NORTHERN SELKIRK PROJECT,

GEOLOGY OF THE LAFORME CREEK AREA

(NTS 082M/01)

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INTRODUCTION

Lower Paleozoic rocks of the northern Selkirk Mountains host 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 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 in the LaForme Creek area (NTS 82M/1) during the summer of 1996. The 1996 field season marks the completion of fieldwork in the Selkirk Mountains. Reconnaissance mapping and deposit studies were initiated in 1993. Mapping in 1994 and 1995 covered the areas east of the Columbia River on 82M/8, 9 and part of 10. The short 1996 program was designed to complete mapping coverage of the Downie Creek map area and trace prospective stratigraphy southward to the northern boundary of Mount Revelstoke Park. This area hosts carbonate replacement Pb-Zn deposits and is on strike with several new massive sulphide occurrences discovered during the 1995 mapping season. Mapping was focused on prospective stratigraphy in the areas north and east of LaForme Creek. The geology farther west, and along the slopes overlooking the Columbia River was compiled from mapping carried out last year with Maurice Colpron and Bradford Johnson, and from published sources.

GEOLOGY

The Selkirk Mountains straddle 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

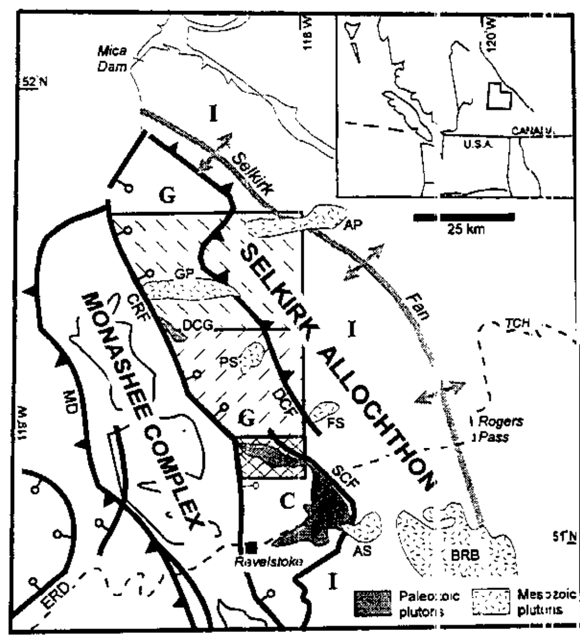

Figure 1. Geological setting and location of the Goldstream River (southeasterly dashed), Downie Creek (southwesterly dashed) and La Forme Creek (hatched) map-areas along the western flank of the Selkirk fan structure, within the Selkirk allochthon; modified after Brown and Lane (1988). I = Illecillewaet 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 pluton, GP = Goldstream pluton, AP = Adamant pluton, DCG = Downie Creek gneiss, TCH = Trans-Canada Highway

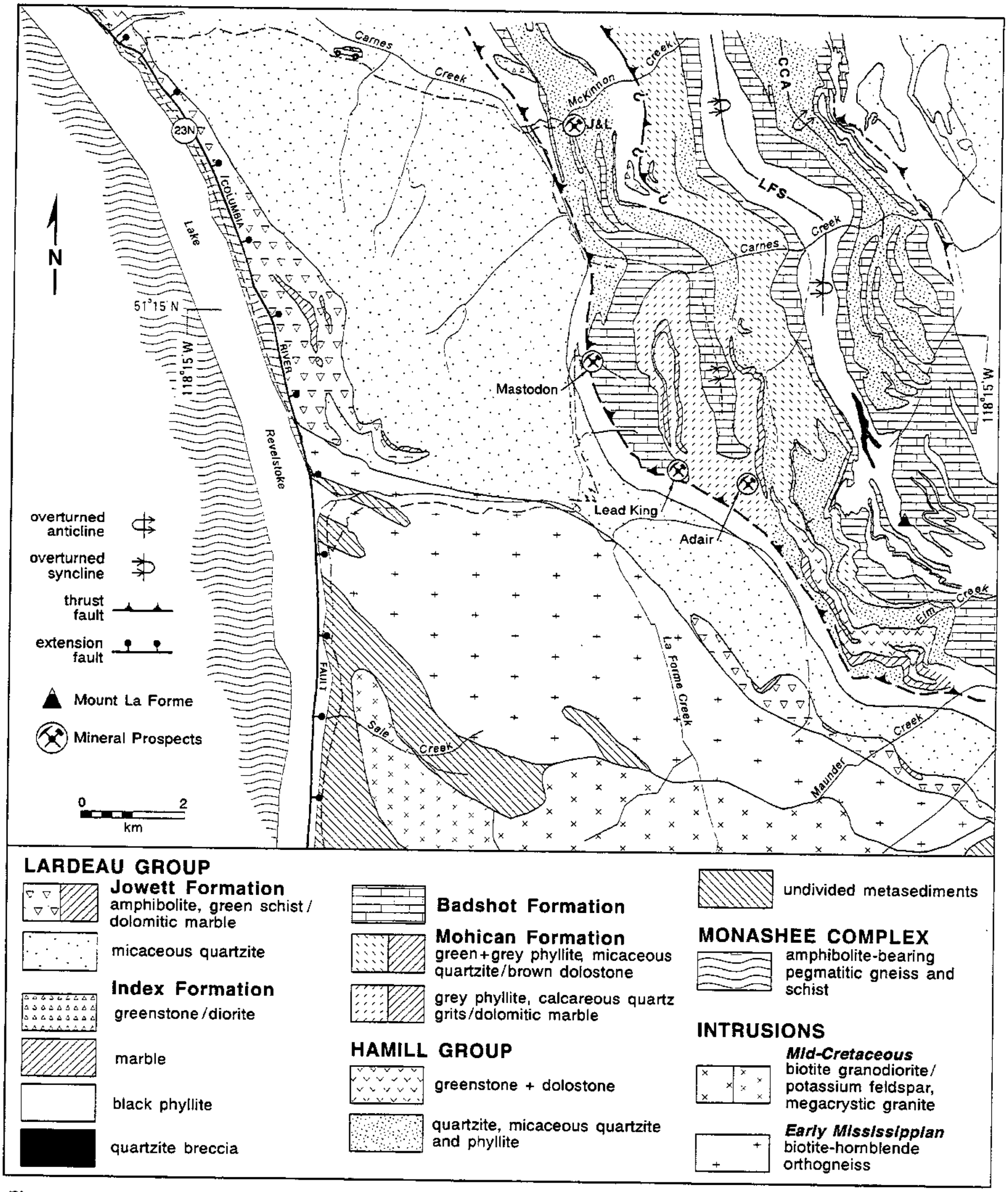

Figure 2. Geological map of the La Forme Creek area compiled from mapping completed in 1995, this year and from Crowley (1992). Fold axis: CCA = Carnes Creek anticline, LFS = La Forme syncline

the Intermontane Superterrane (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 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 to the south, by Walker (1926), Walker and Bancroft (1929), and Fyles and Eastwood (1962) in the Purcell anticlinorium and the Kootenay Arc, northwestward 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, archaeocyathid-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 to 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). The Selkirk allochthon 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. It 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 time. 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 been recognized within the Clachnacudainn Complex (Parrish, 1992)

STRATIGRAPHY OF THE LAFORME CREEK AREA

Rocks of the Hamill and Lardeau groups, and the intervening Mohican and Badshot formations, comprise the majority of exposures in the LaForme Creek area (Wheeler, 1965; Figure 2). The western half of the map-area, between Carnes and LaForme creeks, is underlain by a comparatively simple overturned succession consisting of micaceous quartzite and metavolcanic rocks of the Lardeau Group. East of this quartzite assemblage is a structurally complex series of interlayered Hamill Group siliciclastic rocks, Mohican Formation calcareous siliciclastic rocks, Badshot Formation marble and Index Formation pelites.

South of LaForme Creek are various intrusions of Early Mississippian, Jurassic to Cretaceous, mid-Cretaceous and Late Cretaceous ages (Hakkinen, 1977; Crowley and Brown, 1994) which characterize the northern-half of the Clachnacudainn igneous complex (Crowley, 1992).

HAMILL GROUP

The Hamill Group, in the northern Selkirk Mountains consists of three stratigraphic divisions: a lower sandstone unit; a greenstone-graded sandstone unit; and an upper sandstone unit (Devlin, 1989). The lower and middle units have been mapped in the Goldstream River and Downie Creek areas (Logan and Colpron, 1995; Logan *et al.*, 1996). Interbedded micaceous quartzite and dark phyllite make up most of the Hamill Group exposures in the Downie Creek area. These rocks extend south into the LaForme area and crop out in three main areas: north of Mount LaForme, west and south of Mount LaForme, and in the area of the J&L deposit (Figure 2).

North of Mount LaForme pale greenish-grey massive and trough cross-bedded micaceous quartzites with interbedded phyllite and thin orange-weathering dolostone layers form the eastern exposures of Hamill Group rocks. The interbedded micaceous quartzite and dark phyllite are tightly folded with marbles of the Badshot Formation in the core of the Carnes Creek anticline, a large southwest-verging, south-plunging antiformal structure. The upper contact with the Badshot Formation marbles is gradational through approximately 35 metres of limonitic-weathering grey and green calcareous phyllite and orange-weathering phyllitic dolostone of the Mohican Formation.

West of Mount LaForme are thick-bedded, mature orthoquartzite and interbedded dark grey siliceous phyllite. Orange-weathering, light pink and white orthoquartzite and interbedded greenish-grey, thin laminated micaceous quartzite cap the east-trending ridge 2 kilometres west of Mount LaForme. Tabular cross laminations indicate that bedding tops face to the west; tight symmetrical folds in the rocks indicate that the quartzite occupies an anticlinal fold closure.

South of Mount LaForme, structurally below, but presumably stratigraphically above the Hamill quartzites are mafic metavolcanic rocks. Discontinuous, 5 to 20 metre thick, thinly foliated grey marble interlayered with pink quartzite and calcareous phyllite separate the predominantly volcanic succession from siliceous and calcareous rocks of the Hamill Group and Mohican Formation. The metavolcanic rocks are medium grey to dark green, thinly foliated to massive, homogeneous greenstones composed of actinolite, feldspar, patchy chlorite and calcite and euhedral disseminated magnetite crystals. Massive greenstones are interlayered with thinly foliated, calcareous tuffaceous wacke, orange-weathering phyllitic dolostone, volcanic sandstone and lesser quartzite and phyllite beds. The greenstones are predominantly volcaniclastic rocks. Below this sequence, in fault contact, is black graphitic and calcareous phyllite of the Index Formation.

Preliminary trace element geochemistry from two samples from north of Maunder Creek indicate the volcaniclastic rocks are alkaline basalts of within plate affinity, similiar to Hamill Group and Mohican Formation volcanic rocks from the Goldstream River and Downie Creek areas (Logan *et al.,* 1996). The Hamill greenstone-volcanic assemblage present in the Goldstream and Downie areas do not have a large component of carbonate or calcareous phyllite, but regional continuity northward into the Downie Peak area supports correlation with the Hamill Group and/or Mohican Formation greenstone.

South of the J&L deposit, the Hamill Group is characterized by medium to thickly-bedded white and pink orthoquartzite interbedded with dark grey phyllite and micaceous quartzite. These are gradational into calcareous quartz grits, phyllite and marble of the Mohican Formation. The orthoquartzites occupy the cores of tight folds in this area.

MOHICAN FORMATION

The Mohican Formation (Fyles and Eastwood, 1962) represents the transition between quartz-rich sediments of the Hamill Group and the carbonate-rich rocks of the Badshot Formation. In the Downie Creek map area to the north (Brown, 1991; Logan *et al.,* 1996) the Mohican Formation forms a prominent north-trending belt of rusty-weathering rocks west of Carnes Peak. This belt extends south into the LaForme Creek area east of the J&L deposit, where it is composed of rusty-weathering, green and grey calcareous phyllite, dolostone and micaceous quartzites. This mainly calcareous phyllite sequence includes beds of light grey marble, up to 2 metres thick, interlayered with orange-weathering phyllitic dolostone and metre-thick beds of white, light green and pink micaceous quartzite with thin phyllite partings. Farther west, a second belt of rocks correlated with the Mohican Formation occupies the core of an antiformal structure located 2 kilometres east of the Mastodon mine. The rocks in this area consist of light grey and green phyllite, intercalated with orange-weathering sandy dolostone, calcareous quartz-granule conglomerate and calcareous and siliceous grit. Upper and lower contacts are gradational into Badshot Formation marble and Hamill Group quartzite, respectively. Near its contact with the overlying Badshot Formation the Mohican is characterized by calcareous green phyllite and pale yellow sericite schist.

On the ridge separating McKinnon and Carnes creeks, and east of the Mastodon mine on the ridge overlooking LaForme Creek, the typical calcareous-phyllite-quartzite dominated Mohican Formation contains beds of dark green calcareous phyllite, chlorite schist and rare fragmental volcaniclastic horizons. The greenstone is thinly foliated, consists of white carbonate, chlorite and feldspar, and several percent euhedral magnetite crystals. The volcanic rocks comprise a minor constituent, but potentially important metallogenic component of the Mohican Formation at these locations.

BADSHOT FORMATION

White and light grey archaeocyathid-bearing marble of the Badshot Formation crops out at Roseberry Mountain and Bridgeland Pass (Read and Brown, 1979). The Badshot marbles are traceable southward from Bridgeland Pass to Mount LaForme and beyond the map area. The marble outlines a pair of southwest-verging, south-plunging folds, the Carnes Creek anticline and LaForme syncline (Figure 2). White to buff massive, dolomitic marble crops out in the area of the Mastodon mine on the ridge south of Carnes Creek. A second prominent belt of white to buff marble crops out 1 kilometre to the east. It can be traced north into Carnes Creek, but like the Mastodon marble it pinches out to the south in the steep cliffs above the north tributary of LaForme Creek. These two marble exposures are correlated with the Badshot Formation marble on Roseberry Mountain.

Light grey to brillant white-weathering coarsely crystalline marble characterizes the Badshot Formation in the LaForme area. North of Mount LaForme, the Badshot Formation consists of interlayered coarse crystalline white marble and dark grey fine-grained marble, with rare pisolitic horizons and buff-weathering sandy dolomitic layers. Northeast of Mount LaForme, the upper(?) Badshot is characterized by a siliceous interval. The 50-metre section contains several silicified dolostone conglomerate horizons, 2 to 5 metres thick, massive silicified, white marble, and an interbedded sequence of buff orthoquartzite and dolostone. This section is overlain by interlayered black and green graphitic and calcareous phyllite, limestone conglomerate and quartzite breccia units of the basal Index Formation.

Marble in the lower limb of the Mount LaForme syncline is also highly silicified and brecciated, where it crops out 2 kilometres northwest of Mount LaForme. The upper section of marble is interbedded with orthoquartzites similiar to those in the section northeast of Mount LaForme. The marble layers are variably replaced by silica-flooding along some bedding planes, or cut by quartz stockworks and sigmoidal quartz-filled tension gashes. The buff-coloured quartzite beds are finely crackle-brecciated. Here, the Badshot Formation is less than 25 metres thick.

Upper contacts with the Index Formation and lower contacts with the Mohican Formation are gradational and conformable. The occurrence of archaeocyathid 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. 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 also assigned to the Index Formation (Logan and Colpron, 1995).

In the LaForme Creek area, the Lardeau Group consists of the same five lithostratigraphic units recognized in the Downie Creek area (Figure 4, Logan *et al.,* 1996). They include, in approximate stratigraphic order: 1) black graphitic, calcareous and/or siliceous phyllite, discontinuous quartzite breccia 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. Units 1 to 3 are correlated with the Index Formation, unit 5 is correlated with the Jowett Formation.

INDEX FORMATION

Black Phyllite

The lower part of the Index Formation 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 layers. 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 (Logan *et al.,* 1996).

In the eastern half of the LaForme map area black phyllite and brown-weathering calcareous phyllite of the Index Formation comprise the majority of the Lardeau Group exposures. Black phyllite defines four north-trending belts of Index Formation. Interbedded with the typically thinly-foliated commonly crenulated orange- and black-weathering calcareous and graphitic phyllite are quartzite breccias, limestone conglomerates, green phyllite and micaceous quartzites.

North of Mount LaForme, near Bridgeland Pass (Logan *et al.,* 1996), the contact between the Badshot Formation marble and black phyllite of the Index Formation is marked by a distinctive white orthoquartzite breccia unit. The unit has minor black phyllite layers and directly overlies buff-weathering dolomitic limestone conglomerate, phyllitic marble and massive grey marble of the Badshot Formation.

East of Mount LaForme, approximately 20 metres of white and pale pink crackle-brecciated quartzite is in sharp contact with a limestone cobble conglomerate unit of the Badshot Formation. The quartzite unit is typically fine to medium-grained, with a sucrosic texture. It is always brecciated. The breccias are tectonic in origin and clasts vary from angular and interlocking with minimal amounts of rotation to well-rounded and flattened with mantles of a darker matrix of insoluble residues formed during silica and/or calcite(?) dissolution.

Northwest of Mount LaForme, in the core of the LaForme syncline are several fold-duplicated quartzite breccia layers, within the black phyllite of the Index Formation. These quartzite units are buff-weathering, and locally have a calcareous matrix.

Marble

Light grey and white crystalline marble, thinly foliated buff-weathering phyllitic carbonate, and sandy dolostone beds are interbedded with dark phyllite and calcareous-micaceous quartzites of the black phyllite unit southwest of Mount LaForme. The marble, in general appearance is similiar to marble of the Badshot

Formation. Typical Index marble is phyllitic and a darker grey.

Greenstone

The greenstone unit is exposed north of Maunder Creek and in the Mastodon area. It consists predominately of dark green volcaniclastic units and massive sills which occur within black and green phyllites. The volcaniclastic rocks consist of pale grey-weathering, green tuffaceous phyllites, greenstone and calcareous, feldspathic volcanic wacke. In both these areas individual volcanic layers are less than 15 metres thick and are gradational into black phyllite. The greenstone is characterized by abundant small, white albite porphyroblasts. Sills of foliated metadiorite and metagabbro intrude black graphitic phyllite north of Maunder Creek. A second body of diorite crops out on the slopes north of the confluence of Carnes and McKinnon creeks (R. Pegg, personal communication, 1996). The sills have foliated margins and coarse-grained, equigranular cores, are concordant with the dominant foliation, and are composed of chlorite and plagioclase. The sill at Maunder Creek, which is approximately 20 metres thick; has a core of interlocking, 1 to 3 centimetre crystals of hornblende and plagioclase.

Index Formation volcanic rocks in the Standard and Keystone Peak areas are tholeiitic basalts of mid-ocean ridge basalt (MORB) affinity (Logan *et al.*, 1996).

MICACEOUS QUARTZITE

A thick(?) succession of well-bedded quartzite, micaceous quartzite and quartz-muscovite schist underlies the western-half of the map-area north of LaForme Creek. South and east of the creek, this belt of quartz-rich metasediments narrows and swings eastward following the northern contact of the Clachnacudainn orthogneiss. North, in the Downie Creek map-area, this quartzite and schist unit overlies the black phyllite and greenstone units of the Index Formation. Brown (1991) correlated it with the Broadview Formation; Logan *et al.* (1996) suggested it is older than the Jowett Formation and distinct from the Broadview Formation.

North of Maunder Creek, adjacent to the phyllite unit, the lower sections of the quartzite succession consist of thick-bedded white and pink orthoquartzite and interbedded micaceous quartzite. Up section the quartzites are interbedded with siliceous phyllite and rusty-weathering muscovite schist. Amphibolite, marble and metavolcaniclastic rocks of the overlying Jowett Formation are interlayered and in gradational contact with the top of the micaceous quartzite unit.

In the extreme northeast corner of the map is an upright-facing succession of interbedded rusty phyllite and calcareous quartz-feldspar grit and micaceous quartzite that overlies thinly bedded black graphitic, calcareous and locally pyritic phyllite of the lower Index Formation. Graded bedding and flame structures are present in the grit and provide way-up control north of Tumbledown glacier (Logan *et al.*, 1996).

JOWETT FORMATION

Green metavolcanic rocks and interlayered dolomitic marble are exposed along the slopes of the Columbia River (Brown, 1991; Logan *et al.*, 1996). Brown *et al.* (1983) correlated these rocks with the Jowett Formation, as did Crowley (1992) for the amphibolite, metatuff and interlayered marble exposed south of Mount LaForme (Figure 2). In both areas the rocks occupy an inverted stratigraphic panel; those north of LaForme Creek form the hangingwall of the Columbia River fault. Crowley (1992) shows the latter to occupy the hangingwall of the Lower Standfast Creek fault.

The rock units consist of layered mafic fragmental and epiclastic rocks and massive amphibolite. The amphibolite is characterized by massive sections consisting predominantly of fine acicular crystals of hornblende with rare plagioclase and minor epidote, calcite and pyrite.

INTRUSIVE ROCKS

Intrusive rocks are confined to the northern part of the Clachnacudainn salient of Wheeler (1963, 1965). The large variety of ages, compositions and deformation of the intrusions in the Clachnacudainn igneous complex make it a unique feature of the Selkirk allochthon (Crowley, 1992). Recent age dating in the Goldstream River and Downie Creek areas indicates an equally diverse plutonic history with similar ranges in composition and ages (Logan and Friedman, 1997, this volume). Two of the five major igneous suites present in the Clachnacudainn complex are represented in the LaForme area: the Early Mississippian Clachnacudainn orthogneiss, and the large, east-trending mid-Cretaceous composite granitic body that crops out at the headwaters of LaForme Creek.

EARLY MISSISSIPPIAN CLACHNACUDAINN GNEISS

Biotite hornblende granodiorite orthogneiss crops out south and east of LaForme Creek (Figure 2), and extends southward in an arcuate outcrop pattern to Albert Canyon and just east of Revelstoke (Crowley, 1992) (Figure 1). The orthogneiss at Albert Canyon was dated by Parrish (1992) at 358±6 Ma (U-Pb, zircon). South of LaForme Creek, on the old Mastodon mine road the gneiss is characteristically a well-foliated granitoid composed of alternating quartz and feldspar-rich leucocratic layers and biotite and/or hornblende-rich mafic layers. Quartz and plagioclase grains are flattened and recrystallized. Leucocratic, pegmatites and aplitic dikes are transposed into the main regional northwest-trending foliation. Ovoid crystal aggregates of biotite locally define a well-developed stretching lineation in the gneiss. The main foliation is deformed into north-trending folds and crenulated by steep north-trending kink bands.

The contact zone with the overlying micaceous quartzite and muscovite-garnet-biotite schists of the Lardeau Group is concordant with the dominant regional foliation. The contact is well exposed between the headwaters of LaForme and Maunder creeks. At three separate locations the gneiss is in sharp contact with amphibolite of the Jowett Formation. At the westernmost locale, pendants of rusty weathering micaceous quartzite and calcsilicate schists in orthogneiss define a concordant 5 metre wide contact zone. The contact with the micaceous quartzite succession is interpreted to be intrusive.

MID-CRETACEOUS GRANITOIDS

A composite intrusive body composed of biotite granodiorite, biotite granite and hornblende diorite intrudes the Devono-Mississippian orthogneiss at the southern end of the study area (Crowley, 1992). Pendants and screens of undivided metasediments occur within and along the margins of these two intrusions. The metasedimentary rocks consist of sillimanite, kyanite and amphibole-bearing quartzite, amphibolite and calcareous schist.

Near its western end, at Sale Creek, the granite is a greyish-pink biotite monzogranite with 1 to 4-centimetre long potassium feldspar megacrysts. It contains screens of hornblende biotite quartz monzodiorite and segregations of fine-grained leucogranite. Along its western side, the granite intrudes amphibolite-grade mylonitic metasedimentary rocks correlative with cover gneisses of the Monashee Complex (Brown *et al.,* 1993). It is mainly coarse grained with well-preserved igneous textures, although locally the potassium feldspar megacrysts and xenoliths define a weak to moderate foliation. The granite is mylonitized within a 400 to 500-metre thick north-trending shear zone at Sale Creek (Murphy, 1980). In outcrop the zone is composed of purple and light green mylonites with rounded potassium feldspar porphyroclasts. The contacts are sharp to gradational over a few centimetres between the mylonites and the biotite potassic feldspar megacrystic granite. Locally, the mylonites constitute up to 20 per cent of the granite. The granite is dated as mid-Cretaceous (U-Pb zircon, R.L. Armstrong, unpublished data).

The granitoids are compositionally similiar to, and coeval with the Battle Range batholith, Albert stock and Goldstream pluton; all are part of the mid-Cretaceous Bayonne Plutonic Suite of southeastern British Columbia.

DIKES AND SILLS

Steep-dipping, northeast-trending dikes of dark orange-brown weathering, vesicular porphyritic trachyte, 1 to 2 metres wide, intrude rocks of the Hamill and Lardeau groups west of Mount LaForme. The trachyte is composed of coarse, irregular clots of resorbed hornblende, potassic feldspar and quartz phenocrysts in a fine-grained trachytic groundmass of plagioclase and pyroxene. The dikes intrude the strata at a high angle to the dominant schistosity and consist of two, and in one locale three parallel dikes

STRUCTURE

At the regional scale, the structure of the LaForme area is dominated by northwest-trending, southwest-verging folds and faults that are characteristic of the west flank of the Selkirk fan structure. These are second generation structures as they are superposed upon older isoclinal nappes which locally inverted the stratigraphic sequence, such as in the Downie Creek area to the north (Read and Brown, 1979). Evidence for this early deformation in the Clachnacudainn Terrane is the preservation of an older schistosity in the hinges of the dominant folds, and as inclusion trails in garnets (Crowley, 1994). Both sets of structures are deformed by still younger east-southeast trending open folds.

The dominant structures that define the map pattern in the area around Mount LaForme are second generation, tight to isoclinal, overturned to recumbent or reclined folds and thrust faults (Figures 2 and 3). These have all apparently developed in upright-facing lower Paleozoic stratigraphy. Foliations and the axial planes of folds dip moderately to the northeast. Minor fold axes commonly plunge down-dip to the northeast, such that they and the larger-scale folds have the geometry of reclined folds. The effect of this geometry on the map pattern is that, at least locally, the stratigraphic succession youngs along rather than across the northwest-southeast regional strike This makes tracing out map units particularly difficult in this area.

Stereograms of planar and linear data from the LaForme area show no large variation across the map, and affirm that bedding-cleavage intersections and hinge lines of minor folds plunge moderately to the northeast (Figure 4). This unusual orientation is not directly compatible with the regional southwest-verging folding of the western Selkirk allochthon, which elsewhere is represented at the outcrop scale by northwest or southeast-plunging minor structures No evidence was found for major refolding, such as interference patterns or crenulation foliations, which could account for these structures. The most likely explanation is that local zones of high shear strain produced a progressive rotation of fold elements toward the southwest, the direction of structural vergence.

In the upper reaches of Carnes Creek are two major, moderately dipping, isoclinal folds, the Carnes Creek anticline and the LaForme syncline (Figure 2).

Figure 3. Northwest-trending recumbent isoclinal fold, cored by marble and interlayered schist of the Badshot Formation, located on the north flank of Mount LaForme. Viewed towards the northwest.

The Carnes Creek structure is a southwest-verging, southeast-plunging overturned anticline which is cored by Hamill Group micaceous quartzite. Badshot Formation marble occupies the limbs and forms the closure around the Hamill Group in the headwaters of Carnes Creek. The southwest-verging LaForme syncline is structurally beneath the Carnes Creek anticline. Black phyllite, quartzite breccia, calcareous quartzite and marble of the Index Formation core the syncline. Badshot Formation marble forms the closure north of McKinnon Creek (Logan *et al.,* 1996). The southern extension is not well exposed, but may be enclosed by Badshot Formation marble, in Elm Creek. If this is the case the LaForme syncline is doubly-plunging.

A northwest-trending fault zone(?) divides the western succession of micaceous quartzite and metavolcanic rocks of the Lardeau Group from the tightly folded quartzites, calcareous phyllites, marbles and black phyllites of the Hamill Group, Mohican, Badshot and Index formations of the eastern half of the map area. In the Downie Creek area to the north, the contact between the Index Formation and the micaceous quartzite and quartz-muscovite schist to the west, has been interpreted by Brown (1991) as a west-verging fault (the Standard Peak fault). Close inspection of this contact has revealed that, in most locations, the Index Formation is gradational into the underlying quartzite assemblage (Logan *et al.,* 1996). The fault does not occur at the contact between black phyllite and quartzite at Standard Peak, although the existence of a fault at this horizon elsewhere cannot be ruled out.

In the LaForme area, the westernmost belt of Index phyllite (Figure 2) is in gradational contact with the quartzite assemblage to the west, and fault contact to the east. North of Maunder Creek, on the ridge separating Maunder Creek and the east tributary of LaForme Creek, the western contact with the underlying micaceous quartzite is exposed. The contact is gradational but the change in metamorphic mineral assemblages is abrupt. Black crenulated calcareous phyllite and lesser interbedded greenstone and metadiorite pass directly into structurally lower biotite-muscovite±garnet bearing schist and quartzite. The eastern contact at this same locale is marked by a narrow (less than 2 metres thick), black, siliceous, manganese and iron carbonate-rich unit, separating the black phyllite unit of the Index Formation from mature white and pink orthoquartzite, micaceous quartzites and interbedded greenstone of the Hamill Group.

Northwestward from Maunder Creek, the fault juxtaposes progressively younger rocks over the black phyllite of the Index Formation. The fault appears to truncate the more northerly-trending Badshot and Mohican stratigraphy in the area of the Lead King and Adair mineral prospects, and the Badshot marble at the Mastodon mine (Figure 2). Bedding/foliation-parallel

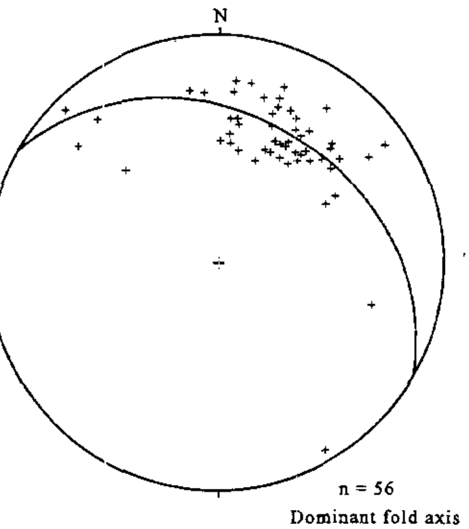

Figure 4. Equal area projection of plunge of minor folds of the dominant phase of deformation.

shear faults are common in the underground developments at the Mastodon mine (White, 1951; Fyles, 1960) and are locally mineralized.

A thrust fault juxtaposes rusty-weathering phyllite and dolostones of the Mohican Formation over black phyllites of the Index Formation, along the east flank of Roseberry Mountain (Figure 3, Logan *et al.*, 1996; Brown, 1991). This fault can be traced southward across McKinnon Creek and up onto the ridge separating McKinnon and Carnes creeks. The contact here between calcareous, rusty-weathering siliceous phyllites of the Mohican Formation and black graphitic phyllite is knife sharp, and it is difficult to envision a fault structure here, but if the structurally lower black phyllite is indeed the Index Formation then stratigraphic relationships require a thrust fault.

The contact between the Early Mississippian Clachnacudainn gneiss and the overlying metasedimentary rocks has been variously interpreted as unconformable, intrusive and faulted. In the LaForme area, Crowley (1992) described the contact as probably intrusive, but he shows a fault (the Lower Standfast Creek) following the contact between the gneiss and metasedimentary rocks. He constrains the upper time limit of motion by the intrusion of a probably mid-Cretaceous granodiorite. No kinematic evidence for ductile deformation was recognized along the contact between the orthogneiss and micaceous quartzite unit in the vicinity of Maunder Creek. We interpreted the contact to be intrusive into the Lower Paleozoic Lardeau Group strata and feel that a fault is not necessary to separate the Clachnacudainn terrane from the Selkirk allochthon in the La Forme Creek area.

The southwest-verging structures are deformed by younger east-trending, gently plunging folds. These structures are well developed farther north in the Goldstream-Downie map areas where they predate emplacement of the mid-Cretaceous Goldstream Pluton (Logan and Colpron, 1995) and postdate the peak of metamorphism. In the LaForme area this younger deformation is limited to the development of crenulation cleavage and small-scale open folds, mainly in phyllites and schists of the Index Formation, and is not reflected in the map pattern. The axial-planar schistosity is vertical to steeply dipping and strikes easterly.

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). The structure is a regional normal fault which strikes northwesterly and dips 20° to 40° to the east in the study 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). 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 décollement (Lane, 1984; Lane *et al.*, 1989; Brown *et al.*, 1992a). The fault migrates from place to place between the lower and upper plates of the décollement.

For the most part, the trace of the fault zone lies in the Columbia River and is not exposed. South of Carnes Creek 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. Discrete 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.

At Sale Creek, amphibolite-grade mylonitic metasedimentary rocks correlative with cover gneisses of the Monashee Complex (Brown *et al.*, 1993) have been mapped in the hangingwall of the Columbia River fault (Murphy, 1980). These are part of a 500-metre thick, post mid-Cretaceous, east-directed mylonite zone interpreted to be part of the Monashee décollement.

METAMORPHISM

Rocks of the Mount LaForme area contain mineral assemblages characteristic of greenschist to amphibolite facies metamorphism. Most of the map area is in the chlorite zone; biotite zone and amphibolite facies rocks are confined to the footwall of the Columbia River fault zone and to a narrow northwest-trending zone which follows the northern contact of the Early Mississippian Clachnacudainn gneiss body.

A metamorphic culmination extends 10 kilometres northwestward from Maunder Creek along the northern contact of the Clachnacudainn orthogneiss to the abandoned Mastodon Mine road. It extends approximately 1 000 to 2 000 metres north from the contact into the structurally overlying metasedimentary rocks. The rocks are garnet-muscovite-biotite-chlorite-andalusite paragneisses and schists. The garnet porphyroblasts are synkinematic with respect to the dominant foliation, which is defined by biotite and muscovite. The garnets commonly have retrograde rims of fine-grained muscovite, chlorite and quartz. Muscovite psuedomorphs andalusite. Calc-silicate horizons contain fine radiating clusters of actinolite arranged in a characteristic 'bow-tie' texture on the dominant foliation surfaces. The metamorphic grade decreases rapidly northeastward, and the gneisses pass structurally upward into biotite and chlorite-zone micaceous quartzite and quartz-muscovite schist. The garnet grade pelitic schist assemblages do not extend beyond the micaceous quartzite-schist unit into the overlying calcareous graphitic phyllite. It is unclear whether the transition between the micaceous quartzites and the phyllite is the result of a fault, decreasing metamorphic grade or compositional controls. The northern contact between the Early Mississippian orthogneiss and micaceous quartzite has been inferred to be a thrust fault (lower Standfast Creek fault; Crowley, 1992). At three separate exposures northwest of Maunder Creek, brittle, minor fault structures cut both the gneiss and its host rocks. No direct evidence for a major fault between the orthogneiss and the Lardeau Group metasedimentary rocks was observed.

Regional relationships and geochronology 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 LaForme Creek is inferred to be Middle Jurassic.

An alternative interpretation for the compressed, higher grade metamorphic zones at LaForme Creek, which takes into account the close proximity of the orthogneiss, is that this narrow belt coincides with an older contact metamorphic aureole around the original Early Mississippian granodiorite intrusion. Since the rocks in the aureole were already partially dehydrated, Middle Jurassic regional metamorphism reached a somewhat higher grade than the surrounding rocks which were undergoing metamorphism for the first time. The same spatial association between narrow metamorphic isograds and adjacent Early Mississippian orthogneiss is present in the Downie Creek area (Logan *et al.,* 1996; Logan and Friedman, 1997, this volume), supporting this interpretation.

MINERAL PROSPECTS

In the LaForme area, stratabound zinc and lead mineralization occurs in well-defined bedding parallel fissures in marble and dolostone of the Badshot Formation and phyllite and micaceous quartzite of the Hamill and/or Lardeau groups; and as disseminated replacements of these lithologies. At the Mastodon mine, zinc and lead mineralization occurs as veins along faults and as replacement zones, developed adjacent to the faults. At the J&L deposit, mineralization consists of a tabular stratiform body of precious and base metals (main zone) as well as zinc and lead replacement zones in the hangingwall marble (Yellowjacket zone). The relationship between these two zones is not clear.

J&L

The J&L is a stratiform precious and base metal deposit. It consists of a Main zone, 1.6 metres (true thickness) of massive and disseminated sulphides, developed over 800 metres underground, and traced on surface for over 1850 metres. Probable/possible reserves are 4.77 million tonnes grading 2.7 % lead, 4.3 % zinc, 7.2 grams per tonne gold and 72 grams per tonne silver. The Main zone is described by McKinlay (1987) and summarized by Meyers and Hubner (1989). It is probably an exhalative volcanogenic massive sulphide deposit, akin to Eskay Creek (Logan *et al.,* 1996). The Yellowjacket zone is a lead-zinc deposit hosted in siliceous carbonates in the hangingwall of the Main zone. It was a blind-deposit discovered in 1990 and has probable/possible reserves of 910,000 tonnes grading 7.4 % zinc, 2.6 % lead and 55 grams per tonne silver (Northern Miner - August 5, 1991. The Yellowjacket zone is an epigenetic carbonate replacement deposit.

MASTODON

The Mastodon mine is approximately 5 kilometres south of the J&L mine on the divide separating LaForme and Carnes creeks, at an elevation of 1525 metres. The abandoned and collapsed remains of the main camp and mill site on the north side of LaForme Creek is approximately 6 kilometres east of Highway 23.

The Mastodon showings were discovered in 1898. Mastodon Zinc Mines Ltd. developed the property in the early 1950s and produced a total of 31,204 tonnes averaging 10% zinc, approximately 0.3% lead and 0.04% cadmium during two short periods in 1952 and 1960. The mine was closed in 1960 and the facilities dismantled. The early history and detailed description of the mine workings are summarized in the Annual

Report of the Minister of Mines for 1950 (White, 1951) and 1959 (Fyles, 1960).

The Mastodon orebodies are on the western side of a lenticular mass of northwest-trending limestone of the Badshot Formation (Figure 2). To the west the carbonate is in contact with black, calcareous phyllite and greenstone correlative with the Index Formation. Phyllitic limestone, calcareous micaceous quartzite and grit, and grey phyllite of the Mohican Formation are exposed to the east. The strata are isoclinally folded and strongly sheared. Foliation strikes northwesterly and dips moderately to the northeast. Minor folds plunge north from 20° to 45°, with a Z-shape symmetry (viewed to the north). Fyles (1959) measured minor folds in the underground workings and concluded that two generations of folds are present. One plunges gently northwest and the other plunges northeast down the dip of the foliation. He recognized several foliation-parallel shear zones (strike faults) underground and the primary control they have on the zinc mineralization. The mineralization either occupies these structures or has spread outwards from them into chemically and/or structurally favourable zones. The orebodies dip to the northeast and pitch to the north (Fyles, 1960).

The sulphide assemblage is simple, consisting of disseminations and streaks of honey-coloured sphalerite and minor amounts of fine-grained galena and tetrahedrite (a silver-bearing sulphosalt). Sphalerite replaces limestone, dolostone and to a lesser extent phyllite. Pyrite is notably absent. Mineralization is localized at carbonate-phyllite contacts (predominantly within carbonate rocks) adjacent to faults and concentrated along fold hinges. Bleached alteration zones correspond to shear zones, and zones of silicification and dolomitization of the carbonate. Alteration of the phyllitic rocks is restricted to silicification and sericitization (Fyles, 1960). Partial to complete oxidation of the zinc mineralization, to considerable depths has resulted from groundwater circulation along solution cavities in the calcareous rocks (White, 1951). These ground conditions have proven to be inhospitable to most of the diamond drilling programs initiated on the property.

The age of mineralization is not well constrained. The only intrusive in the area is the Early Mississippian Clachnacudainn orthogneiss south of LaForme Creek. Sulphide textures indicate mineralization has undergone at least some post deposition deformation (probably in the Jurassic). Remobilized quartz and sphalerite fill sigmoidal tension gashes which crosscut early layer-parallel sphalerite replacement and galena-rich layers that contain rounded clasts of sphalerite, quartz, carbonate and phyllite in a fine-grained sulphide matrix (*durchbewegung* texure - a texture common in deformed and metamorphosed massive sulphide deposits). Lead isotopic model ages for the carbonate replacements of the Lower Cambrian Badshot Formation in the area are either Devonian or Jurassic.

Two diamond drill holes were completed on the Mastodon property by Banff Resources Inc. in 1994. Neither intersected economic concentrations of mineralization, but hole 1994-1, collared and drilled 121.39 metres in Index phyllites, intersected a faulted 9.7 metre thick zone containing garnets and minor sulphides. Geochemistry (Christopher, 1994) indicated elevated manganese, but generally lower lead, zinc and copper values than overlying strata. This horizon is geochemically similiar to the "garnet zone" in the hangingwall to the orebody at the Goldstream mine.

The Lead King prospect is located 3 kilometres southeast of the Mastodon Mine. Development work was limited to surface trenching and possibly a shallow adit. The showings are located at the southeastern end of the Mastodon marble lens (Figure 2). The rocks consist of variably silicified dolostone and grey phyllite, the former is locally so siliceous it resembles grey or buff quartzite (Fyles, 1960). Strata is isoclinally folded and sheared; strike is almost easterly and the dip is gentle to the north, into the hill. Galena and sphalerite occur as disseminations and fracture fillings replacing silicified limestone and dolostone. Four or five lenses of sulphides are exposed along the dolostone for about 60 metres (Fyles, 1960).

The Adair adit and trenches are located approximately 1.5 kilometres east of the Lead King prospect. The showings are hosted in grey limestone, grey dolostone and green and grey phyllite, correlated with the Mohican Formation. The rocks strike northwest and dip moderately northward into the hill. Mineralization is hosted in five or six steep to vertical white quartz veins which cut the main foliation at a high angle. The veins are irregular in thickness, continuity and sulphide content (Fyles, 1960). Pyrite, arsenopyrite, pyrrhotite, minor sphalerite, galena and chalcopyrite occur as irregular clusters in boudinaged quartz veins. A second showing about a kilometre to the southeast contains disseminated galena and sphalerite as replacements in limestone and dolostone (Fyles, 1960).

NEW PROSPECTIVE HORIZONS

In the Goldstream area, a distinctive spessartine garnet-bearing, pyrrhotite-rich, thinly laminated graphitic coticule unit, termed the "garnet-zone", is associated with the massive sulphide layer. It is interpreted to be an exhalite manganese-iron-rich seafloor hydrothermal precipitate (Höy *et al.*, 1984). These garnet zones are important exploration targets and mapping this summer recognized two additional iron-manganese-silica-rich horizons in the Mount LaForme area.

The two zones, both forming gossans, were recognized within lower Index Formation black phyllite close to the contact with the Badshot Formation. Both zones contained up to 3 per cent stratabound disseminated and massive sulphides consisting of pyrrhotite and/or pyrite with rare chalcopyrite. Sulphides occurred in zones of tight folding and silicification, and exhibited textures indicative of remobilization. The distribution and base metal content of these zones was not anomalous, and the manganese content was only slightly anomalous.

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