NORTHERN SELKIRK PROJECT, GEOLOGY OF THE DOWNIE CREEK MAP AREA (82M/8)

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KEYWORDS: Downie Creek, Carnes Creek, Columbia River, J&L, Standard, Rain, Keystone, Lardeau Group, Index Formation, Badshot Formation, Hamill Group, volcanogenic massive sulphide, iron-manganese exhalatives.

INTRODUCTION

Lower Paleozoic rocks of the northern Selkirk Mountains are host to numerous volcanogenic massive sulphide occurrences. These include the Goldstream copper-zinc mine, which has produced 70 000 tonnes of copper and 49 000 tonnes of zinc from 1 738 500 tonnes milled, between April, 1991 and October, 1995 (S. Robertson, personal communication, 1995), and the arsenical gold-rich J&L deposit which has probable and possible reserves in excess of 5 million tonnes averaging 2.71 % Pb, 4.33 % Zn, 7.23 g/t Au and 72 g/t Ag. The stratiform nature of these deposits makes understanding the regional stratigraphic and structural setting fundamental to the assessment of mineral potential and exploration for new deposits. The main objectives of the Northern Selkirk project are to establish the stratigraphic and structural framework of known volcanogenic massive sulphide deposits in the northern Selkirk Mountains, and to assess the potential for similiar deposits in correlative successions elsewhere.

This report presents the results of regional bedrock mapping of the Downie Creek area (NTS 82M/8), completed east of the Columbia River, during the summer of 1995. This program marks the second full season of mapping in the Northern Selkirk Mountains. Reconnaissance mapping and deposit studies were initiated in 1993 (Logan and Drobe, 1994). Mapping of the area around the Goldstream deposit (82M/9 and part of 10) was completed in 1994 (Logan *et al.*, 1995, Colpron *et al.*, 1995). Our 1995 study area ties onto the southern boundary of the Goldstream River area, traces prospective stratigraphy southward (Logan *et al.*, 1996) and builds upon previous compilation of the area by Brown (1991).

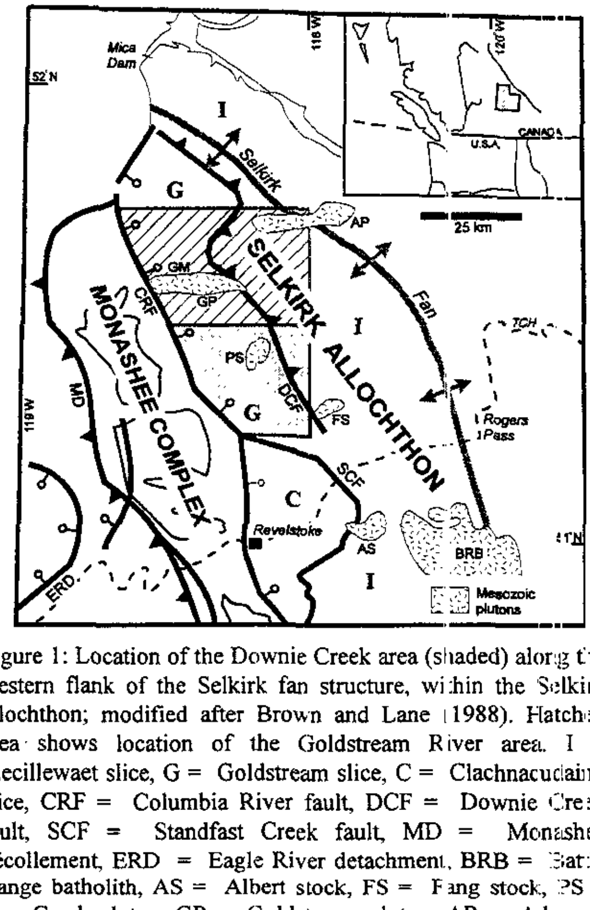


Figure 1: Location of the Downie Creek area (shaded) along the western flank of the Selkirk fan structure, within the Selkirk allochthon; modified after Brown and Lane (1988). Hatched area shows location of the Goldstream River area. I = Illecillewaet slice, G = Goldstream slice, C = Clachnacudainn slice, 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 pluton, GP = Goldstream pluton, AP = Adamant pluton, GM = Goldstream mine, TCH = Trans-Canada Highway.

REGIONAL GEOLOGY

The Downie Creek 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, 1965; 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).

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 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). Okulitch *et al.* (1975) and Parrish (1992) have shown that orthogneisses of the Clachnacudainn Complex are, in part, Devonian-Mississippian in age.

The northern Selkirk Mountains form part of a large allochthon that was displaced eastward some 200 to 300 kilometres between Late Jurassic and Paleocene time (Price, 1981; Brown *et al.*, 1986, 1992a). 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 this 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, extending 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)

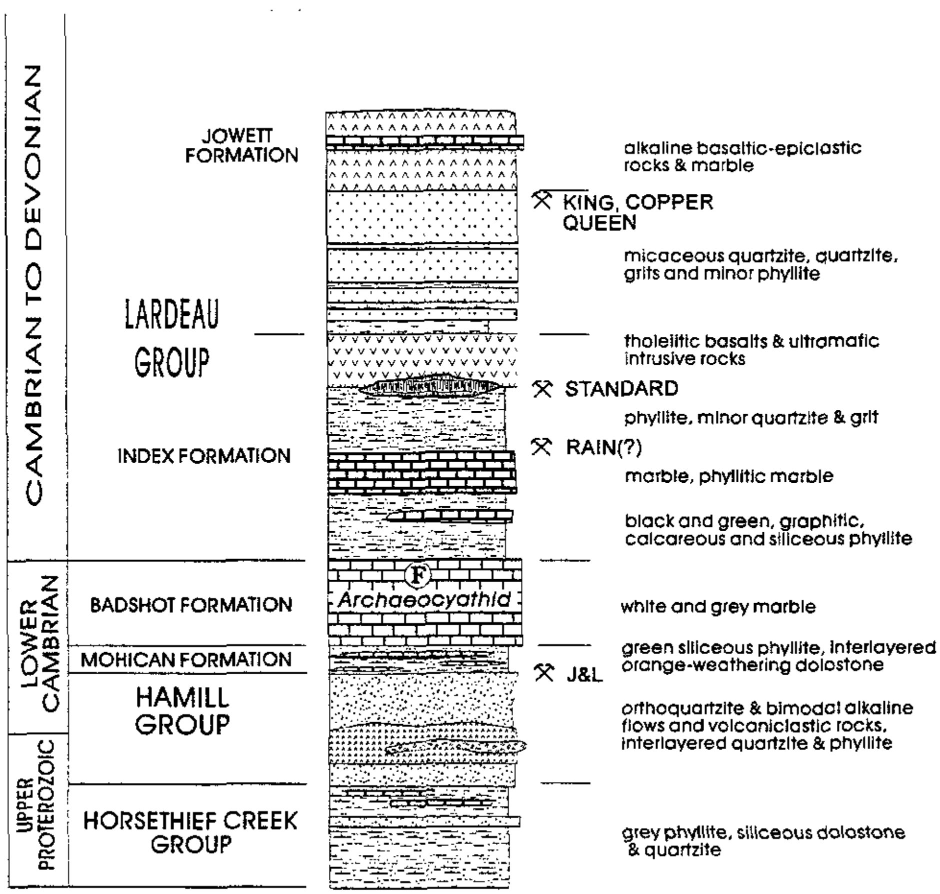


Figure 2: Summary of stratigraphic units mapped in the Downie Creek area.

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 THE DOWNIE CREEK AREA

Rocks of the Hamill and Lardeau groups, and the intervening Mohican and Badshot formations, comprise the majority of exposures in the Downie Creek area (Brown, 1991; Wheeler, 1965; Figure 3). Two narrow belts of rock correlated with the Horsethief Creek Group (Wheeler, 1965) are also exposed in the area northeast of Downie Creek (Figure 3).

HORSETHIEF CREEK GROUP

The stratigraphy of the Horsethief Creek Group in the northern Selkirk Mountains has been defined by Brown *et al.*(1978). They have subdivided the Horsethief Creek stratigraphy into lower pelite, middle marble, and upper pelite members. They further suggested that the upper part of the upper pelite member grades westward into a sequence of calcareous pelitic schists with intercalations of marble, impure psammite and quartzite.

In the Downie Creek area, rocks assigned to the Horsethief Creek Group comprise a sequence of soft, tan-weathering, pale green or pinkish grey phyllite, intercalated with pink to light brown siliceous dolostone (5 cm to 2 m thick) and white, pink and light green quartzite. The quartzite beds range from 5 centimetres to 2 metres in thickness and are fine grained and massive. They generally represent less than 30% of the map unit, although micaceous quartzite locally makes up 40-50%.

HAMILL GROUP

Devlin (1989) recognized three stratigraphic divisions within the Hamill Group in the northern Selkirk Mountains: a lower sandstone unit; a greenstone - graded sandstone unit; and an upper sandstone unit. In the Goldstream River area, we mapped the lower two divisions of the Hamill Group (Logan and Colpron, 1995; Colpron *et al.*, 1995). The middle unit of greenstone and volcaniclastic rocks is only locally present in the Downie Creek area, and, as a result, the distinction between lower and upper sandstone units is not easily made.

Most exposures of the Hamill Group are composed of interbedded quartzite and pelite. The quartzite is light green, white or pink, texturally mature, fine to medium grained, and occurs in beds 3 centimetres to 2 metres thick. It is interbedded, in variable proportions, with light green, light grey or dark grey siliceous phyllite in beds a few centimetres to a maximum of 1 metre thick. The quartzite-pelite assemblage is commonly graded, with medium-grained quartzite showing a sharp erosional base and grading into dark siltstone and pelite. The beds are typically characterized by fine, dark, parallel laminations; they locally display tabular crossbeds with well defined mud drapes on the foresets. Locally, smal mud chips are present at the base of quartzite beds. Minor buff-weathering sandy dolostone beds are locally interbedded with the quartzite-pelite assemblage. South of Carnes Peak, buff dolostone beds locally represent up to 30-40% of the quartzite-pelite assemblage.

South of Mount Craib, a pure, white to pink orthoquartzite underlies a small peak and extends southeastward for at least 5 kilometres. The orthoquartzite occupies the core of a southwest-verging antiform and has an apparent thickness of less than 100 metres. The quartzite occurs in beds 3 to 4 metres thick, with centimetre-scale interbeds of light grey to light green, rusty weathering siliceous phyllite.

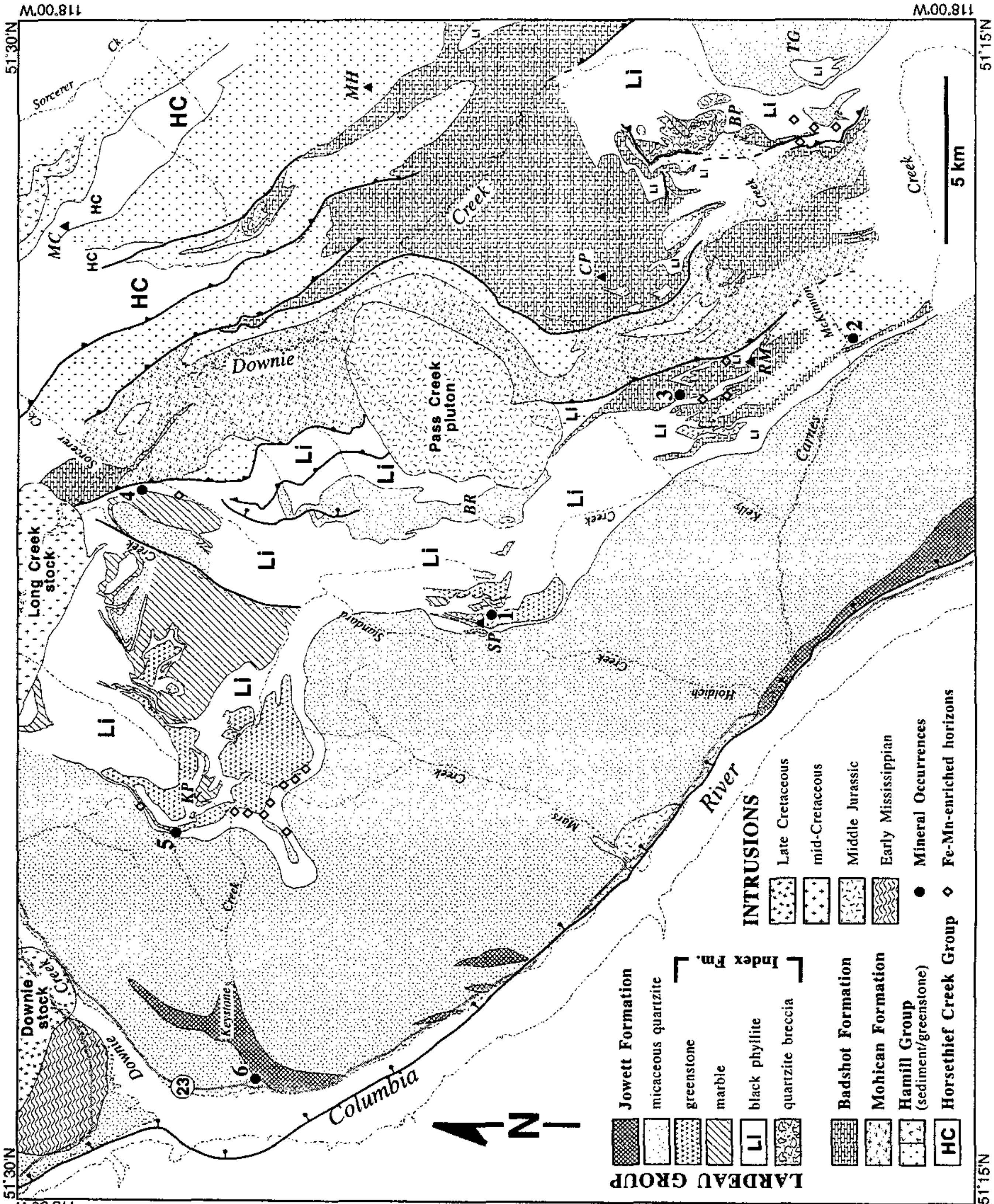
Near its contact with the overlying Mohican and Badshot formations, the Hamill quartzite is typically more massive and thickly bedded (average of 1-2 m) and locally displays large sets (30-50 cm) of trough crossbeds. Its lower contact with the Horsethief Creek Group appears to be gradational; it is marked by an increase in quartzite content and a decrease in dolostone. The Hamill Group has a minimum thickness of about 300 metres in the area northeast of Downie Creek.

Exposures of the greenstone-volcaniclastic assemblage of the Hamill Group are limited to few outcrops along Sorcerer Creek and to alpine exposures of massive greenstone and minor intermediate trachyandesite rocks northeast of Mount Craib (Figure 3).

MOHICAN FORMATION

The Mohican Formation forms a prominent belt of exposures from the west flank of Carnes Peak northward to the confluence of Sorcerer and Downie creeks (Figure 3). Elsewhere, it is represented by only a few metres of section between the Hamill quartzite and the Badshot marble, and locally is absent.

The Mohican Formation consists of light green, light grey, and medium grey siliceous phyllite, commonly intercalated with brown and orange-weathering sandy dolostone beds (1-25 cm thick). Locally, the Mohican also includes light green, fine-grained micaceous quartzite, and beds of light to medium grey marble up to 2 metres thick. East of Roseberry Mountain, a succession of orange-brown weathering dolostone at least 20 metres thick occurs within the Mohican Formation. Near the confluence of Sorcerer and Downie creeks, a light to medium grey pisolitic dolostone can be traced for a few kilometres within the formation. This same dolostone has



118°00'W
51°30'N
51°15'N
118°30'W
LARDEAU GROUP
Jowett Formation
micaceous quartzite
greenstone
marble
Li
black phyllite
quartzite breccia
Index Fm.
Badshot Formation
Mohican Formation
Hamill Group
(sediment/greenstone)
HC
Horsethief Creek Group
INTRUSIONS
Late Cretaceous
mid-Cretaceous
Middle Jurassic
Early Mississippian
Mineral Occurrences
Fe-Mn-enriched horizons
N
5 km
Columbia
River
Downie stock
Long Creek stock
Pass Creek pluton
Downie
Sorcerer
Creek
Keystone
Mars
Holdich
Standard
Kelly
Carnes
McKinnon
MC
MH
CP
BP
TG
RM
BR
SP
KP
23

been traced northward along the north-side of the Long Creek stock for 5 kilometres (Colpron *et al.*, 1995). White tremolite-bearing marble occurs in scattered exposures along the east side of the Long Creek stock.

BADSHOT FORMATION

Marble of the Badshot Formation forms the prominent peaks of the Carnes Peak massif. It consists of white, light grey, and medium grey marble, locally dolomitic. Near Roseberry Mountain, the Badshot also includes dark grey to black, bioturbated, argillaceous limestone, in which the burrows are filled with brown-weathering sandy dolostone. A few layers of soft, tan phyllite (3-5 m) are also present west of Roseberry Mountain. At Bridgeland Pass, the Badshot includes lenses of dolostone breccia 2 to 3 metres thick. The thickness of the Badshot Formation varies from a few metres to about 300 metres. Rapid changes in thickness are common along the valley of McKinnon Creek. It is uncertain whether they are the result of primary or tectonic processes.

Read and Brown (1979) and Brown (1991) reported the occurrence of *Archeocyathid* in marble of the Badshot Formation at Roseberry Mountain and Bridgeland Pass. In addition to the localities documented by Brown (1991), we have found two new *Archeocyathid* localities, west of Roseberry Mountain and north of Bridgeland Pass. The occurrence of *Archeocyathid* indicates a late Early Cambrian age for marbles of the Badshot Formation.

LARDEAU GROUP

The Lardeau Group (Walker and Bancroft, 1929) conformably overlies the Badshot Formation and is unconformably overlain by the Milford Group (Read and Wheeler, 1976). As defined by Fyles and Eastwood (1962) in the Ferguson area, it includes six formations (Figure 4). In ascending stratigraphic order these are; 1) dark grey and green phyllites, thin limestone and volcanic rocks of the Index Formation, 2) black siliceous argillite of the Triune Formation, 3) grey quartzite of the Ajax Formation, 4) grey siliceous argillite of the Sharon Creek Formation, 5) volcanic rocks of the Jowett Formation, and 6) grey and green quartz-feldspar grit and phyllite of the Broadview Formation. As the Lardeau stratigraphy is traced northward into the Akolkolex River area, the Ajax quartzite pinches out and an intervening unit of grit is exposed between the black phyllites of the Index Formation and the overlying Sharon Creek and Jowett formations (Read and Wheeler, 1976; Sears, 1979). 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 (Colpron and Price, 1993). Colpron and Price (1993; 1995a) assigned all three units to the Index Formation. A similar three-fold subdivision of the Lardeau Group has been recognized in the Goldstream River map area (Gibson and Höy, 1994; Logan and Drobe, 1994) and was assigned to the Index Formation (Logan and Colpron, 1995).

Figure 3: Geological map of the Downie Creek area compiled from our 1995 mapping and from Wild (1990) and Brown (1991). Mineral occurrences: 1 = Standard; 2 = J&L; 3 = A&E; 4 = Rain; 5 = Keystone; 6 = King. Topographical features: MC = Mount Craib; MH = Mount Holway; CP = Carnes Peak; BP = Bridgeland Pass; TG = Tumbledown galcier; RM = Roseberry Mountain; SP = Standard Peak; KP = Keystone Peak.

In the Downie Creek area, the Lardeau Group consists of five lithostratigraphic units which have complex stratigraphic inter-relations (Figure 4). They include, in approximate stratigraphic order; 1) black graphitic, calcareous and/or siliceous phyllite, discontinuous quartzite and limestone; 2) light grey marble; 3) greenstone and metavolcaniclastic rocks; 4) micaceous quartzite, quartzite, quartz grit and grey phyllite; and 5) metavolcaniclastic rocks, greenstone and marble.

BLACK PHYLLITE

The lower part of the Lardeau Group consists of a 250 to 500-metre succession of dark grey to black calcareous phyllite, brown-weathering phyllitic dolostone and black graphitic phyllite which contains minor dark grey calcitic marble. Locally, dark grey micaceous and dolomitic quartzite beds, light grey marble up to 20 metres thick, quartz grit and chlorite phyllite occur within the black phyllite unit. Black phyllite occurs both below and above the greenstone units exposed in the Keystone and Standard areas (Figures 3 and 4).

South of Keystone Peak, dark grey siliceous phyllite, black cherty quartzite and graphitic phyllite stratigraphically overlie the massive greenstone in the overturned limb of the Keystone antiform. The quartzite and phyllite are rhythmically interbedded, on a centimetre to 10-centimetre scale. Carbonaceous material, pyrite and manganese oxide are ubiquitous throughout the unit in this area. This sequence crops out in the upper drainage basin of Keystone Creek, and can be traced south and east into the upper reaches of Mars Creek.

East of Standard Peak, in the pass between Standard and Kelly creeks and extending up to Belcher Ridge, a sequence of black calcareous and siliceous phyllite, and minor micaceous quartzite and marble, overlies the greenstone unit. The phyllite becomes more siliceous up-section as it gradually passes into the quartzite that underlies Belcher Ridge.

Thin (<3 m) intraformational carbonate conglomerate units are present within black phyllite of the lower Index Formation at Roseberry Mountain and north of Tumbledown glacier. The limestone is typically dark grey or dark brown, contains round and subangular clasts of black and light grey limestone and black phyllite. These units occur stratigraphically above the Badshot-Lardeau contact and the basal conglomerate described by Brown *et al.*, (1983).

Southeast of Mount Holway, the base of the black phyllite unit is represented by pale greenish grey sericite phyllite, brown-weathering carbonate and minor pink micaceous quartzite. These rocks are interlayered with, and stratigraphically overlie the Badshot marble. The green phyllite is in sharp contact with the black marble that characterizes the top of the Badshot Formation in the area. It is, in turn, gradationally overlain by dark grey to black, orange-weathering phyllite more typical of the Index Formation. The phyllite consists of thin layers of light green to silver sericite phyllite, and dark brown weathering carbonate, pink micaceous quartzite and grey phyllite. Similar interlayered green phyllite and yellowish brown marble crop out at the contact between light grey marble and black phyllite along the base of Keystone Peak.

LIGHT GREY MARBLE

A sequence of light grey to white marble, with an apparent thickness of 150 to 300 metres, is exposed in the Keystone area. The marble underlies Keystone Peak and occupies the core of the Keystone antiform; Brown (1991) interpreted it as part of the Index Formation. On Keystone Peak, it is an homogenous light grey to white marble with the bedding outlined by dark grey, wispy laminations.

Light grey and white crystalline marble, thinly foliated buff-weathering phyllitic carbonate and brown-weathering massive dolomitic marble crop out along the ridge-top northeast of Keystone Peak, and down the west slope into Standard Creek. The marble forms the upright limb of the Keystone antiform. It is underlain (in the core of the antiform) by thin-layered black and orange-weathering graphitic phyllite on the slopes overlooking Downie Creek, 5 kilometres to the north. Thinly foliated limonitic-weathering phyllitic carbonate forms the uppermost part of the marble. It is gradational into a thin (<20 m) clastic succession of micaceous quartzite, grey phyllite and feldspathic grit, which in turn are overlain by massive greenstone. Dolomitization affects extensive irregular zones that crosscut bedding within the light grey marble. These zones follow, or terminate abruptly against the foliation, bedding and breccia zones, suggestive of a dolomitizing fluid front.

To the south, in the Standard area, a similar marble occurs in the core of the Standard antiform. However, here the marble appears to be only 5 to 10 metres thick,

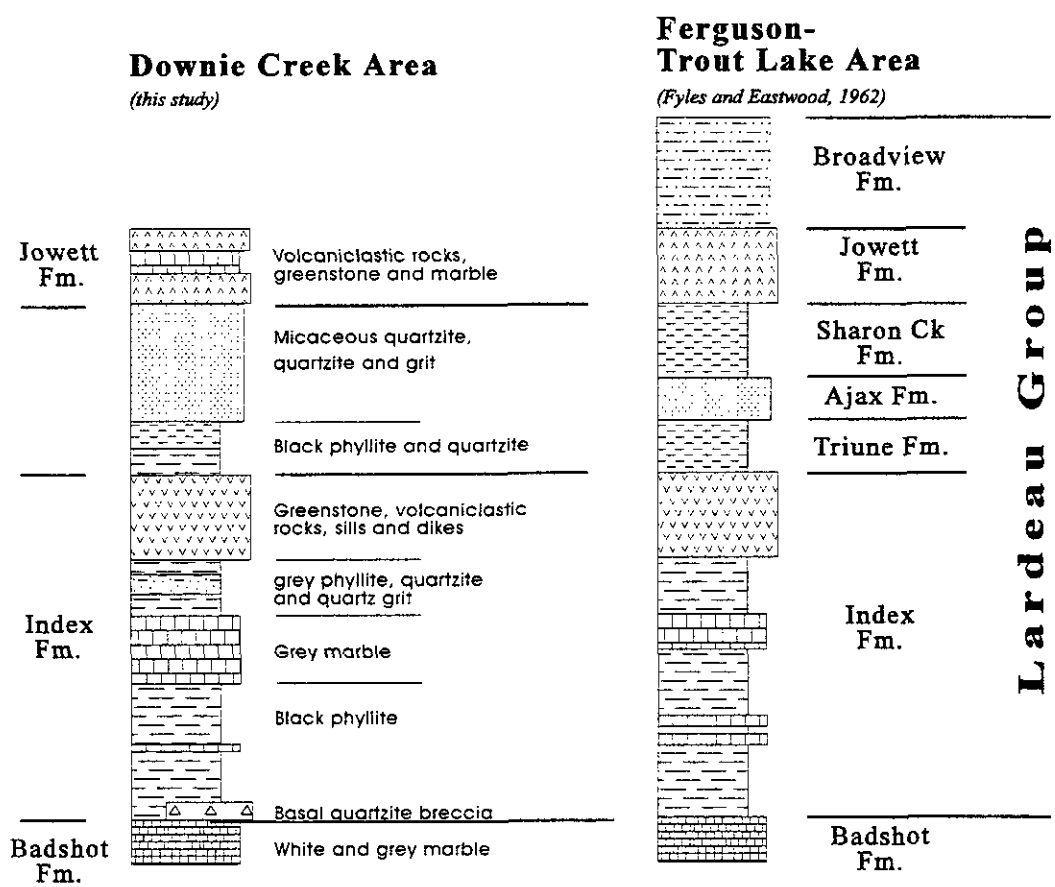


Figure 4: Stratigraphic relations within the Lardeau Group in the Downie Creek area. Ferguson-Trout Lake area stratigraphy after Fyles and Eastwood (1962).

and is underlain by black graphitic and calcareous phyllites. Minor brown-weathering phyllitic dolostone lenses are present within the marble unit at Standard.

GREENSTONE

Greenstone is present near the top of the black phyllite member in the Keystone and Standard areas. In both areas, black phyllite underlies and overlies the greenstone. The greenstone unit consists of dark khaki-green, massive to weakly foliated metavolcanic rocks. Locally, the massive greenstone is interlayered with thinly foliated phyllite and greenschist of probable tuffaceous origin. In other places, coarser grained, medium grey plagioclase-phyric flows and poorly formed pillowed breccia flows are present. Both lithologies are competent units and typically occur as boudins in more phyllitic greenstone units.

In the Keystone area, the greenstone locally contains epidote pods (*ca.* 30x50 cm). In the Standard Peak area, it is commonly characterized by the presence of abundant, small albite porphyroblasts. In the Keystone area the greenstone unit forms at least two distinct stratigraphic horizons within the black phyllite. Both lower and upper contacts of the greenstone layers are characterized by interdigitations of greenstone, green phyllite and black phyllite on the scale of 10 centimetres to several metres, indicating that the greenstone layers are conformable with the black phyllite unit.

In both the Keystone and Standard areas, ultramafic rocks are common at and near the contact between black phyllite and greenstone. They consist of black, massive antigorite schist; light grey, light green and white talc schist; brown and orange-weathering talc-magnesite schist, serpentine-anthophyllite schist and serpentinite. Small pods and lenses of coarse-grained metadiorite are also commonly associated with ultramafic occurrences in the Standard area. Sills of foliated metadiorite intrude black siliceous phyllite east of the head of Standard Creek. They are 2 to 25 metres thick, concordant with the dominant foliation in the area and composed of medium to very coarse grained, mottled, albite and chlorite. They are typically medium green and white in colour and display a penetrative foliation, outlined by flattened feldspar with chloritic pressure shadows. The thickest sill is medium grained, medium grey in colour and relatively massive, with only a weak fabric outlined by feldspar phenocrysts. The largest intrusion of metadiorite is intruded low in the Lardeau Group stratigraphy, near the contact with the Badshot Formation on the west flank of Roseberry Mountain. These intrusions may be related to similar rocks associated with the greenstone units in the Standard and Keystone areas.

Preliminary geochemistry indicates that the greenstone, green phyllite and the subvolcanic sills in the Standard and Keystone Peak areas, and near the Goldstream River to the north, are tholeiitic basalts of mid-ocean ridge basalt (MORB) affinity.

MICACEOUS QUARTZITE AND GRIT

Throughout the area, the black phyllite is stratigraphically overlain by a succession of quartzite, micaceous quartzite and grit. These form three northwesterly trending belts in the Downie Creek map area: Tumbledown glacier, Belcher Ridge and the western third of the map area, between Standard, Keystone and Roseberry peaks and the Columbia River (Figure 3).

In the southeastern corner of the map area, between Bridgeland Pass and Tumbledown glacier, the Lardeau Group stratigraphy includes an upright-facing succession of thinly bedded black graphitic, calcareous and locally pyritic phyllite, a mixed package of interlayered green phyllite, quartzite and buff calcareous quartz and feldspathic grits, and an upper package of interbedded rusty phyllite and calcareous quartz-feldspar grit and micaceous quartzite. Graded bedding and flame structures are present in the grit north of Tumbledown glacier.

On Belcher Ridge, the black phyllite unit is gradationally overlain by dark grey and brown quartzite, that locally has a dolomitic cement. The quartzite unit also comprises light grey to pink micaceous quartzite, grey siliceous phyllite and quartz-sericite schist, and subordinate quartz-feldspar grit. A 15 to 20-metre gritty, feldspathic quartzite is locally present at the base of the quartzite unit. The contact with the underlying black phyllites is characterized by intercalated black phyllite and light green micaceous quartzite, with quartzite becoming more abundant up stratigraphic section. Farther north, the contact is sharp and is marked by an intervening unit (up to 20 m thick) of interbedded orange-brown phyllitic dolostone, light green siliceous phyllite, micaceous quartzite and minor grey marble. The quartzites in the Belcher Ridge area are lithologically similar to those exposed along the east side of the Columbia valley, described below.

A thick (?), monotonous package of micaceous quartzite and quartz-muscovite schist stratigraphically overlies the black phyllite and greenstone units of the Lardeau Group along the east flank of the Columbia valley. This quartzite succession occupies the overturned limb of a southwest-verging antiform; it underlies a northwest-trending belt 5 to 10 kilometres wide, east of the Columbia River and extends north into the Goldstream map area (Logan and Colpron, 1995; Colpron *et al.*, 1995; Figure 3).

West of Standard Peak, green siliceous phyllite and micaceous quartzite are in gradational contact with green phyllitic-volcaniclastic rocks, micaceous quartzite, grit and black graphitic phyllite. Graded bedding in the micaceous quartzite indicates that they stratigraphically overlie the black phyllite and greenstone units of the Index Formation.

Adjacent to the contact with the phyllite, the lower sections of this quartzite package are characterized by a resistant medium-bedded white and pale pink or green quartzite and brown micaceous quartzite between Mars and Standard creeks and at Standard Peak. North of Keystone Peak, black phyllite is stratigraphically overlain by green chloritic schist and interlayered buff marble. A covered section separates these schists from green, gritty, chlorite-quartz schist and micaceous quartzite of the quartzite unit, and it is uncertain whether the covered interval contains a transitional facies or a structural break.

Along Carnes Creek, near the mouth of McKinnon Creek, the lower (?) part of the quartzite unit consists of quartzite and light green quartz-sericite schist, interlayered on the scale of a few centimetres and containing abundant white quartz veins and augen of vein quartz. Elsewhere, interbedded micaceous quartzite and green, grey or black phyllite characterize the lower part of the unit. The remainder of the quartzite section is chiefly greenish grey micaceous quartzite and interlayered rusty weathering quartz-muscovite schist. Compositional layering is defined by centimetre-thick, white, fine-grained quartzite layers. Coarse-grained quartzite and local grit layers, contain granules of blue and/or smokey quartz.

GREENSTONE AND MARBLE

Brown *et al.* (1983) correlated the green metavolcanic rocks and interlayered dolomitic marble exposed along the slopes overlooking the Columbia River with the Jowett Formation. In this area, these rocks are confined to several narrow, north-trending, belts in an inverted stratigraphic panel forming the immediate hangingwall of the Columbia River fault. They consists of a variety of mafic fragmental and epiclastic rocks, including massive to fragmental actinolite schists, dark green calcareous chlorite-albite-muscovite-quartz schist and green chloritic phyllite. They are characterized by a greenschist facies metamorphic assemblage of plagioclase-actinolite-calcite-epidote-chlorite and are interlayered with carbonate. At Holdich Creek, green chlorite-albite-quartz-calcite schist contains 25 metres of white and grey marble. The marble is typically thinly layered, coarsely crystalline, with buff to orange-weathering dolomitic and phyllitic sections at the upper and lower contacts. The contact with the structurally overlying micaceous quartzite and phyllite is gradational.

Preliminary trace element chemistry indicates that the calcareous greenstone exposed along roadcuts at Carnes Creek are alkaline basalts of within-plate affinity and have chemical signatures similar to Jowett Formation volcanic rocks in the Trout Lake area.

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 describe the contact in the Ferguson area as strongly sheared and the stratigraphic relationship not entirely certain. Reinterpretation of stratigraphic relationships in the Trout Lake area, and regional stratigraphic correlations with the lower Paleozoic rocks in northeastern Washington (Covada Group), has lead Smith and Gehrels (1992a, b and c) to propose that the Lardeau Group has been tectonically juxtaposed over the Badshot Formation and that its present stratigraphic succession may be inverted as a result of thrust imbrications, along layer-parallel faults, of a largely upright sequence. Work in the Illecillewaet synclinorium (Zwanzig, 1973; Colpron and Price, 1993; 1995a) indicates that the Index Formation conformably overlies the Badshot Formation in an upright stratigraphic section.

The contact between the Badshot Formation and the Lardeau Group is exposed at several localities in the Downie Creek area. The basal Lardeau Group displays wide lithological variation; pale green sericite schist, black calcareous and graphitic phyllite, limestone conglomerate and white orthoquartzite breccia are present in different localities. Near Downie Lake (82N/5), marble of the Badshot Formation is overlain by a dolostone-cobble conglomerate (Colpron and Price, 1993). South of Mount Holway, along strike with the Downie Lake section, a green sericite schist abruptly overlies the grey marble of the Badshot Formation. It is in turn overlain by a black phyllite unit. Near Bridgeland Pass, a white orthoquartzite breccia unit is interlayered with minor black phyllite and directly overlies buff-weathering dolomitic limestone conglomerate, phyllitic and massive grey marble of the Badshot Formation. On Roseberry Mountain, the contact is gradational over about 10 metres, and is marked by the presence of dark grey to black argillaceous limestone at the top of the Badshot Formation. The argillaceous limestone gradually becomes more phyllitic up-section and gives way to a sooty graphitic phyllite. Farther west, on Roseberry Mountain, a lensoidal body of white and pale pink quartzite is present along the north-striking contact between massive grey marble of the Badshot Formation and black graphitic phyllite. At its northern end, centimetre-thick quartzite beds are interlayered and continuous with the black phyllite. The orthoquartzite is similar to that comprising the breccia at Bridgeland Pass.

The wide variety of lithologies which overlie the Badshot Formation between Carnes Peak and Downie Lake suggests that the transition from shallow water quartzites and carbonates of the Hamill-Badshot sequence to deeper water facies of the Lardeau Group marks a period of instability along the shelf-margin. This abrupt transition has been interpreted to record the foundering of the sedimentary basin.

Stratigraphic relationships of Lardeau Group

Rocks of the Lardeau Group in the Downie Creek area are broadly similar to the type section in the Ferguson area (Figure 4). In the Downie Creek area, the lower part of the Lardeau Group is characterized by graphitic, calcareous and pyritic black phyllite, green phyllite, phyllitic carbonates and minor quartzite and grit units, typical of deep-water, marginal-basin deposits. Thick accumulations of basaltic flows and volcaniclastic deposits are present near the top of the phyllite package at Keystone and Standard peaks, and are interpreted to reflect local centres of volcanic activity. The greenstones are tholeiitic basalts of mid-ocean ridge (MORB) affinity. This sequence is equivalent to the Index Formation in the Ferguson area, where the Index is subdivided into a lower graphitic phyllite and an upper green phyllite and greenstone units (Figure 4; Fyles and Eastwood, 1962).

The greenstone and black phyllite of the Index Formation are stratigraphically overlain by micaceous quartzite, phyllite and quartz grits in the Downie Creek area. The uppermost stratigraphic unit represented in the area comprises volcaniclastic rocks and interlayered marble; preliminary chemistry indicates that the volcanic rocks are alkaline basalts of within-plate affinities, similar to the Jowett Formation in the Kootenay Arc. On the basis of lithologic and geochemical similarities, the upper volcanic unit of the Downie Creek area is correlated with the Jowett Formation, as suggested by Brown *et al.* (1983).

The micaceous quartzite package has been correlated with: 1) an allochthonous slice of the Neoproterozoic Windermere Supergroup (Wheeler, 1966), 2) the upper Index Formation (Brown *et al.*, 1983; Brown and Lane, 1988), and 3) the Broadview Formation (Brown, 1991; Gibson and Höy, 1994). Our stratigraphic and structural interpretation indicates that it conformably overlies the Index Formation and occurs below the volcaniclastic rocks of the Jowett Formation. Therefore, this unit occupies the same relative stratigraphic position as the Triune, Ajax and Sharon Creek formations in the Ferguson area (Figure 4). These formations comprise a distinctive fine-grained siliceous succession of cherty argillite, phyllite and dark quartzite, bounded below by the volcanic rocks of the upper Index Formation and above by the volcanic rocks of the Jowett Formation. This succession contrasts with the coarser grained sequence of micaceous quartzite and grit present in the Downie Creek area. The Broadview Formation, which overlies the Jowett in the Kootenay Arc, is not present in the Downie Creek Area.

INTRUSIVE ROCKS

DOWNIE CREEK GNEISS

Lineated granite, quartz monzonite and granodiorite gneiss crops out in the northeastern corner of the map area at Downie Creek (Figure 1). The gneiss extends north into the Goldstream River map area, where it has been included within a mixed package of orthogneiss and paragneiss (Logan and Colpron, 1995). The two-mica granite of the Downie stock intrudes the eastern edge of the gneiss and the Columbia River fault separates it from rocks of the Monashee Complex to the west. Thin sills of orthogneiss intrude paragneiss south of Downie Creek.

The Downie Creek gneiss includes sills and foliated sheets of granitic orthogneiss up to a kilometre thick. The suite is I-type in character and is distinguished by oval aggregates of biotite along the foliation. Locally, fine-grained mafic gneiss occurs as rounded inclusions within more felsic gneiss. It has been affected by the main phases of regional deformation and metamorphism, and overprinted by younger brittle deformation and chlorite alteration associated with the development of the Columbia River fault zone.

Preliminary U-Pb dating on zircon indicates an early Mississippian age for the Downie Creek orthogneiss (R. Friedman, personal communication, 1995). Similar orthogneisses are a major component of the Clachnacudainn Complex, south of the Downie Creek area (Figure 1). Orthogneiss exposed in the CPR quarry, at Albert Canyon, about 28 kilometres east of Revelstoke, has yielded a U-Pb zircon age of 358±6 Ma (Parrish, 1992). West of the Monashee Complex, orthogneiss with similar lithologic characteristics and age are present in the Seymour Range (359±3 Ma; Parrish, 1992) and near Shuswap and Adams lakes (Mount Fowler, 372±6 Ma; Okulitch *et al.*, 1975).

PASS CREEK PLUTON

The Pass Creek pluton is the largest intrusive body in the Downie Creek area (Figure 3). It is a potassium feldspar megacrystic, hornblende-biotite quartz monzonite. Potassium feldspar megacrysts are up to 5 centimetres long and, together with hornblende and biotite, locally define a weak magmatic foliation that parallels the margin of the pluton. Epidote occurs as coatings along fractures and, locally, as fine-grained aggregates within the quartz monzonite. The quartz monzonite phase is cut by dikes of quartz-feldspar porphyry 2 to 3 metres wide. About 1 kilometre west of the Pass Creek pluton, a small body of medium-grained, melanocratic hornblende-biotite monzonite intrudes quartzites of the upper part of the Lardeau Group. Although more mafic in composition, this small intrusion is probably related to the main body of the Pass Creek pluton.

The pluton cuts most of the dominant fold and fault structures in its wallrocks (Figure 3). Along its east side, the trend of structures is apparently deflected around it. Metamorphic minerals (including garnet and andalusite) in the contact aureole appear to postdate the development of the tectonic fabric in the wallrock. These relationships indicate that intrusion of the Pass Creek pluton postdates the development of most of the regional structures, but predates (or is synchronous with) the development of structures along its east side. Brown *et al.* (1992b) report a U-Pb titanite age of 168±3 Ma for the Pass Creek pluton.

East of Carnes Peak, a small body of medium-grained, hornblende-biotite quartz monzodiorite intrudes black phyllites and ultramafic rocks of the lower part of the Lardeau Group. This small intrusion is lithologically similar to both the Pass Creek pluton to the west, and Fang stock to the east, and is, accordingly, probably Middle Jurassic in age.

DOWNIE STOCK

The southern half of the Downie stock is exposed in the northwest corner of the Downie Creek area (Figure 3). Exposures along Highway 23, north of Downie Creek, are of a medium to fine-grained two-mica leucogranite (Logan and Colpron, 1995). The stock has yielded a Rb-Sr date (whole-rock and biotite) of 66±3 Ma (R. L. Armstrong, unpublished data).

LONG CREEK STOCK

The southern half of the Long Creek stock is sparsely exposed along the northern border of the Downie Creek area (Figure 3). It consists of a medium-grained biotite quartz monzonite. Because of its lithologic similarity to the felsic phase of the Goldstream pluton, it is inferred to be mid-Cretaceous in age (Logan and Colpron, 1995).

DIKES AND SILLS

Southeast of Mount Holway, a few dikes (or sills) of light green, foliated plagioclase ± biotite porphyry, 1 to 2 metres wide, intrude rocks of the Hamill and Lardeau groups. The porphyry dikes have a well developed tectonic fabric parallel to the dominant foliation in the area, but intrude the strata at a high angle along the limbs of the main-phase folds. These relationships are interpreted to indicate that the dikes were intruded during the development of the dominant regional structures in the area.

STRUCTURE

The structure of the Downie Creek area is dominated by northwest-trending, southwest-verging folds and faults that characterize the west flank of the Selkirk fan structure. These structures are superposed upon older isoclinal folds which locally overturned the stratigraphic sequence (Read and Brown, 1979). Both set of structures are deformed by younger east-southeast-trending open folds, and, locally, by another set of northerly trending open folds.

The earliest structures are most readily identified in the area northeast of Downie Creek, where primary sedimentary structures in strata of the Hamill Group provide good control on the stratigraphic facing direction. Here, most of the succession was inverted prior to development of the dominant southwest-verging structures. This panel of inverted stratigraphy extends south into the Carnes Peak and Bridgeland Pass areas; the fault mapped to the west and north of Carnes Peak marks its western limit. At the outcrop scale, the earliest structures are only locally identified by the presence of a bedding-parallel foliation and, rarely, small isoclinal folds that are transected by the dominant foliation. Brown and Lane (1988) interpreted these early isoclinal folds as part of a large-scale west-facing nappe: the Carnes nappe.

The dominant structures are characterized by tight to isoclinal southwest-verging folds. In the area northeast of Downie Creek, moderately dipping, southwest-verging antiforms commonly have sheared overturned limbs. The thrust faults along the overturned limbs of these antiforms may collectively be the northerly continuation of the Downie Creek fault as mapped by Colpron and Price (1993) along strike to the southeast. In general, the fold axes in this area plunge moderately to the northeast, and the large-scale folds have the geometry of reclined folds.

To the west, in the Keystone area, the structural style in rocks of the Lardeau Group is characterized by the southwest-verging, recumbent Keystone antiform (Lane, 1977; Höy, 1979). The core of the antiform is occupied by a thick sequence of marble. Brown (1991) interpreted this marble as part of the Lardeau Group. Lane (1977) and Brown (1991) reported facing directions in grits along the limbs of the Keystone antiform that suggested that the stratigraphic sequence was inverted before the development of the Keystone antiform. However, our mapping in the Keystone area indicates that the stratigraphic sequence was upright prior to formation of the recumbent fold. Thus, the recumbent fold in the Keystone area is an anticline and the marbles in the core of the fold are the oldest rocks in the area.

Farther south, in the Standard Peak area, rocks of the Lardeau Group are folded by a moderately east dipping, tight to isoclinal antiform that Lane (1977) and Brown (1991) correlated with the Keystone antiform. Again, graded beds in quartzite and grits along the northwest flank of Standard Peak indicate that the stratigraphic sequence was upright prior to formation of the antiform.

A thrust fault juxtaposes phyllite and dolostones of the Mohican Formation over black phyllites of the Index Formation, along the east flank of Roseberry Mountain (Figure 3; Brown, 1991). Brown has traced this fault northward to the Pass Creek pluton. It reappears north of the pluton where it juxtaposes the Mohican Formation against a light grey marble that we assign to the Lardeau Group. The fault is truncated again to the north by the Long Creek stock. This fault may be equivalent to the southern segment of the French Creek fault, mapped northeast of the Long Creek stock in the Goldstream River area (Colpron *et al.*, 1995; Logan and Colpron, 1995).

West of Carnes Peak, a fault juxtaposes an overturned panel of the Badshot Formation to the east, over an upright sequence of the Mohican Formation and Hamill Group to the west (Figure 3). To the north, the Mohican is truncated along the fault and the Badshot is juxtaposed against Hamill quartzites that grade westward into siliceous phyllite and dolostone of the Mohican

Formation. The same sequence of rocks extends northward around the east side of the Pass Creek pluton, into the Downie Creek valley and, therefore, the fault can be inferred to extend into the valley, where it appears to be truncated by, or to merge with a southwest-verging thrust fault. There is no direct evidence to constrain the sense of displacement along this fault. Brown (1991) interpreted it as a normal fault, with the possible implication that it is a synthetic extension fault in the hangingwall of the Tertiary Columbia River fault (also Brown and Lane, 1988). The relationships decribed above imply that this fault either predates or is synchronous with the development of the southwest-verging thrust faults, which are elsewhere documented to be Middle Jurassic in age. Alternatively, this fault may be a southwest-verging thrust fault.

The contact between the Index Formation and the assemblage of micaceous quartzite and quartz-muscovite schist to the west, has been interpreted by Brown (1991) as a west-verging thrust fault (the Standard Peak fault). Close inspection of this contact has revealed that, in most locations, the Index Formation is gradational into the structurally underlying quartzite assemblage. In addition, our proposed correlation with similar quartzites in the core of the west-facing synform on Belcher Ridge, east of Standard Creek, limits the displacement that could have occurred along the Standard Peak fault. Although we cannot rule out the existence of the Standard Peak fault, it does not occur along the contact between black phyllite and quartzite at Standard Peak and displacement is therefore apparently not large.

Younger structures which deform the dominant foliation are limited to the development of a crenulation cleavage and small-scale open folds. The most prominent expression of this deformation is seen at Keystone Peak, where the dominant foliation is deformed by an east-southeast-trending open synform. North-northwest-trending open folds are also locally developed. Again the most spectacular example of this episode of folding is seen at Keystone Peak, where the dominant foliation dips toward the peak on either side of the mountain. As a result of the superposition of three phases of folding, the overturned sequence of marble at Keystone Peak occupies the core of a structural basin.

COLUMBIA RIVER FAULT

The Columbia River fault zone separates rocks of the Selkirk allochthon in its hangingwall from rocks of the Monashee Complex in its footwall (Read and Brown, 1981; Figure 1). This ductile-brittle fault of Eocene age is superposed on older, amphibolite-grade mylonites that have been attributed to displacement along the ductile Jurassic to Paleocene Monashee décollment (Lane, 1984; Lane *et al.*, 1989; Brown *et al.*, 1992a). The Columbia River structure is a normal fault which strikes northwesterly and dips 20° to 40° to the east in the Downie Creek map area. 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).

For the most part, the trace of the fault zone lies in the Columbia River and is not exposed. South of Holdich and Carnes creeks the fault is exposed in road cuts along Highway 23. At Carnes Creek, rocks in the footwall are silicified mylonitic gneisses, possibly Devono-Mississippian orthogneiss of the Clachnacudainn Complex (Brown *et al.*, 1993). Mafic plagioclase-actinolite-calcite metavolcaniclastic and interlayered dolomitic marble of the Jowett Formation occupy the hangingwall. Discreet, late-brittle fault zones, less than a metre wide and characterized by ankeritic and clay-altered fault gouge, cut the main fault trace exposed south of the Carnes Creek Road turnoff on Highway 23.

The intensity and variety of alteration varies between rocks in the hangingwall and footwall of the fault zone. Rocks in the footwall, exposed in road cuts south of Carnes Creek, include black amphibolite, interlayered grey, white and brown carbonates, calcsilicate and quartz-rich semipelites of the Monashee Complex. These rocks are intruded by sheeted gneisses of granitic and granodioritic composition that are mylonitic and that are cut by younger foliated and nonfoliated muscovite pegmatites. Footwall rocks are thoroughly fractured, faulted and pervasively altered: as a result, roadcuts south of Carnes Creek are highly unstable. Pervasive silicification of footwall rocks has locally produced pale grey, green and white mottled, homogeneous quartzofeldspathic rocks in which the only texture preserved is the mylonitic fabric. Late-stage, brittle deformation overprints earlier ductile fabrics. Anastomosing brittle fractures, most prevalent in the silicified rocks, are curviplanar, trend northerly and dip steeply to the west. Fluid infiltration along these fractures has resulted in one or all of these alteration processes: sericitization, chloritization, pyrite and late-stage iron carbonate alteration.

Rocks in the hangingwall are less pervasively altered. The Jowett Formation, south of Carnes Creek, is weakly chloritized and iron carbonate altered along discreet fractures and fault zones. Cataclasite and chloritic breccias have developed in competent hangingwall rocks, in particular in the Downie Creek orthogneiss and Downie stock north of Downie Creek.

Additional late-stage, brittle deformation includes east-trending, north-side-down normal faults and, less commonly, north-side-up reverse faults (Lane, 1984). These are generally foliation-parallel shear zones.

METAMORPHISM

Rocks of the Downie Creek area contain mineral assemblages characteristic of greenschist to amphibolite facies metamorphism. Most of the map area is underlain by assemblages characteristic of the chlorite zone; amphibolite facies rocks are confined to the footwall of the Columbia River fault zone and to the metamorphic culmination at Downie Creek. Relatively narrow metamorphic contact aureoles surround the Downie, Long Creek and Pass Creek plutons.

A metamorphic culmination extends 7 kilometres northeastward up the Downie Creek arm of Lake Revelstoke. It arches over the Downie stock and extends northward into the Goldstream River map area (Colpron *et al.*, 1995). It is bounded to the west by the Columbia River fault. The rocks are garnet-muscovite-biotite-chlorite paragneisses and schists, that are intruded by sills and thick sheet-like bodies of the Downie Creek orthogneiss. The garnet porphyroblasts are synkinematic with respect to the dominant foliation, and the foliation is defined by alignments of biotite and muscovite. The garnets commonly have retrograde rims of fine-grained muscovite, chlorite and quartz. The metamorphic grade decreases progressively eastward, and the gneisses pass structurally upward into biotite and chlorite-zone micaceous quartzite, quartz-muscovite schist and semipelite. It is unclear whether the transition between the gneisses and the micaceous quartzites is defined by a fault or is a result of decreasing metamorphic grade. In roadcuts along Highway 23, at the western end of Keystone Creek, foliation-parallel graphitic shear zones are present within the paragneiss (Gibson, 1989). North of the Downie stock, in the Goldstream River area, the contact between gneiss and micaceous quartzite has been inferred to be a fault, on the basis of scattered exposures of high-strain gneiss near this contact (Logan and Colpron, 1995).

Regional relationships indicate a Middle Jurassic age for southwest-verging deformation and the peak of regional metamorphism (Archibald *et al.*, 1983; Colpron and Price, 1995b). Accordingly, the age of garnet-grade regional metamorphism at Downie Creek is inferred to be Middle Jurassic.

Regional metamorphic assemblages at Downie Creek are, in part, overprinted by the contact aureole of the Late Cretaceous Downie stock. Contact metamorphic assemblages include garnet, biotite, muscovite and, in pelitic and psammitic rocks, muscovite pseudomorphs of andalusite up to 10 centimetres long. Fresh andalusite is present along the northern margin of the Downie stock (Logan and Colpron, 1995). Calcsilicate rocks contain fine radiating clusters of actinolite arranged in a characteristic 'bow-tie' texture along the main foliation surfaces.

The contact aureole along the southern margin of the Pass Creek pluton is less than 250 metres wide and the metamorphic assemblage includes garnet, muscovite, biotite and muscovite pseudomorphs after andalusite. The garnet porphyroblasts are euhedral and devoid of inclusions. They appear to postdate the development of the dominant foliation. Contact aureole assemblages are observed over a distance of about 1 kilometre west of the pluton, where a small monzonite intrusion is exposed. There, muscovite pseudomorphs of andalusite up to 5 centimetres long are randomly oriented along the dominant foliation.

The small, undeformed quartz monzodiorite intrusion east of Carnes Peak has a narrow contact aureole (*ca.* 50 m) in which calcsilicate rocks of the Lardeau Group have the assemblage garnet-biotite-diopside-tremolite-clinozoisite-plagioclase-quartz±muscovite. The assemblage biotite-tremolite-quartz defines the foliation in the country rocks, and the garnet porphyroblasts appear to be synkinematic with respect to developement of the foliation. Although the intrusion itself is undeformed, the textural relations of the calcsilicate minerals suggests that metamorphism was synkinematic with regional deformation.

MINERAL OCCURRENCES

Stratabound mineral occurrences within the Downie Creek map area can be divided into two main types: stratiform volcanogenic massive sulphide (VMS) and carbonate replacement deposits. Copper-zinc and arsenical lead-zinc-gold-silver mineral assemblages characterize the massive sulphide occurrences. The Standard and Rain copper-zinc prospects are VMS deposits associated with tholeiitic volcanism in the lower Paleozoic Lardeau Group (Index Formation). The King and Copper Queen copper-zinc occurrences are associated with alkaline volcanic rocks of the lower Paleozoic Lardeau Group (Jowett Formation). The J&L gold-rich base metal deposit is hosted in marble and siliciclastic strata of the Eocambrian Hamill Group, which, contains bimodal alkaline volcanic rocks to the north. Lead-zinc-silver assemblages characterize the carbonate replacement occurrences, which include the Yellowjacket zone (J&L), Keystone and A&E(?) (Figure 3).

In addition to these occurrences there are scheelite skarn showings in calcareous rocks of the Index Formation at the southern contact of the Long Creek stock, and disseminated base metal and molybdenum showings in micaceous quartzites in the hangingwall of the Columbia River fault zone.

MASSIVE SULPHIDE DEPOSITS

STANDARD

The Standard showings comprise a series of discontinuous massive and disseminated sulphide lenses within albite-chlorite-calcite schist, massive greenstone, volcaniclastic sandstone, black phyllite and marble of the Index Formation (Höy, 1979; Höy *et al.*, 1984). Sulphide lenses occur on both limbs of the Standard anticline within the greenstone unit, at contacts between massive greenstone and thinly foliated actinolite-albite-chlorite schist, and between greenstone and ultramafic dikes. Surface trenching has traced the sulphides intermittently for 1500 metres and much of the exploration work has been concentrated in areas where young, easterly trending, upright cross-folds deform the older northerly trending structures, bringing the sulphide-bearing horizon close to the surface.

Sill-like bodies of serpentinite, ultramafic rocks, gabbro and diorite intrude along the contacts between black phyllite and greenstone units and are spatially associated with some of the sulphide occurrences. Sulphides include fine-grained interlayered pyrrhotite, pyrite, arsenopyrite and lesser chalcopyrite and sphalerite. Deformation has produced gneissic textures in the sulphides and remobilized chalcopyrite into pressure shadows around pyrite grains and wallrock inclusions within the massive sulphide layer. Most of the exploration at Standard has been confined to the volcanic package. The sulphide horizon at the Goldstream deposit is hosted by graphitic phyllites adjacent to greenstones. A thick package of black graphitic and calcareous phyllite overlies the greenstone on either side of the Standard anticline; its potential to host base metal sulphide mineralization remains largely untested.

Early reports describe the mineralization as consisting of arsenical iron and copper pyrites with a little bornite, and selected samples returned assays of 10.9 g/t Au, 47.9 g/t Ag and 15 % Cu (Carmichael, 1906). Of note is not the relative amounts but the presence of gold and arsenopyrite, a mineral assemblage found at the J&L and A&E prospects. Lithogeochemical arsenic-gold and copper anomalies occur in pyritic and sericite-altered limestone and quartzose phyllite in the headwaters of Kelly Creek, 2 kilometres south of the Standard showings. These sediments are stratigraphically below the greenstone in the core of the Standard anticline.

J&L - MAIN ZONE

The J&L property is a stratiform precious and base metal deposit located at the confluence of Carnes and McKinnon creeks, approximately 9 kilometres east of the Columbia River. Considerable underground and surface development has been carried out on the property since it was staked in 1896. In the early to middle 1980s Selco Inc. (subsequently BP Canada Ltd., Selco Division), then Noranda (1986-87), Equinox Resources Ltd. (1988-94) and finally Cheni Gold Mines Inc. (1990-1993) carried out substantial exploration and development work, including underground drilling, bulk sampling and metallurgical testing under option agreements with Pan American Minerals (Meyers and Hubner, 1989; Weicker, 1991). The deposit consists of a Main zone of massive and disseminated sulphides and the Yellowjacket zone, a lead-zinc carbonate replacement (discussed below).

The underground workings were not accessible at the time of our mapping. Höy (1984) described the distribution of mineralization and lithology in a detailed section through the main sulphide layer in the 10+350-metre East crosscut; this, together with McKinlay (1987) and Meyers and Hubner (1989) provide a good description and summary of the geology of the deposit. More recent work is described in B.C. Ministry of Energy, Mines and Petroleum Resources assessment reports by Wright *et al.* (1989) and Weicker (1991).

The Main zone averages 1.6 metres thick (true thickness), developed over 800 metres of strike length underground and traced on surface for over 1.35 kilometres (probable and possible reserves, 5.25 million tonnes averaging 2.71 % Pb, 4.33 % Zn, 7.23 g/t Au and 72 g/t Ag; Canadian Mines Handbook 1995-96, p. 188). Host stratigraphy to the Main zone is the upper part of the Hamill Group, which is composed of interlayered quartzite, micaceous quartzite, quartz-sericite and chlorite schist and grey carbonaceous limestone. The latter forms the footwall of the main sulphide layer. The Main zone is a complex tabular body which follows the limestone-phyllite contact and, in places, branches or splits into multiple parallel layers (Meyers and Hubner, 1989). Sulphide minerals include pyrite, arsenopyrite, sphalerite, galena, and trace amounts of chalcopyrite, pyrrhotite and silver-lead-antimony sulphosalts. The immediate area of the J&L deposit is strongly deformed by west-verging thrust faults and tight to isoclinal folds, it is unclear whether the stratigraphy was inverted prior to the main phase of folding. Pyritized sericite and clay-altered schists in the footwall of the Main zone are crenulated by late southwest-trending cross-folds.

The North zone, possibly an extension of the Main zone, occurs north of McKinnon Creek. It comprises four parallel lenses containing arsenopyrite, pyrite and variable amounts of galena and sphalerite, and extends for a strike length of 1.5 kilometres northwesterly. Together the Main and North zones define a mineralized strike length in excess of 3.3 kilometres. The blind discovery of the Yellowjacket zone in 1990 attests to the high potential for additional mineralized zones in this area, which has not been fully evaluated.

A long-standing controversy regarding the origin of the J&L deposit is based in part on the presence of incompatible mesothermal and epithermal mineral assemblages, finely laminated and crosscutting sulphide textures, mineral zonation and variation in strain along and across the sheet-like massive sulphide body. As a result both the syngenetic massive sulphide (Grant, 1984) and the epigenetic shear-hosted vein (McKinlay, 1987; Wright *et al.*, 1989; Weicker, 1989) classifications have been ascribed to the deposit (see discussion in Meyers and Hubner, 1989). The J&L is a gold-rich base metal deposit with distinct epithermal characteristics; it has all the characteristics of a shallow submarine hydrothermal system (Hannington, 1993) and may be a tectonized exhalative volcanogenic massive sulphide deposit, akin to Eskay Creek.

RAIN

The Rain property is located between Standard and Murder creeks, south of Downie Creek (Figure 3). Early exploration of the property by Noranda Exploration Company Limited focused on the skarn potential of copper-tungsten mineralization near the confluence of Downie and Sorcerer creeks. Bethlehem Resources Corporation restaked the property in 1989 on the basis of the similiarity between its stratigraphy and that at the

Goldstream mine. Geological mapping, geochemical sampling and diamond drilling confirmed the stratigraphy, and identified anomalous base metal values and the presence of semimassive sulphides associated with manganese-enriched exhalative horizons.

Wild (1990) discovered stratabound banded pyrite in manganese-enriched graphitic phyllites in Murder Creek. He recognized the similiarities to the dark banded phyllites at the Goldstream mine and correlated the graphitic phyllite, sericite schist and carbonate with the Lardeau Group strata. Follow-up geochemical soil sampling traced two base metal anomalies northwesterly from the discovery zone, parallel to the dominant strike of the stratigraphy. Diamond drilling at the northern extension of one of these anomalies intersected several manganese-enriched, garnetiferous and sulphide-bearing horizons correlative with the garnet zone at Goldstream (Cavey and Raven, 1992).

On the Rain, the Index Formation consists of dark calcareous and graphitic phyllite and sericite schist. Massive, light grey, banded marble forms the ridge to the west and structurally underlies the dark phyllites exposed in the creek. Farther west, in Standard Creek, interbedded pale yellow and grey micaceous quartzite and grey, rusty weathering phyllite underlie the grey marble. Thinly interbedded phyllite and carbonate correspond to the calcareous phyllite in the drill holes. Coarse disseminated, stratabound pyrite is common in some graphitic units and Wild (1990) describes a garnet zone within these rocks. The dark phyllite and sericite schist are strongly contorted adjacent to the contact with underlying marble and are overprinted by a quartz-vein stockwork. The contact appears to be faulted. Our mapping (Figure 3) shows that rocks of the lower phyllite member (host to mineralization) are structurally overlain by rusty weathering, typically recessive, pale green, sericite and quartz-sericite schists with interlayered marble of the Mohican Formation. This unit is traceable south along the lower slopes of the Downie Creek valley, across Kelly Crest and then south to Roseberry Mountain.

Much of the lower slopes on the property are covered by thick glacial till and rock exposures are restricted to road and stream cuts. Continuous stratigraphy is rare and interpretation relies on drill core. The stratigraphy of two drill holes (92RN-1 and 92RN-3) is described by Logan and Drobe (1994). Difficulty in correlating stratigraphy from one hole to the next, and the presence of multiple garnet and sulphide horizons intersected by the drilling, are probably the result of structural repetition, possibly by west-verging tight to isoclinal folds and thrust faults similar to those mapped on ridges between Pelkey and Standard creeks, to the south. In addition to the structural complications, mapping by Campbell (1994) indicates that graphitic phyllite (the probable source of the copper, lead, zinc and manganese geochemical anomalies) extends up-slope farther than previously recognized, suggesting that the 1992 drilling may not have extended far enough to intersect the source of the anomaly.

KING SHOWING

The King showing is a stratabound massive sulphide horizon in micaceous quartzite and quartz-sericite schist exposed in a roadcut along Highway 23, 250 metres south of Keystone Creek. The property has been explored intermittently since 1976, by soil and stream geochemical and geophysical techniques, mapping and limited diamond drilling. Boulders of massive sulphide and anomalous soil geochemistry suggest that mineralization extends for approximately 2 kilometres to the north (Wild, 1988). Sulphides include pyrite, pyrrhotite and small amounts of chalcopyrite and sphalerite. Pyritic quartz-sericite schist exposed on the Key Road, up-slope and farther east, may represent a fold repetition of this same horizon.

The property is underlain by micaceous quartzite, quartz-sericite and chlorite schist, graphitic phyllite and the Downie orthogneiss. Strata are isoclinally folded about north-verging fold axes and are crenulated by younger northeast and southeast-trending cross-folds. Two northeast-trending, layer-parallel graphitic shear zones transect the property. These have been accurately located by electromagnetic surveys, diamond drilling and surface geological mapping, and divide the property into three separate structural slices (Gibson, 1989). The King showing is in the footwall of the westernmost shear, separating the sulphide-bearing micaceous quartzites from chlorite-calcite schists and phyllites in the hangingwall. Drilling in 1986 did not intersect significant mineralization.

Geochemical sampling of mineralized and altered sections along the highway and Key Road in 1993 and 1995 returned low base and precious metal values. Similar mylonitic and pyritic quartzite and sericite schist is exposed 5 kilometres to the south along Highway 23. Analysis of these rocks has also returned low metal values.

COPPER QUEEN

The Copper Queen showings are located 10 kilometres south of Carnes Creek on the west-facing slope above the Columbia River, at 1500 metres elevation (82M/1). They occur in a thick section of micaceous quartzite, rusty weathering phyllite, interlayered mafic volcanic rocks and carbonate. The showings were not visited this past summer, but are reported to consist of chalcopyrite, sphalerite and pyrite disseminations and lenses located near the base of the Jowett Formation volcanic-carbonate sequence, close to its contact with the structurally overlying micaceous quartzite and sericite schist (Lund and Hajek, 1976).

CARBONATE REPLACEMENTS

KEYSTONE

The Keystone showings are located at the headwaters of Keystone Creek, less than a kilometre northwest of Keystone Peak (Figure 3). They consist of carbonate replacements in marble, and quartz veins hosted by chlorite-sericite phyllite (Gunning, 1929; Wheeler, 1965). The main showing has been tested by two short adits and surface trenching which expose a medium grey marble, 2 metres thick, within calcareous, rusty weathering and bleached sericite-chlorite schist, dark grey phyllite and micaceous quartzite. Mineralization occurs as foliation-parallel pods of massive and coarsely crystalline intergrowths and crosscutting fracture fillings within or underlying the marble (Höy, 1979). Sulphides, in order of relative abundance, include pyrrhotite, sphalerite, galena, pyrite and minor chalcopyrite. Pyrrhotite occurs as massive lenses enclosing blebs of sphalerite, galena and euhedral grains of pyrite. Deformation has remobilized sphalerite, galena and the trace amounts of chalcopyrite into pressure shadows adjacent to pyrrhotite and into crosscutting fractures.

Sulphide textures suggest that the mineralization predates the main phase of deformation (see Plate XII *in* Höy, 1979). Galena-lead isotopes give a Cretaceous Pb-Pb model age, making it reasonable to correlate at least part of the mineralizing event with intrusion of either the Goldstream pluton or possibly the Long Creek stock, both part of the mid-Cretaceous magmatic suite in the area.

J&L - YELLOWJACKET ZONE

The Yellowjacket zone is a lead-zinc deposit hosted in siliceous carbonate in the hangingwall of the gold-bearing polymetallic Main sulphide zone at the J&L property. It was discovered in November, 1990, by drilling in the McKinnon Creek valley, north of the 830-metre level portal. Subsequent drilling has outlined probable and possible reserves of 1 003 000 tonnes, grading 7.37 % Zn, 2.59 % Pb and 55.5 g/t Ag (Canadian Mines Handbook 1995-96, p. 188). The Yellowjacket zone strikes generally parallel to the Main zone, but dips more steeply and plunges to the east at 40 to 50° (Weicker, 1991). Mineralization is confined to a carbonate sequence in a succession of sericite and chlorite phyllite, quartzite, carbonate and minor volcanic rocks correlated with the Hamill Group (Weicker, 1991).

The sulphide assemblage is simple, consisting of disseminated pale honey-coloured sphalerite, and silver-bearing galena. The low iron content of the Yellowjacket ore is reflected in the pale sphalerite which contrasts with the dark reddish brown, iron-rich variety in the Main zone. The limestone is variably silicified; gangue minerals include quartz and fluorite.

A&E AND ROSEBERRY

The A&E showings are located on the northeast slope of Roseberry Mountain. The principal mineralized zone has been explored by two adits, located on opposite sides of a tributary draining north into Burke Creek. Underground maps of the adits by Westairs Mines Ltd. (Hope, 1966 *in* Weicker, 1989) show the sulphide zone follows the contact of Badshot marble with sericite schist and phyllite of the Index Formation. Sulphide minerals present at the portal include coarse crystalline intergrowths of arsenopyrite, pyrite, sphalerite and galena, with average base and precious metal grades similiar to the Main zone at the J&L (Weicker, 1989). A second, weakly mineralized zone, approximately 125 metres to the west, occupies the faulted(?) contact between Badshot marble and black graphitic Index phyllite. Sulphide minerals include pyrite and arsenopyrite and minor amounts of sphalerite and galena. The zone is deeply weathered and assay results indicate low metal values (Weicker, 1989).

Mineralization at the A&E occupies two parallel zones, generally less than 1 metre thick, within limestone and schist near the top of the Badshot Formation and in phyllite of the Index Formation. Mineral assemblages are arsenical and gold rich, similar to the Main zone at the J&L, but stratigraphic position correlates with hangingwall strata which host the arsenic-free zinc-lead Yellowjacket zone at the J&L.

The Roseberry showing is on the southwest side of Roseberry Mountain. Its exact location and details of the geology are poorly known. Hostrocks include sericite-chlorite schist and marble of the Badshot Formation. In this area the rocks are intruded by a coarse-grained, foliated metagabbro-diorite intrusion and associated sills. The mineralization is reported to consist of disseminated and podiform massive arsenical sulphides with pyrite, galena and sphalerite. Gold and silver values are reported from underground development on a 1.5-metre vein of massive sulphides within a 15-metre zone of disseminated mineralization (Gunning, 1929).

CARBONATE-HOSTED MASSIVE SULPHIDE MINERALIZATION, McKINNON CREEK AREA

Fine-grained pyrite, sphalerite, and galena occur in layers up to 5 centimetres thick in the uppermost white to light grey marble of the Badshot Formation, south of McKinnon Creek. Several bedding-parallel mineralized layers are present within 25 centimetres of the contact with underlying laminated, orange-brown and olive-brown carbonates.

NEW PROSPECTIVE HORIZONS

During the course of mapping, several new prospective horizons were discovered in the Downie Creek area. In the McKinnon Creek area, these include laminated pyrrhotite, sphalerite and pyrite horizons and massive lenses of galena-arsenopyrite in black siliceous units within phyllites of the Index Formation, and sphalerite in marble of the Badshot Formation. There are also iron-manganese-silica±copper and zinc-enriched horizons in phyllite of the Index Formation both stratigraphically above and below the greenstone in the Keystone Peak, Roseberry Mountain and Tumbledown glacier areas.

IRON-MANGANESE-SULPHIDE ENRICHED GRAPHITIC AND SILICEOUS HORIZONS

In the Goldstream area, a distinctive spessartine-bearing, pyrrhotite-rich, thinly laminated graphitic coticule unit, termed the "garnet-zone", is associated with the massive sulphide layer. It is interpreted to be a manganese-iron-rich seafloor hydrothermal precipitate; an exhalite (Höy *et al.*, 1984). The garnet zone also occurs at the Rain property. These garnet zones are important exploration targets and mapping this summer resulted in the discovery of four new iron-manganese-silica-rich horizons in the Index Formation. All of them are characterized by abundant pyrrhotite and/or pyrite and manganese oxide, rhythmic interlaminations of graphitic phyllite and very fine grained, cherty quartzite, but a paucity of spessartine garnets, due to the relatively low grade of metamorphism. Preliminary geochemistry indicates several orders of magnitude above background for manganese, iron and, locally, copper and zinc. These horizons are located south of Keystone Peak, east and west of Roseberry Mountain, and north and west of Tumbledown glacier, between McKinnon and Carnes creeks (Figure 3).

Dark grey siliceous phyllite, black quartzite and graphitic phyllite structurally underlie massive greenstone south of Keystone Peak. The quartzite and phyllite are rhythmically interbedded, on a millimetre to 10-centimetre scale and contain abundant carbonaceous material, pyrite and manganese oxide. Chalcopyrite is present locally in minor amounts. The anomalous manganese and iron content of this siliceous unit makes it readily traceable from the upper reaches of Mars Creek, west and north into the upper drainage basin of Keystone Creek (Figure 3). The Keystone showing lies on strike with this unit, as does a large silicified, pyritized and iron carbonate alteration zone in the structurally overlying green phyllitic volcaniclastic rocks.

Very fine grained, light grey cherty quartzite, finely interlaminated with black carbonaceous phyllite, forms a unit 2 to 3 metres thick in phyllite of the lower Index Formation at Roseberry Mountain. The unit crops out both west and east of the mountain. Weathered surfaces are variably coated with bluish manganese oxide and hematite. Pyrite is abundant, commonly as millimetre-thick, bedding-parallel seams of finely crystalline sulphides. Pyrrhotite and minor chalcopyrite are present locally. Deformed quartz veins up to 10 centimetres wide that cut this unit contain abundant coarse pyrite

Dark grey, very thinly layered graphitic and calcareous phyllite overlie marble of the Badshot Formation, in a structurally upright panel, between Bridgeland Pass and Tumbledown glacier. Within the phyllite, possibly spatially related to a nearby, narrow intrusive greenstone body, is a rusty weathering, siliceous, pyrite and pyrrhotite-rich zone at least 8 metres thick. The gossan consists of fine-grained bedding and foliation-parallel pyrrhotite, crosscut by zones of coarsely recrystallized euhedral pyrite and locally by quartz stockworks. Well rounded, black, mineralized chert clasts occur at several horizons within the gossan. Mineralized clasts contain layers and blebs of sphalerite and/or pyrrhotite. This gossan can be traced south for 1.5 kilometres to the ridge separating Carnes and McKinnon creeks. On the ridge the greenstone unit is not present and the manganiferous unit occurs within the black phyllite unit, a few hundred metres below the sequence of quartzite and grits that core the Illecillewaet synclinorium to the southeast.

An interval of interlaminated, very fine grained quartzite (metachert?) and black graphitic phyllite, at least 15 metres thick and up to about 30 metres in structural thickness where it has been thickened by folding, is exposed to the west, in the headwaters of McKinnon Creek, in a separate panel of black phyllite. Four to five metres of gossan within this siliceous unit contains fine-grained laminated pyrite and sphalerite and massive sulphide lenses up to 30 centimetres thick by about 1 metre long. The massive sulphide lenses contain pyrite, galena, arsenopyrite, possible sphalerite and minor chalcopyrite, and nodular quartz. A 10-centimetre layer of white, fine-grained crystalline barite is present at one locality in the black phyllite unit.

A 2 to 3 metre thick unit of hematite and manganese oxide coated, fine-grained, laminated quartzite with graphitic partings occurs within interlayered phyllitic dolostone, green siliceous phyllite, and black phyllite south of the Rain property, in the Pelkey-Murder creeks area. Massive to foliated greenstone is also exposed within the section, about 20 metres above the laminated siliceous unit. Manganese, iron and base metal values are only slightly elevated above background values. Lithology and stratigraphic position of these rocks correlate well with rocks south of Keystone Peak.

All of these horizons have been sampled. Major and trace element analyses will permit comparisons between those associated with mineralization (Goldstream deposit), metal-poor systems and background phyllites.

DISCUSSION AND CONCLUSIONS

Stratigraphic relationships established in the Goldstream River area (82M/9) have been traced southeastward into the Downie Creek area. However, the recognition of two distinct volcanic successions (upper part of the Index Formation and the Jowett Formation) in the Downie Creek area, and facing directions within the intervening quartzite package, have resulted in revisions to stratigraphic correlations within the Lardeau Group. The stratigraphic sequence in the Downie Creek area consists of the Index Formation (black phyllite, limestone and greenstone), a micaceous quartzite-grit unit, and the Jowett Formation (greenstone and marble; Figure 4). In the Goldstream River area, the sequence of black phyllite, greenstone and quartzite-grit units was assigned to the lower, middle and upper parts of the Index Formation, respectively. The Index Formation in this area is now thought to comprise only the black phyllite and greenstone units, the quartzite-grit unit being younger and a possible lateral equivalent to the Triune, Ajax and Sharon Creek formations of the Kootenay Arc.

The structural style of the Downie Creek area is dominated by southwest-verging folds and thrust faults. These structures deform earlier recumbent folds. Our mapping has extended the areal extent of these early structures to the northeast in rocks of the Hamill Group. These early folds do not appear to be as significant to the northwest, in the Goldstream River area.

Synkinematic, garnet-grade paragneisses and thick sheet-like bodies of Devono-Mississippian orthogneisses define a metamorphic culmination along the Downie Creek arm of Lake Revelstoke. These gneisses show remarkable similarities to Devono-Mississippian orthogneisses in the Clachnacudainn Igneous Complex. They underlie, in possible fault contact, an inverted stratigraphic panel of micaceous quartzite and Jowett Formation, and are truncated by the Columbia River fault to the west.

Known stratabound/stratiform sulphide occurrences in the area include the copper-zinc deposits at the Standard, Rain, Copper Queen and King showings and the arsenical, gold-silver-zinc J&L deposit. At least two mafic volcanic centres are recognized in the Downie Creek area at Keystone and Standard peaks. Gossan zones, and manganese and silica-enriched iron sulphide horizons, occur along the contacts between black phyllite and mafic volcanic units and within the volcanic units at Standard. This stratigraphy is equivalent to that hosting the Goldstream deposit (Index Formation). The "garnet-zone" at the Goldstream mine may be represented in the Keystone area by a black carbonaceous and manganiferous siliceous phyllite and interbedded quartzite which overlies the volcanic rocks. This unit locally contains sulphides and has been traced laterally for 3 kilometres. A similar horizon crops out east of the J&L deposit in black graphitic and calcareous phyllites of the Index Formation at the southern boundary of the map area. Laminated pyrrhotite, sphalerite and pyrite horizons, massive galena-arsenopyrite-sphalerite lenses, and a layer of white barite are present in black siliceous sections of this phyllite. Exhalative horizons and semimassive sulphides are known on the Rain property; four other horizons have been traced regionally and sampled. The major and trace element geochemistry from these samples provides a substantial database allowing comparisons with the geochemistry from various horizons above and below the mineralization at the Goldstream mine. It is hoped that this will provide a useful exploration tool to differentiate between metalliferous and barren hydrothermal exhalative horizons preserved in the Index Formation in the northern Selkirk Mountains.

Current mapping and regional correlations indicate that the stratiform mineral deposits in the Downie Creek area are hosted by strata ranging in age from Eocambrian to lower Paleozoic. The massive sulphides occur at three stratigraphic levels; 1) the J&L deposit in the middle to upper part of the Lower Cambrian Hamill Group; 2) the Standard and Rain prospects in the upper part of the Index Formation, lower Paleozoic Lardeau Group; and 3) the King and Copper Queen prospects in the Jowett Formation, also lower Paleozoic Lardeau Group. These stratigraphic positions correspond to regionally extensive volcanic episodes, and with the exception of J&L, all are associated with volcanic rocks.

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