder Creek slope where it has been tested by open cuts and trenching for 250 metres. At its eastern end it has been tested by a short adit. The trace of the sulphide horizon corresponds with three zones of moderate to high airborne electromagnetic conductors (Bottomer and Dvorak, 1990) which trend westward, following topography for 3.6 kilometres from the western contact of the Long Creek stock. The extent of this horizon is apparent in the field and can be traced as discontinuous rusty zones exposed along cliff faces. Disseminated pyrrhotite is ubiquitous, but massive sulphides occur as discontinuous lenses along the horizon and base metal content, copper in particular, is low and erratic (Schindler, 1982). The width of the massive sulphide layers varies from 1 to 3.5 metres. Gunning (1929) reports a second zone of stratabound mineralization 215 metres vertically above and north of the adit. He describes disseminated pyrrhotite mineralization with low copper values, in a silicifed calcareous sediment. This zone was not visited during the 1994 field season, but it appears to have a similiar geophysical signature to that of the main horizon (see Bottomer and Dvorak, 1990), and a strike length of 500 metres.

Towards the eastern end of the sulphide zone, at the adit, hangingwall rocks are quartz-rich graphitic and rusty weathering biotite-sericite schists that contain chalcopyrite, pyrrhotite and traces of sphalerite. The sulphide zone contains mainly massive pyrrhotite with minor chalcopyrite and clear, rounded fragments of quartz, and dark green chlorite inclusions identical to the Goldstream ore. The footwall to the sulphides is mafic chlorite-biotite-quartz schist and calcsilicate. Felsite apophyses from the Long Creek stock crosscut the succession and skarns are developed in calcareous units. The sulphide layers have been folded about east-trending cross-folds and, at the portal, the sulphide layer dips south out of the hill. Limited sampling of the sulphide layer at the adit by Schindler (1982) showed a range of values between 0.3% to 0.7% Cu, and grades of 1% to 2% Cu where chalcopyrite is concentrated along the margins of the sulphide bed. Zinc averages approximately 0.5%. Analysis of a single grab sample from the adit returned values greater than 1 % Cu, 3120 ppm Zn, 116 ppm Pb, 37 ppb Au and 11.6 g/t Ag.

Two diamond-drill holes were completed in October of 1990 to test the down-dip extension of the massive sulphides exposed at the adit (Campbell and Lewis, 1991). The holes were collared approximately 85 metres northeast of the adit (B. Meyer, personal communication, 1994). Multiple, narrow massive sulphide horizons were intersected over 12 metres in thinly intercalated biotite schist and calcsilicate rocks structurally above the projected sulphide layer. The massive sulphide body that crops out at the adit was not intersected.

Along strike to the northwest, several sloughed trenchs expose deeply weathered iron oxide coated fine-grained massive pyrrhotite and silicified, sulphidized biotite-sericite schists. Two hundred metres northwest of the adit, sulphides are exposed in a vertical cut. Massive pyrrhotite, chalcopyrite and minor sphalerite occur in two layers, 0.3 and 3 metres thick, separated by 1 metre of sulphidic sericite schist. The thicker and lower layer has a hangingwall quartz zone containing coarse chalcopyrite and pyrrhotite filling crosscutting fractures in the quartz. A 3-metre chip sample across the massive sulphides returned in excess of 1% Cu, 3540 ppm Zn, 500 ppm Pb, 29 ppb Au and 12.6 g/t Ag. The massive ore has the same mineralogy, gangue inclusions and texture as ore at Goldstream.

Farther west, in the Boulder Creek watershed, the zone can be traced as a rusty stratabound horizon for at least 250 metres across cliff faces. Host stratigraphy is pale orange weathering, black phyllite and mica schist of the lower Index Formation. Structurally above the schist is a thick package of buff, grey and white, crystalline, calcareous and dolomitic impure marble. The massive sulphide layer and schistose country rocks are tightly folded about northeast-plunging east-verging structures.

The sulphide bodies are lensoidal, not exceeding 10 metres in length or 2 metres in thickness, and discontinuous along strike. Pyrrhotite is the dominant sulphide. Chalcopyrite is concentrated along siliceous margins of the lenses and occurs as disseminated blebs and streaks within the pyrrhotite groundmass, or as pressure shadows to clear, rounded quartz inclusions. Alteration of the enclosing metasediments is most obvious in the footwall rocks. They consist of thinly foliated, silicified and sericitized pink mafic volcanic rocks which pass downward into a chloritic, actinolite greenschist (mafic metavolcanic rock) and thinly foliated, rusty weathering biotite-chlorite-quartz schists. Hangingwall rocks are thin-layered, dark grey quartzose biotite schists with variable disseminated pyrrhotite. The sulphide zone and host stratigraphy were sampled as part of the regional alteration study.

UPPER MONTGOMERY

A disseminated sulphide bearing horizon crops out high above Montgomery Lake on the east-trending divide between Goldstream River and Downie Creek (Figure 3). The sulphide horizon is hosted by rusty weathering, thinly foliated actinolite schist and siliceous schist/metachert which form the hangingwall of a metadiorite sill 1 to 3 metres thick. The horizon can be traced for approximately 500 metres in a sequence of interlayered graphitic pelite, marble and micaceous quartzite which is coarsening upward. The sequence above the sulphide horizon consists of clean quartzite, mica schist and marble. The latter hosts the lead-zinc mineralization of the KJ showing.

The Upper Montgomery sulphide horizon has a prominent electromagnetic signature (Bottomer and Dvorak, 1990). It was sampled near its eastern and western ends and analyses returned low base and precious metal values, but elevated manganese.

Diamond drilling in 1994 tested the eastern end of this zone (Meyer, 1994). Drill hole 94-2 intersected two semimassive pyrrhotite zones separated by 26 metres of interlayered greenstone, dark graphitic pelite and carbonate units. The upper (3.8 metres) and the lower (3.2 metres) zones returned trace to insignificant copper values. Drill hole 94-3, collared 100 metres north-northwest of 94-2, intersected only the upper sulphide zone. Analysed samples returned trace amounts of copper.

ICE

The Ice showing was discovered in 1989 during a regional exploration program conducted by Bethlehem Resources Corporation and Goldnev Resources Inc. Numerous, subangular massive pyrrhotite boulders up to 0.5 metre square are dispersed along the north wall of a cirque at 2500 metres elevation (Figure 3). The southern margin of the Goldstream pluton crops out in the cliffs immediately to the north. A single grab sample consisting of chips from five of these boulders returned 6.23 g/t Au, 3.23 g/t Ag, 540 ppm Cu and 96 ppm Zn. These values compare well with those reported by Gibson (1989).

Polished thin section studies by J. Payne of Vancouver Petrographics Ltd., describe the sulphide sample as a fine-grained skarn dominated by pyrrhotite with interstial grains of diopside and lesser plagioclase. Chalcopyrite, minor bismuth minerals and traces of arsenopyrite and electrum occur mainly in patches and fractures in diopside (Gibson, 1989).

Massive pyrrhotite, with similiar gold grades to those reported here, has been discovered in place during the summer of 1994, in the cliffs above the boulder train. The massive pyrrhotite layer is 1 to 2 metres thick and exposed along strike for over 5 metres in a north-northeasterly direction. Analysed samples returned up to 7.5 g/t Au and elevated copper, bismuth and tungsten. The layer is hosted by a pelitic calcareous pendant in the Goldstream pluton (Meyer, 1994).

Boulders from the Ice showing have low base metal values, but their source is an interesting target due to the elevated gold values which are unknown in the other copper-zinc volcanogenic massive sulphide deposits of the area, except perhaps at the J&L, about 25 kilometres to the south.

BREW

The Brew massive sulphide showing was discovered in 1989. It is located at the head of Granite Creek, approximately 6 kilometres northwest of, and on strike with the Montgomery showings. The showing is at the southern margin of the Goldstream pluton which is characterized by east-trending pendants and sill-like bodies.

Mineralization consists of at least two stratabound massive pyrrhotite lenses, each up to 0.7 metre thick, (Gibson, 1989) hosted by a pendant within the Goldstream pluton. Pendants in the vicinity of the showing are predominantly marble, micaceous quartzite and biotite-quartz-amphibolite gneiss. Foliation-parallel zones of coarse garnet-diopside-calcite skarn, 0.5 metre thick, are present in the marbles. Dikes of biotite-hornblende diorite cut the pendants, and locally envelop and digest the smaller country rock inclusions. Lithologies hosting the sulphides include rusty weathering micaceous calcsilicates and micaceous quartzite. These lithologies are similiar to the hostrocks at the Montgomery, which are correlated with the lower Index Formation and are equivalent to the Goldstream mine sequence.

Hornblende-biotite diorite of the Goldstream pluton is exposed where creeks have incised these pendants, suggesting that the main intrusive contact follows the steep south-facing slope and not the east-trending margins and main foliation of the pendants. Sketch maps by Gibson (1989) show hostrocks and massive sulphides at the Brew showing are folded into a south-closing anticline with a north-dipping axial plane. He projects the sulphide beds and strata downdip to the north. The apparent south-facing, dip-slope intrusive contact, may truncate the pendant relatively close to the present surface, limiting the potential for any down-dip continuity to the mineralization.

The sulphide zones are exposed along steep inaccessible cliffs that have inhibited assessment and sampling. The sulphide zone contains minor amounts of streaky disseminated chalcopyrite. Samples from the 1989 field program returned copper grades below 0.1 % (Gibson, 1989). Preliminary results from seven samples collected during the 1994 sampling were not higher than 650 ppm Cu (Brian Meyer, personal communication, 1994). The low copper content of the massive sulphide horizons, the small area of the pendant and its probable truncation by the pluton, limit its potential to host economic copper mineralization.

CARBONATE REPLACEMENT

The KJ prospect is a carbonate hosted lead-zinc sulphide occurrence. Small pods of coarse cubic galena with traces of sphalerite and pyrrhotite are localized in silicified breccia zones and quartz veins in grey, fine-grained dolomitic marble. The prospect has been described by Höy (1979) as stratabound within a pure to siliceous marble-calcsilicate gneiss layer several tens of metres thick.

Drilling on the carbonate unit (Ramani, 1975), shows the mineralized interval to be approximately 35 metres thick, with a down-dip continuity greater than 200 metres (Höy, 1979). Drilling in the fall of 1994 intersected approximately 47 metres of quartz flooding and veining. This includes a central 8-metre intercept of quartz stockwork with sporadic galena. Sulphide mineralization is weak, with 1 to 5 % pyrrhotite, traces of galena and very low precious metal values (Meyer, 1994).

GOLD-QUARTZ VEINS

The occurrence of gold-bearing quartz veins in the Groundhog basin was first reported shortly after the discovery of placer gold in adjacent creeks in 1865. The best known claims, Ole Bull and Orphan Boy, were explored in 1896 (Gunning, 1929; Wheeler, 1965). The Grounhog basin has been intermittently explored since 1900 (summarized in Schindler, 1984).

The mineralized veins trend north-northeast and are subvertical, cutting the gentle easterly dip of the dominant foliation at a high angle. At least two other sets of barren veins are identified in the Groundhog basin area (Schindler, 1984): veins that are concordant with the dominant foliation; and discordant veins 1 to 2 metres wide that trend east-southeast, parallel to the attitude of late crenulation cleavage in the area.

The mineralized veins average 25 to 30 centimetres wide (with a maximum width of about 4 metres) and are composed of milky quartz and pyrite, with trace amounts of pyrrhotite, scheelite, galena and free gold (Schindler, 1984). Pyrite cubes, 2 to 3 centimetres across, are locally observed in the veins. Ankeritic alteration is commonly developed in the wallrocks. Disseminated pyrite is also present in country rock adjacent to the veins. The veins locally have a limonitic alteration. Fuchsite is a common mineral in calcareous schist throughout the Groundhog basin. It shows no particular spatial or genetic relationship to the gold-quartz veins.

Schindler (1984) and Horne (1985) report that the best gold values are found in veins developed within graphitic schist of the Index Formation (Lardeau Group). However, Horne also mentions that the quartz veins are discontinuous and that the gold distribution is erratic.

PLACER GOLD

Placer gold deposits in French, McCulloch, Graham, and Old Camp creeks, and lower Goldstream River were discovered in 1865 (Gunning, 1929), and have been exploited intermittently since then. Production figures compiled by Holland (1980) show that the largest reported production originated from French Creek. Today, only a few small-scale operations on McCulloch Creek and Old Camp Creek are active. Thousand Hills Mining, has acquired a large block of ground and spent considerable time and money on exploration and production testing on its French Creek property. The gold occurs as coarse, angular nuggets close to bedrock, and as fine colours in gravels, and is commonly associated with galena (Gunning, 1929). The Groundhog basin area is the most likely source of placer gold.

EXPLORATION PARAMETERS

Periods of intermittent extensional tectonism are interpreted to have occurred along the western margin of North America throughout Late Proterozoic to early Paleozoic time (Gordey *et al.*, 1987, Turner *et al.*, 1989, Root, 1987). In the Selkirk Mountains, rocks of the Horsethief Creek and Hamill groups are interpreted to record Neoproterozoic and latest Proterozoic - Early Cambrian extensional tectonism (Bond *et al.*, 1985; Devlin, 1989; Ross, 1991), and the lower Paleozoic stratigraphy of the Lardeau Group may be explained in terms of extensional deformation (Colpron and Price, *in press*). Volcanogenic massive sulphide deposits of the Besshi-type form in various extensional environments (Slack, *in press*). The critical factors defining this deposit type include a spreading ridge to provide heat and basalt, and proximity to a land mass to provide clastic detritus. Interpretations of the geology of the northern Selkirk Mountains indicate that a rifted continental margin environment characterized the region at least three times during latest Proterozoic to Paleozoic.

All volcanogenic massive sulphide deposits in the region are hosted by the lower Lardeau Group. In the Goldstream River area, the Horsethief Creek Group contains only limited amounts of mafic volcanic rocks and, therefore, has limited potential to host Besshi-type deposits. The mafic volcanic rocks of the Hamill Group are chiefly barren and unaltered. Locally, strongly foliated Hamill greenstones have abundant malachite stain but no visible sulphides.,

The lower and middle members of the Index Formation in the Goldstream area consist of black carbonaceous phyllite and green calcareous phyllite that contain talc schist lenses and mafic to ultramafic volcanic rocks. This sequence of fine-grained euxinic clastic rocks, talc schist and mafic volcanic rocks may represent a sediment-sill complex similar to those forming at modern sediment-covered ocean spreading centres (Einsele *et al.*, 1980; Morton and Fox, 1993). Sulphide accumulation at these spreading centres (Escanaba Trough, Middle Valley and the Guaymas Basin) is similiar in its form, mineralogy and chemistry to Besshi-type volcanogenic massive sulphide deposits (Zierenberg *et al.*, 1993). The Index Formation, in the northern Selkirk Mountains, hosts numerous copper-zinc deposits that have characteristics similiar to the Besshi deposits in Japan (Höy et al., 1984). The Guaymas Basin, an ocean spreading centre at a rifted continental margin, is a possible modern analog of the tectonic environment that prevailed during deposition of the Lardeau Group. Trace element chemistry of the sill and dike complex in the Goldstream River area is compatible with this environment. Thus, the lower and middle members of the Index Formation are an important regional metallotect in the northern Selkirk mountains.

The Goldstream ore horizon, with or without its garnet zone, has been traced by drilling for approximately 3 kilometres northwest and 3 kilometres southeasterly, around the cross-fold south of the open pit and into the Goldstream pluton. Stratabound zinc-lead-silver mineralization occurs at the C-1 zone, approximately 8 kilometres farther west along strike and probably occupies a higher stratigraphic position (*i.e.*, lower in the hangingwall). A simliar sulphide-bearing horizon can be traced for over 3.5 kilometres on the south side of the Goldstream pluton from the Montgomery adit to possibly as far as the Brew showing. This horizon outcrops at high elevations along steep cliff faces, in dark phyllite correlative with the lower Index Formation. In addition, an isolated, fault-bounded occurrence of the garnet zone was discovered in 1993 east of Downie Peak (Logan and Drobe, 1994). It is unlikely that these horizons occur along a single stratigraphic level. They probably reflect active hydrothermal venting at various times during deposition and intrusion of the sediment-sill complex.

All of these horizons are extensive and capable of containing substantial massive sulphide inventories over restricted distances. The sulphide layer at the Goldstream mine averages 300 metres in strike length and 1 to 3 metres in thickness. The ore horizon has been drill tested for more than 6 kilometres without another substantial massive sulphide deposit being located. Besshi-type deposits occur as clusters of orebodies and, therefore, all prospective horizons require careful testing in order to evaluate their mineral potential.

There are several areas with high potential to host undiscovered volcanogenic massive sulphide deposits in the Goldstream River map area. The area west of the Goldstream mine is currently under exploration by Bethlehem Resources Corporation. North of the Goldstream River, between French Creek and the Columbia River, a large area underlain by rocks of the lower, middle and upper Index Formation probably contains rocks equivalent to the stratigraphy that hosts the Goldstream deposit. Rock types include dark graphitic and calcareous phyllite; chloritic schists (greenstones), phyllite and carbonates; and quartz and feldspathic grits and micaceous quartzites. This area has been prospected for gold-quartz veins but never fully assessed for its massive sulphide potential. Serpentine-talc bodies and abundant fuchsite are associated with mineral occurrences at the Rift showing, at the Goldstream mine and, to the south, at the Standard showing, and are ubiquitous in the rocks north of the Goldstream River, particularly in the Groundhog basin. This belt of rocks is under explored and warrants thorough assessment.

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