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GEOLOGY ADJACENT TO THE WESTERN MARGIN OF THE SHUSWAP METAMORPHIC COMPLEX (Parts of 82L, M)

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ABSTRACT

The west margin of the Shuswap metamorphic complex is bounded by low to moderate-angle, ductile-brittle, west-side-down, Eocene normal faults of the Okanagan - Eagle River fault system, which between 50°30'N and 51°30'N latitude juxtapose upper amphibolite facies rocks of the Shuswap assemblage against greenschist to lower amphibolite facies rocks of the Eagle Bay and Mount Ida assemblages. The Shuswap assemblage contains a succession of migmatitic semipelite, psammite, calcareous amphibolite, calcsilicate gneiss and marble that is inferred to be correlative with the Hadrynian Horsethief Creek Group. The Eagle Bay and Mount Ida assemblages contain quartzite, semipelite, marble, calcsilicate schist, metabasite, and calcareous and graphitic phyllites that are interpreted to be correlative with uppermost Hadrynian to lower Paleozoic rocks of the Hamill Group, Badshot Formation and Lardeau Group.

Compositional layering and subparallel S_1 foliation in all three assemblages are folded by tight to isoclinal, recumbent to gently inclined, synmetamorphic D_2 folds. The metamorphic peak predated or was synchronous with development of upright (in the Eagle Bay) to moderately inclined (in the Shuswap), gently northwest and southeast plunging D_3 folds. S_3 crenulation cleavage is well developed in the Eagle Bay and Mount Ida assemblages and in the Shuswap assemblage near Adams Lake.

Footwall mylonites in the Eagle River and northern Adams Lake segments of the Okanagan - Eagle River fault system consistently display west-directed shear sense and are overprinted by retrograde metamorphism and cataclasis beneath a brittle detachment. In the Scotch Creek segment, strain is partitioned in a zone of ductile-brittle and brittle faults that strike at low angles to the shearing direction.

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INTRODUCTION

The boundary of the Shuswap metamorphic complex has long been recognized as a sharp transition between upper amphibolite facies rocks within the complex and rocks of greenschist facies that overlie it (*see* Okulitch, 1984, for a review). Mapping and geochronology during the past decade have demonstrated that the Shuswap and other metamorphic complexes in the southern Omineca Belt are bounded by low to moderate-angle Eocene normal faults, which juxtapose rocks of different metamorphic grades and with different cooling histories (Parrish, 1984; Parrish *et al.*, 1985, 1988; Parkinson, 1985; Bardoux, 1985 and in preparation; Tempelman-Kluit and Parkinson, 1986; Carr *et al.*, 1987).

The present study focused initially on structural analysis of a transect near the Trans-Canada Highway (Johnson, 1988), through the part of the Shuswap complex that lies structurally beneath the Eagle River fault, a low-angle normal fault that bounds the Shuswap complex on the west, and above the Monashee décollement, a crustal-scale ductile thrust fault. Emphasis then shifted to documentation of the structure of the Eagle River fault, where the shear zone in its footwall is reasonably well exposed at various paleocrustal levels along Mara Lake and in the Eagle River valley (Johnson, 1989a, b). Together with reconnaissance and local detailed mapping between Shuswap Lake and Adams Lake, this work has given insight into the distribution of strain related to what here is termed the Okanagan - Eagle River fault system, and has highlighted problems for future investigation into the nature of strain partitioning in detachment fault systems in general.

Detailed mapping has led to identification of stratigraphic successions in both the footwall and hangingwall of the Eagle River fault, which allows for comparison and preliminary correlations with known miogeoclinal strata in other parts of the southern Omineca Belt. In conjunction with seismic reflection data from the LITHOPROBE Southern Canadian Cordillera transect (Cook *et al.*, 1990), these geological data have implications for construction and restoration of crustal cross-sections through the Omineca Belt (Johnson and Brown, 1989, 1990a, b; Johnson, in preparation).

PREVIOUS WORK

The study area encompasses parts of areas mapped at a scale of 1 inch to 4 miles by Jones (1959), Campbell (1963) and Wheeler (1965), and at 1:250 000 by Okulitch (1979). Details of the structure in the Shuswap Lake and Mara Lake areas have been investigated by Fyson (1970) and by Nielsen (1978, 1982).

The northwest corner of the accompanying map adjoins and compliments the 1:100 000 scale map by Schiarizza and Preto (1987). The Okanagan Valley segment of the Okanagan - Eagle River fault system has been mapped south from Enderby to Kelowna by Bardoux (1985 and in preparation). To the east, geology of the Monashee Mountains has been mapped at 1:100 000 scale by Höy and Brown (1981) and by Read (1979). Detailed maps by Bosdachin (1989) and by Harrap (1990) delineate the boundary between the Monashee complex and the overlying allochthon near the Trans-Canada Highway.

GEOLOGY

GEOLOGICAL SETTING

The accompanying map shows the distribution of four tectonostratigraphic assemblages and various plutons that intrude them. Each assemblage has distinctive lithologic and metamorphic characteristics, and three of them are separated by major shear zones.

The structurally deepest assemblage is the Monashee complex, which consists of Aphebian basement gneisses (Wanless and Reesor, 1975; Armstrong, 1983) and a thin metasedimentary cover of Hadrynian to Cambrian(?) age (Parrish and Scammell, 1988; Höy and Godwin, 1988). The other three assemblages belong to a composite sheet (termed the Selkirk allochthon by Read and Brown, 1981) of accreted terranes and metamorphosed rocks of the North American pericratonic prism, which were thrust eastward over the Monashee complex in the Mesozoic to Paleocene along the Monashee décollement (Brown *et al.*, 1986).

The Shuswap assemblage, as redefined here, consists of high-grade metamorphic rocks of the Selkirk allochthon that lie structurally beneath the Okanagan - Eagle River detachment fault. Above the detachment are low to medium-grade metamorphic rocks that were termed Mount Ida group by Jones (1959). These are subdivided into the Eagle Bay assemblage (as defined by Schiarizza and Preto, 1987; formerly Eagle Bay formation of Jones, 1959) and the Mount Ida assemblage (here defined as those rocks of Jones' Mount Ida group that structurally underlie the Eagle Bay assemblage).

The Eagle Bay assemblage is correlative with Paleozoic strata of the North American pericratonic prism (Okulitch, 1979; Schiarizza and Preto, 1987). The Mount Ida assemblage may also be correlative with Lower Paleozoic strata, as discussed below, but alternatively could at least in part be exotic with respect to the North American craton, as was suggested by Okulitch (1979). The nature of formational contacts within the Mount Ida assemblage and between the Mount Ida and Eagle Bay assemblages awaits clarification.

Investigations of the structure and kinematics of the Monashee décollement have demonstrated a consistent east-directed (*i.e.*, upper plate to the east) sense of shear for emplacement of the Selkirk allochthon (Journeay and Brown, 1986; Journeay, 1986; Scammell, 1986; Bosdachin and Harrap, 1988; Bosdachin, 1989; Coleman, 1989 and in preparation; Harrap, 1990). In contrast, mylonites of the Okanagan - Eagle River fault system consistently display west-directed shear sense (Bardoux, 1985; Journeay and Brown, 1986; Johnson, 1988, 1989a, 1989b). Unpublished U-Pb zircon and monazite geochronological data from the present study corroborate the conclusions of related studies elsewhere in the southern Omineca Belt (Carr *et al.*, 1987; Carr, 1989a, 1989b, in preparation; Parrish *et al.*, 1988) that the time gap between the cessation of east-directed thrusting and the onset of Eocene extensional faulting can be no more than a few million years.

STRATIGRAPHY

SHUSWAP ASSEMBLAGE

Metasedimentary successions in the Hunters Range are dominated by migmatitic garnet-biotite semipelite and feldspathic psammite, with locally abundant garnet-sillimanite-biotite metapelite (Units **Sus**, **Ss**). These units locally contain boudins of massive clinopyroxene and garnet-bearing amphibolites, notably at Three Valley Lake (Ghent *et al.*, 1977) and at Mount Mara (Johnson, 1989a). Calcsilicate and marble units along Mara Lake (**Sm**), in the Mount Mara area (**Sc**, **Sm**), and on ridges east of Kingfisher Creek (**Suc**, **Sm**) are tentatively correlated with one another based on their lithology and their association with distinctive layered amphibolites (Unit **Sa** and in Unit **Suc**). The amphibolites consist of layers of hornblende-biotite(-garnet) and diopside-plagioclase, which alternate on a scale of a few millimetres to a few centimetres. On outcrop scale they are interlayered with semipelite, psammite and minor pelite like those of Unit **Ss**. At Mount Mara, the structural top of Unit **Sa** is marked by a thin discontinuous layer of brown diopsidic marble and calcsilicate.

Lithologically, much of the Shuswap assemblage in the Hunters Range resembles semipelite-dominated successions of the Windermere Supergroup. In particular, units with amphibolite boudins could be correlative with the semipelite-amphibolite (SPA) division of the Horsethief Creek Group (*e.g.* Poulton and Simony, 1980; Pell and Simony, 1981, 1982). Layered, diopsidic amphibolites, like those of Unit **Sa**, have been reported from the upper part of the SPA and within the overlying middle marble division of the Horsethief Creek Group in the northern Adams River area (Sevigny, 1987). Units mapped as **Sc** and **Sm** could be correlative with the carbonate intervals within the middle marble division (*e.g.*

Brown *et al.*, 1978; Pell and Simony, 1982, 1987). Amphibolite (**Sa**) and a thick marble unit (**Sm**) exposed 6 kilometres east of Kingfisher Creek are tentatively correlated with the middle marble. These structurally overly a heterogeneous succession of calc-silicate, semipelite and pelite (**Suc**), which contains numerous thin marble layers and could be correlative with the carbonate-calcsilicate and upper pelitic zones of the SPA described by Pell and Simony (1981).

Poorly exposed calcareous rocks in Unit **Suc** southwest of Mount Mara may in part be correlative with those on alpine ridges of the Hunters Range, but in part structurally overlie them and may be correlative with Lower Paleozoic strata (Index Formation?). Southeast of this map area, on the southern flanks of Thor-Odin dome, the Shuswap assemblage consists of a condensed Windermere section and overlying rocks that range from Lower Paleozoic to Triassic age (Carr, 1989a). The southern vergence of F_2 folds in the Hunters Range suggests an increase in structural level toward the south and is consistent with a southward younging of strata, assuming they are right-way up.

Garnet-biotite-hornblende-quartz-feldspar gneiss and biotite-hornblende granodiorite gneiss dominate the northeastern Hunters Range (Units **Suh** and **Sh**). These rocks are medium grained and layered but are quite homogeneous. They are inferred to be orthogneisses and are of unknown age.

In the region between Seymour Arm and Adams Lake, and on the west flank of Celista Mountain in the southern Seymour Range, the Shuswap assemblage is dominated by semipelitic (sillimanite-garnet-)biotite-muscovite schists with thin interbeds of feldspathic psammite and quartzite. Graded bedding has been observed in three localities south of Pukeashun Mountain, but the rocks are tightly folded by pre-D_3 structures and no regional sense of stratigraphic facing could be determined. It is tentatively postulated that these rocks are correlative with Windermere strata (Kaza or Cariboo Group?). Semipelites on the southern flank of Pukeashun Mountain contain abundant layers and boudins of hornblende-rich amphibolite and probably belong to the SPA division of the Horsethief Creek Group.

EAGLE BAY ASSEMBLAGE

In the Shuswap Range north of Sicamous, the Eagle Bay assemblage consists of a tripartite stratigraphic succession (Units **Ec**, **Em** and **Eq**) that is structurally repeated by folds and possibly by thrusts, and within which stratigraphic tops have yet to be identified.

Unit **Em** is a distinctive, clean, white to grey marble that ranges from 0 to 200 metres in structural thickness. It is inferred to be correlative with the Lower Cambrian Tshinakin marble (Schiarizza and Preto, 1987) in the Adams Lake area, with the Badshot Formation in the Selkirk Mountains and Kootenay Arc, and possibly with the Bralco marble of the Snowshoe Group in the Cariboo Mountains and Quesnel Highland.

Unit **Ec** is a heterogeneous assemblage of thinly interbedded calcsilicate schist, fine-grained grey and brown marble, quartz-sericite-chlorite phyllite, metasiltite, grey fine-grained quartzite, semipelitic to pelitic mica schist, and minor white quartzite. Epidote-biotite-chlorite-actinolite schists are abundant and in some places dominant (Unit **Eca**). They locally crosscut calcareous strata, and are interpreted as mafic metavolcanic rocks and related shallow intrusions. Unit **Ec** is inferred to be correlative with the lower Lardeau Group (Index and perhaps Jowett formations), based on its similarity to descriptions by Fyles (1964); with Unit EBG of Schiarizza and Preto (1987); and possibly with the Downey succession of the Snowshoe Group (*cf.* Struik, 1986, 1988).

Unit **Eq** is a thick succession of light brown to greenish grey, fine to medium-grained, micaceous quartzites interbedded with pelitic to semipelitic biotite-quartz-muscovite schist and minor feldspathic granule conglomerate. In intervals where pelite is abundant, the quartzite layers weather white to light grey. Where composition and metamorphic grade are appropriate, the schists contain porphyroblasts of garnet and staurolite. Mafic metavolcanic rocks like those of Unit Ec are occur within the quartzite succession, especially on the flanks of North Queest Mountain and near the contact with Unit **Em**. Rusty yellow and dark greenish grey weathering sericitic phyllites are also common near this contact. The stratigraphic thickness of unit **Eq** is unknown. Structural thicknesses of more than 300 metres, with no obvious repetitions, are well exposed east of Queest Mountain and on the southeast flank of North Queest Mountain; the total thickness of the unit is likely at least twice that. Unit **Eq** is tentatively correlated with the Hadryno-Cambrian Hamill Group on the basis of lithological similarity and on its association with probable Lower Cambrian marble of Unit **Em**.

If the correlations outlined above are correct, then the section is mostly inverted between Sicamous and Queest Mountain, is repeated by tight folds and possible thrusts in the Queest Mountain area, and is right-way-up at North Queest Mountain. Additional mapping will focus on sorting out the details of the structure in these areas.

In the Kwikoit Creek drainage east of Adams Lake, Unit **Ec** has been subdivided into units that are collectively correlative with Unit EBG of Schiarizza and Preto (1987) and probably with the Lardeau Group. Sericite-quartz and pyrite-graphite-sericite phyllites (**Ecp**) are probably Index Formation. Grey impure marbles of Unit

Ecm resemble the Sicamous Formation (Mount Ida assemblage) and probably also correlate with the Index Formation, although they may correlate with the Tshinakin (and Badshot) marble as mapped by Okulitch (1979). Mafic metavolcanic rocks (**Eca**) are presumably correlative with the Jowett Formation. Unit **Ec** is structurally overlain in the Kwikoit Creek area by quartzites, metasiltites, quartz-sericite phyllites, and feldspathic granule conglomerate mapped as Unit **Eq**. These may either be Hamill Group or part of the Lardeau (Broadview Formation?).

MOUNT IDA ASSEMBLAGE

The Sicamous Formation (**Isc**) consists of grey, fine-grained, phyllitic marble, and calcareous and carbonaceous phyllites. Although it may be of Triassic age (Campbell and Okulitch, 1973; Okulitch and Cameron, 1976), it is strikingly similar to calcareous units of the Eagle Bay assemblage (Unit **Ecm**) and is more likely correlative with Lower Paleozoic strata of the Lardeau Group; calcarous and graphitic pelites are common in the Index, Triune and Sharon Creek formations in the Kootenay Arc (Fyles and Eastwood, 1962; Fyles, 1964).

Mafic metavolcanic rocks of the Tsalkom Formation (**Ita**) have previously been regarded as equivalent to the Fennell Group of the Slide Mountain Terrane (Okulitch, 1979; Okulitch and Cameron, 1976). Considering the favoured correlation of the overlying Sicamous Formation with Lardeau strata, the Tsalkom could instead be correlative with the Jowett Formation. It resembles metabasites in the Eagle Bay assemblage that are associated with Lower Cambrian marble (Unit EBG of Schiarizza and Preto, 1987). A comparative geochemical investigation of metabasites of the Tsalkom, Eagle Bay, Fenell, and Lardeau groups seems warranted.

The Silver Creek Formation (**Isq**) contains semi-pelitic to pelitic quartz-muscovite and garnet-biotite-quartz-muscovite schists, micaceous and feldspathic quartzites, and minor carbonate and mafic schist. These rocks bear resemblance to unit **Eq**, and to Unit **Su** in the Adams Lake area and at Celista Mountain. The Silver Creek Formation may be correlative with the Lardeau Group (distal Broadview?), or with Hadrynian to Lower Cambrian strata of the Windermere and Hamill. The latter possibility would suggest that the contact between the Silver Creek and the structurally overlying Sicamous and Tsalkom formations is a fault. The uppermost part of the Silver Creek, 2.5 kilometres west of Sicamous on the Trans-Canada Highway, is cut by zones of graphitic clay gouge several metres thick that are subparallel to layering. Both the Silver Creek and the overlying Sicamous Formation are cut by steeply northeast-dipping brittle faults. This constitutes good evidence for a fault contact between these two units, but whether the fault is a thrust or a normal fault remains unresolved as do the ages of the rocks.

INTRUSIVE ROCKS

Devonian granitoid gneiss of the Mount Fowler suite (Okulitch, 1979; Unit **Dg**) forms extensive discordant to subconcordant sheets within the Eagle Bay assemblage. The suite is typified by medium to coarse-grained granodiorite gneiss that contains up to 25 per cent biotite (plus hornblende and epidote locally), is strongly foliated, and commonly bears a lineation defined by biotite aggregates and/or quartz ribbons. Granitoid gneiss that intrudes the Shuswap assemblage at Celista Mountain looks identical to the Mount Fowler gneiss and thus probably is also Devonian.

Units **T(?)gm** and **T(?)gb** consist of multiple generations of medium-grained leucogranite and pegmatite that intrude, and engulf screens of metamorphic rocks of the Shuswap assemblage (the contacts shown on the map are approximate, marking the transition from mainly granite to mainly metamorphic rocks with 50 per cent or less granite sheets and dikes). Leucogranite of Unit **T(?)gm**, well exposed at Pukeashun Mountain, contains 10-15 per cent muscovite and generally less than 5 per cent biotite and garnet. Similar two-mica granites were observed in reconnaissance north of the map area between the North Thompson River and Adams River. Late Paleocene granites described by Sevigny *et al.* (1990) in the northern Adams River area have identical field relationships and probably are of the same suite. Medium to coarse-grained biotite monzogranites of Unit **T(?)gb** form plutons and sheets north of Four Mile Creek that could be part of either the Late Paleocene - Early Eocene Ladybird suite (Carr *et al.*, 1987; Parrish *et al.*, 1988; Carr, 1989a) or a Late Cretaceous suite (R. Parrish and J. M. Journeay, unpublished data, 1989) in the northern Anstey Range. Dikes and sills of medium-grained biotite leucogranite intrude biotite-hornblende gneisses of Unit **Suh** at Mount Griffin. Small plutons of fine to medium-grained leucogranite, mapped as Unit **T (?)g**, intrude the Eagle Bay assemblage and the Devonian orthogneiss in the Shuswap Range near Queest Mountain. These rocks contain virtually no varietal minerals, except for small weathered pyrites, and are unstrained.

The Shuswap assemblage is extensively intruded by sheets, dikes and stocks of pegmatite that commonly form over 50 per cent of the exposure and that vary in texture from undeformed to mylonitic. Much of this pegmatite is of the Late Paleocene - Early Eocene Ladybird suite, but some of it is Mesozoic (Johnson, unpublished data, 1989).

Medium to coarse-grained diabase (**Tl**) forms small stocks in the Eagle Bay and Shuswap assemblages east of Adams Lake. These rocks are altered but are not strained. They are composed of plagioclase (calcic andesine) laths with intergranular ferromagnesian minerals. The latter include relic clinopyroxene that locally is mantled by hornblende and that generally is replaced by uralitic actinolite of probable deuteric origin. Biotite, epidote and oxides are other common constituents. Medium-grained biotite quartz diorites, also undeformed, intrude the Shuswap assemblage north of Kwikoit Mountain and were not mapped separately. Because these rocks are undeformed, they are likely post-Early Eocene in age. They may be related to swarms of lamprophyre and potassium-feldspar porphyry dikes that intrude the Shuswap assemblage and, at Mount Fowler, orthogneiss of Unit **Dg**. The dikes strike north-northwest in the Hunters Range and northeast in the Mount Fowler and Pukeashun Mountain areas.

ECONOMIC GEOLOGY

The Eagle Bay assemblage hosts numerous occurrences of sulphide minerals with associated copper, lead, zinc, silver and gold (Preto and Schiarizza, 1985; Schiarizza and Preto, 1987; Okulitch, 1979). Sulphides (mainly chalcopyrite and pyrite, some bornite and tetrahedrite) are disseminated and locally concentrated in the calcareous rocks of Unit Ec. Actinolite-epidote skarns are common in Unit Ec near contacts with Devonian orthogneiss. Along the Adams River valley, disseminated sulphides (including chalcopyrite, pyrite and pyrrhotite) occur in sheared metapelites, biotite-hornblende gneiss and calcareous amphibolite of the Shuswap assemblage.

STRUCTURAL GEOLOGY AND METAMORPHISM

SHUSWAP ASSEMBLAGE

Compositional layering and a subparallel penetrative foliation (together called S_0S_1) are deformed by close to isoclinal, recumbent to gently inclined, second-phase folds (F_2). Hingelines of F_2 folds, and an intersection lineation ($S_0S_1 \wedge S_2$) defined by mica edges, trend northeast in the Hunters Range and southeast between Shuswap Lake and Adams Lake. They are subparallel to a stretching lineation defined by aligned inequant minerals (such as sillimanite and strained quartz) and mineral aggregates. Layers of biotite schist in hinge areas are deformed by a subhorizontal S_2 crenulation cleavage. As noted by Jones (1959), most of the F_2 folds in the Hunters Range verge southward. They typically are of the order of a few metres in scale, but some south-verging folds near Mount Griffin have short limb lengths on the order of 100 metres.

A younger set of upright to moderately inclined, overturned, southwest-verging folds (F_3) deforms D_2 structures and the stretching lineation. These folds typically are open, although minor folds in pelites are close to tight and have angular hinges. Their axial surfaces dip subvertically to moderately northeastward, and hingelines are subhorizontal to gently plunging. The largest folds in the Hunters Range, notably at Mount Mara, have short limbs well over 100 metres long. Metapelites locally exhibit an axial-plane S_3 cleavage defined by parallel sillimanite and micas. Between Adams Lake and Scotch Creek, S_3 is a well developed crenulation cleavage in mica schists. Steeply dipping crenulation cleavage in the Mount Celista area and north of Kwikoit Creek was mapped as S_2 because only two foliations were recognized; its orientation and style, however, suggest that it actually is S_3.

Mylonitic pegmatites in the northeastern part of the Hunters Range and in the southern Jordan Range exhibit asymmetric feldspar porphyroclasts and shear bands indicative of east-directed shear. The east-directed fabrics affect rocks as young as latest Paleocene (B.J. Johnson, unpublished data, 1989), and are interpreted as being caused by thrusting (Johnson, 1988; Bosdachin, 1989).

Metamorphic grade in the Hunters Range, and in parts of the southern Anstey and Jordan ranges, is upper amphibolite facies; pelitic rocks contain sillimanite and potassium and are commonly migmatitic. Muscovite and sillimanite are present in pelites on ridge tops near Mount Griffin, in the footwall of the Eagle River fault along Craigellachie Creek, and throughout the area mapped between Shuswap Lake and Adams Lake. Sillimanite is parallel to the stretching lineation in both east and west-directed tectonites, and occurs in pressure shadows on garnets in the west-directed shear zone beneath the Eagle River fault. The metamorphic peak may therefore have been as late as Early Eocene, and may have been diachronous. The cooling history of the Shuswap assemblage is currently under investigation.

D_2 structures could have formed as early as Early or Middle Jurassic, in response to accretion of the Intermontane Superterrane (*cf.* Price *et al.*, 1985; Terrane I of Monger *et al.*, 1982). They seem to have been variably rotated into subparallelism with the east-northeast trending stretching lineation, in response to Mesozoic-Paleocene shearing above the Monashee décollement. F_3 folds deform the stretching lineation in rocks that contain indicators of west-directed shear and hence may be as young as Eocene, although they could be older structures that were amplified during Eocene shearing beneath the Eagle River fault. F_3 folds are locally cut by discrete, chloritic, west-directed shears of probable Early Eocene age.

EAGLE BAY AND MOUNT IDA ASSEMBLAGES

First-phase foliation (S_1) is subparallel to primary layering (S_0) and is only locally preserved, probably because growth and recrystallization of metamorphic minerals that define S_1 (*e.g.* micas) outlasted its formation.

S_0S_1 is deformed by a pervasive, penetrative, D_2 foliation (S_2) and tight to isoclinal folds (F_2). The folds have gently plunging, southeast to northeast-trending axes, and are most prominent on a mesoscopic scale in thinly interlayered quartzites and metapelites of Unit **Eq.** Control on the geometry of megascopic D_2 structures, and on their timing and tectonic significance, is limited; speculations are withheld until further mapping and geochronology are completed.

S_2 is folded about gently northwest or southeast-plunging axes by open, steeply inclined F_3 folds and crenulations. An axial-plane crenulation cleavage (S_3), defined by foliae of parallel muscovite and biotite (locally retrograded to chlorite) spaced a few millimetres apart, is developed in phyllites and pelitic schists. The map pattern in the Shuswap Range south of Queest Mountain is dominated by an F_3 synform that has a wavelength of several kilometres. On the outcrop scale, D_3 structures are geometrically similar to D_3 structures in the Shuswap assemblage, and to crenulations in the Eagle Bay assemblage west of Adams Lake that Schiarizza and Preto (1987) noted to be older than the mid-Cretaceous Baldy batholith.

Metamorphic grade increases to the northeast from biotite to garnet zone of greenschist facies in the Adams Lake area. Metamorphism of the Silver Creek Formation in the Larch Hills is upper greenschist facies (garnet zone). Staurolite occurs at several localities in metapelites of the Shuswap Range, indicating lower amphibolite facies.

Porphyroblasts of garnet and staurolite in the Shuswap Range overgrow S_2 in some places, but in others S_2 wraps around the porphyroblasts. Garnets are locally deformed by F_3 crenulations, but locally overgrow S_3. Protracted metamorphism therefore accompanied D_2 and D_3, and peaked before or during the early stages of D_3. Porphyroblasts of biotite cross S_3, indicating that metamorphism outlasted D_3.

OKANAGAN - EAGLE RIVER FAULT SYSTEM

The Eagle River fault (Journeay and Brown, 1986) is a plastic-brittle normal fault that juxtaposes low to medium-grade metamorphic rocks of the Eagle Bay and Mount Ida assemblages against the Shuswap assemblage. Mylonites in the immediate footwall exhibit C/S fabrics, rotated feldspar porphyroclasts with asymmetric recrystallized tails, and shear bands that consistently indicate relative westward movement of the upper plate (Johnson, 1988, 1989a; lineation symbols with open half-arrows on the accompanying map show locations where at least two independent indicators of westward shear sense were observed in the field).

Shear fabrics in mylonites near Sicamous and along the east side of Mara Lake are defined by garnet-biotite-sillimanite-potassium feldspar assemblages. Quartz-feldspar aggregates, sillimanite, and pressure shadows marginal to porphyroclasts define a strong west-trending stretching lineation. Some discrete shears contain retrograde chlorite after biotite, and local cataclastic zones display slickensides with west-directed chlorite-fibre lineations subparallel to the stretching lineation. About 150 metres beneath the projected position of the brittle detachment on the west side of Mara Lake, retrograded west-verging mylonites exhibit slickensided shear planes, spaced about 2 millimetres apart, defined by chlorite and relic sillimanite (Johnson, 1989a).

Calcsilicate and amphibolite rocks in the Larch Hills near the southwest end of Mara Lake (designated on the accompanying map as Units **Sua?** and **Suc**) were inferred to be correlative with similar rocks on the east side of the lake by Nielsen (1978, 1982). They are apparently in fault contact with the Sicamous (**Isc**) and Tsalkom (**Ita**) formations, and have been interpreted as part of the footwall of the Eagle River fault, exposed in a small antiformal culmination (Johnson, 1989a). However, the rocks in the Larch Hills do not display mylonitic fabrics and are of lower metamorphic grade (interlayered pelites lack sillimanite and contain muscovite) than footwall rocks on the east side of Mara Lake and on peninsulas along the northwest shore. An alternative interpretation is offered here, that Units **Sua?** and **Suc** in the Larch Hills constitute a slice that is bounded by the Eagle River fault and a low-angle splay. The main detachment probably continues from southwest of Black Point along the western shorelines of Mara Lake and Rosamond Lake. South of Rosamond Lake, the fault trace follows the Shuswap River beyond Grindrod, and probably merges with the Okanagan Valley fault as suggested by Journeay and Brown (1986).

Northeast of Sicamous, the fault trace parallels the Eagle River valley and dips about 15° northwestward. North of the village of Cambie, a thick mylonitic marble (**Sm**) in the footwall is juxtaposed against hangingwall orthogneiss of unit **Dg** along a zone of chloritic microbreccia several metres thick. The covered contact between the marble and underlying semipelite migmatites (**Ss**) strikes oblique to the mylonitic foliation in both units, and the marble is therefore interpreted as a slice bounded by splays of the Eagle River fault.

At the head of a large reentrant in the fault trace 25 kilometres northeast of Sicamous, the Eagle River fault steepens and dips southwestward along Craigellachie and Four Mile creeks. Near North Queest Mountain, fractured and weathered sillimanite-biotite-muscovite schist of the footwall (Unit **Su**) is separated from hangingwall granitoid gneiss of the Mount Fowler suite (**Dg**) by 50 metres of cataclasite and clay gouge (Johnson, 1989a).

Between Craigellachie Creek and Adams Lake, the margin of the Shuswap complex is characterized by a system of brittle and ductile-brittle faults that apparently root in a ductile shear zone. Due to poor exposure along Scotch Creek and uncertainty about the nature and age of strain in Devonian orthogneiss of the Mount Fowler suite (Unit **Dg**), the geometry of this segment of the fault system is not precisely known; it appears to be either a breakaway zone that formed at a low angle to the westward transport direction of the Okanagan - Eagle River fault system, or a series of splays of the main detachment that were progressively abandoned during uplift of the footwall.

Ductile strain in the footwall is concentrated in retrograded migmatites near the north end of Adams Lake, and in the leucogranites of Unit **T(?)g** exposed along Adams Lake and at Pukeashun Mountain. Stretching lineations in both Units **Su** and **T(?)gm** plunge southeast and northwest. Semipelite migmatites at Momich River, 8 kilometres from the north end of Adams Lake, display west-directed C/S fabrics and westerly rotated feldspar porphyroclasts. The granites of Unit **T(?)gm** are typically mildly sheared and display northwest-directed C/S fabrics in several localities. Near the east shore of Adams Lake, strain increases upward in the granite sheet, and the upper part is mylonitic. Overlying metasedimentary rocks of the Shuswap assemblage are cut by brittle faults characterized by zones of cataclasite and clay gouge. At this locality, therefore, the contact between the granite and the metasediments is interpreted as the sole fault, or main detachment, of the Okanagan - Eagle River fault system.

Eight kilometres farther south, coarse-grained biotite-muscovite schists of Unit **Ss** that contain fibrous sillimanite are exposed within 200 metres of chloritic phyllites of the Eagle Bay assemblage. The metamorphic mismatch here requires that this contact also be a fault, but it appears to be predominantly a brittle structure. This fault truncates Eagle Bay strata, isolating them and, apparently, the Devonian orthogneiss of Unit **Dg** in its hangingwall. Steeply dipping, brittle, normal-slip shears parallel the foliation in the orthogneiss near its upper contact (with Unit **Eq**) west of Kwikoit Creek, so this contact also is (brittly) faulted to some extent; however, the lower contact of the orthogneiss (with Unit **Su**) near Kwikoit Creek is characterized by a zone of intense chloritization, silicification, fracturing and brecciation that involves both units, and is interpreted to be the same fault that separates the Shuswap and Eagle Bay assemblages along Adams Lake. Slickensides and epidote veins persist in the orthogneiss above this zone. Because of poor exposure around Kwikoit Mountain, it is not clear whether Unit **Dg** remains confined to the hangingwall of this fault between Kwikoit Creek and Scotch Creek. The best constraint on the location of the fault east of Kwikoit Creek is near the headwaters of Snuffbox Creek, on the southwest flank of Lichen Mountain, where the contrast in metamorphic grade between garnet-sillimanite-muscovite-biotite schists of Unit **Sus** and chlorite phyllites of Unit **Eca** requires that the contact between them be a fault.

Where the orthogneiss (**Dg**) and the Shuswap assemblage (**Sus**) cross Scotch Creek east of Lichen Mountain, the contact between them was not observed but it apparently is steeply dipping and not faulted. Just west of the Seymour Arm of Shuswap Lake at Five Mile Creek, Unit **Dg** intrudes Unit **Su** and the contact appears to not be faulted. Southeast of Scotch Creek, orthogneiss of Unit **Dg** displays an east-plunging stretching lineation that persists across Mount Fowler to the Seymour Arm. Local, discrete, chloritic shears cut obliquely across the foliation in the orthogneiss near Mount Fowler; west-directed slickenfibre lineations and shear bands were observed in one of these shears. The contact between Unit **Dg** and the structurally overlying metasediments of Unit **Ec** near Mount Fowler has yet to be investigated in detail, but it could be a splay of the Okanagan - Eagle River fault system. Further mapping in the Mount Fowler and Lichen Mountain areas and petrographic analysis of samples collected from the orthogneiss of Unit **Dg** may help to better constrain the geometry of the fault system in this area.

In summary, the main detachment of the Okanagan - Eagle River fault system, which separates a plastically deformed footwall from a predominantly brittly deformed hangingwall, crosses along the west side of Mara Lake, dips gently northwestward along the Eagle River valley, and dips moderately southeastward along Craigellachie Creek. The Scotch Creek segment of the detachment, between Shuswap Lake and Pukeashun Mountain, has yet to be positively identified; it may lie above (or within) the east-west lineated Devonian orthogneiss in the Mount Fowler area or somewhere within the Shuswap assemblage, structurally beneath the intrusive contact with the orthogneiss. The detachment lies above leucogranite in the Pukeashun Mountain area, separates the leucogranite from overlying high-grade schists on the east side of Adams Lake, and continues northward through Adams Lake, separating the Shuswap assemblage from the Eagle Bay assemblage and the mid-Cretaceous Baldy batholith.

Above the basal detachment east of Adams Lake is a stack of fault slices that, up structural section, consist of progressively lower grade rocks and are juxtaposed against one another by faults that display progressively less ductile and more brittle characteristics. The geometry of this segment of the fault system has yet to be worked out in detail, but it is interpreted as either *i*) a breakaway zone that formed at a low angle to the westward extension direction, or *ii*) a series of horses bounded by segments of the main detachment that were progressively abandoned during uplift of the footwall.

Late Brittle Faults

Brittle high-angle faults strike northwest in the Hunters Range to northeast in the Scotch Creek area, and are subparallel to post-Early Eocene dike swarms. They cut both the footwall and hangingwall of the Okanagan - Eagle River fault system and do not have much displacement. One such fault near the east edge of the map area crosses the Trans-Canada Highway at Victor Lake, displaces the Monashee décollement several hundred metres in a dextral west-side-down sense (Read and Klepacki, 1981), and juxtaposes the Shuswap assemblage against the Monashee complex.

CONCLUSIONS

The west margin of the Shuswap metamorphic complex is delineated by the Okanagan - Eagle River fault system. Between 50°30′ and 51°30′N latitude, the fault system juxtaposes high-grade metamorphic rocks of the Shuswap assemblage against low to medium-grade rocks of the Eagle Bay and Mount Ida assemblages. The Eagle River segment of the fault system dips gently westward at Mara Lake, gently northwestward along the Eagle River valley, and moderately southwestward along Craigellachie and Four Mile creeks. The Scotch Creek segment strikes at a low angle to the extension direction and consists of a stack of (imbricate?) fault slices. The northern Adams Lake segment apparently dips gently westward, and is inferred to link up with the North Thompson River fault. The nature of the boundary between the Raft batholith and high-grade rocks on Raft Mountain is uncertain, and it may be another splay of the fault system.

Tentative stratigraphic correlations have been made between the Shuswap assemblage and the Hadrynian Windermere Supergroup, and between the Eagle Bay assemblage and Hadrynian to lower Paleozoic strata of the Hamill Group, Badshot Formation and Lardeau Group. The Mount Ida assemblage may in part be correlative with Lardeau strata and in part with older rocks (*e.g.*, Hamill Group), but previous interpretations that regard the assemblage as part of the Intermontane Superterrane have not been disproven.

Three phases of structural fabrics have been recognized in rocks of both the hangingwall and footwall of the Okanagan - Eagle River fault system. The structural styles of D_2 (recumbent, tight) and D_3 (upright to inclined, open to close) folds in the footwall resemble those in the hangingwall, but the relative ages are uncertain. The metamorphic peak in the Eagle Bay assemblage predated or was synchronous with D_3, and probably occurred prior to mid-Cretaceous. In the Shuswap assemblage, D_2 structures are pre-Late Paleocene; D_3 structures could be as young as Early Eocene, but more likely are older structures (mid-Cretaceous or older) that were amplified by Eocene shearing. The metamorphic peak in the Shuswap assemblage may have been diachronous, but sillimanite was apparently still growing in the footwall of the Eagle River fault near Sicamous in the Early Eocene. The cooling history of the Shuswap assemblage is currently under investigation.

ACKNOWLEDGMENTS

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MONASHEE MOUNTAINS
SHUSWAP FOREST
(COLUMBIA MOUNTAINS)
ADAMS
SHUSWAP
HIGHLAND
FOREST
ANSTEY RANGE
PROVINCIAL
SHUSWAP HIGHLAND
ADAMS PLATEAU
SHUSWAP PROVINCIAL FOREST
SHUSWAP LAKE
SALMON ARM
SHUSWAP HIGHLAND PROVINCIAL FOREST
SALMON ARM PROVINCIAL FOREST
SPALLUMCHEEN PROVINCIAL FOREST
SALMON ARM DISTRICT MUNICIPALITY
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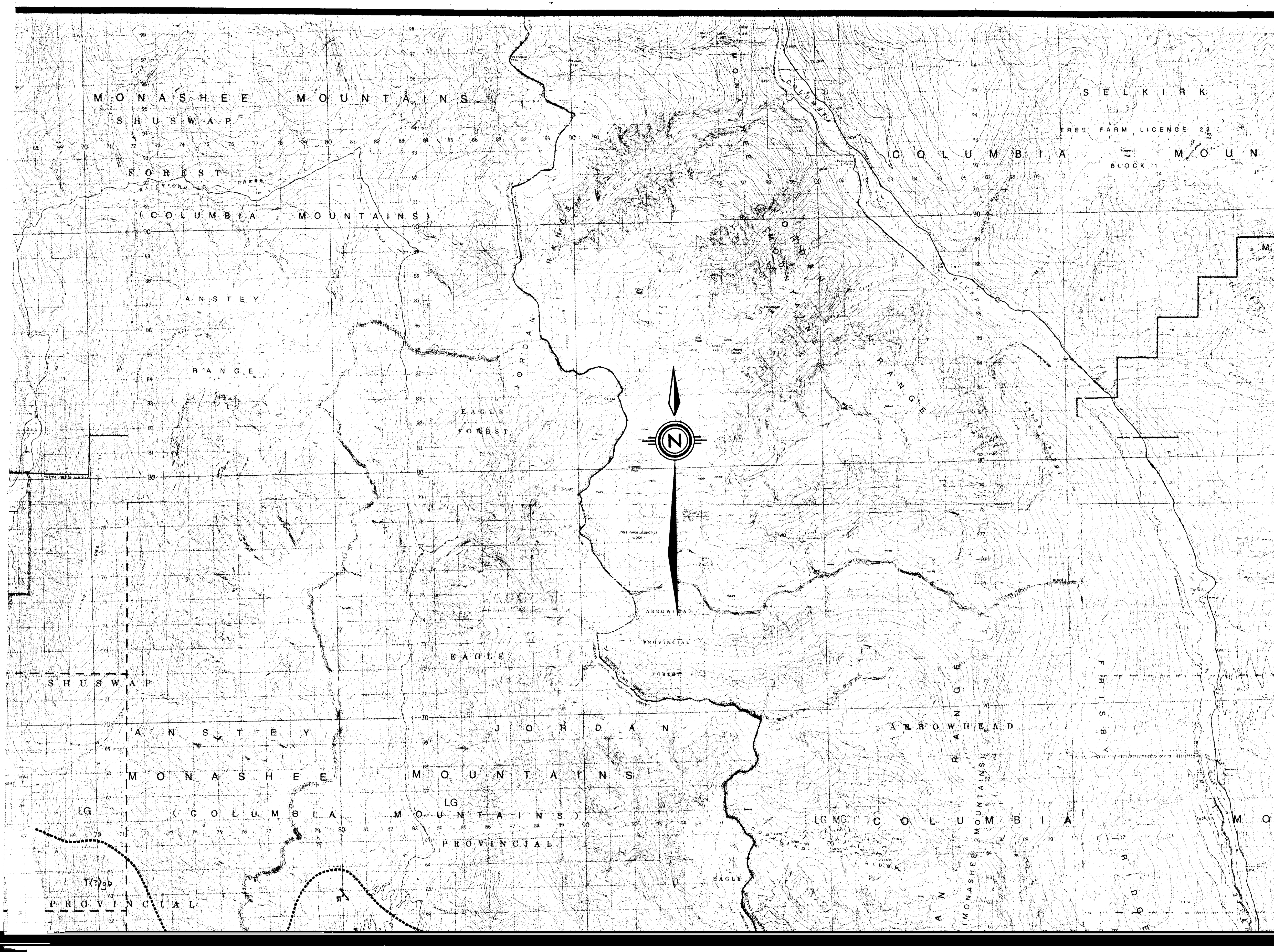


Ministry of Energy, Mines and Petroleum Resources

BRITISH COLUMBIA GEOLOGICAL SURVEY

OPEN FILE 1990-30 ①

GEOLOGY ADJACENT TO THE WESTERN MARGIN OF THE SHUSWAP METAMORPHIC COMPLEX

NTS 82L, 82M

Geology by Bradford J. Johnson

Scale 1:100 000

Tertiary:

Ti Diabase stocks characterized by pervasive deuteric (?) alteration.

Late Cretaceous or early Tertiary:

T(?)g Medium-grained leucocratic granites. **T(?)gb** and **T(?)gm** are biotite and biotite-muscovite granites, respectively, which locally contain abundant screens of country rock.

Early Cretaceous:

Kg Biotite monzogranite of Baldy batholith.

Devonian:

Dg Medium to coarse-grained biotite granodiorite to monzogranite gneiss and epidote-hornblende-biotite granodiorite gneiss (**Dgh**) of Mount Fowler suite.

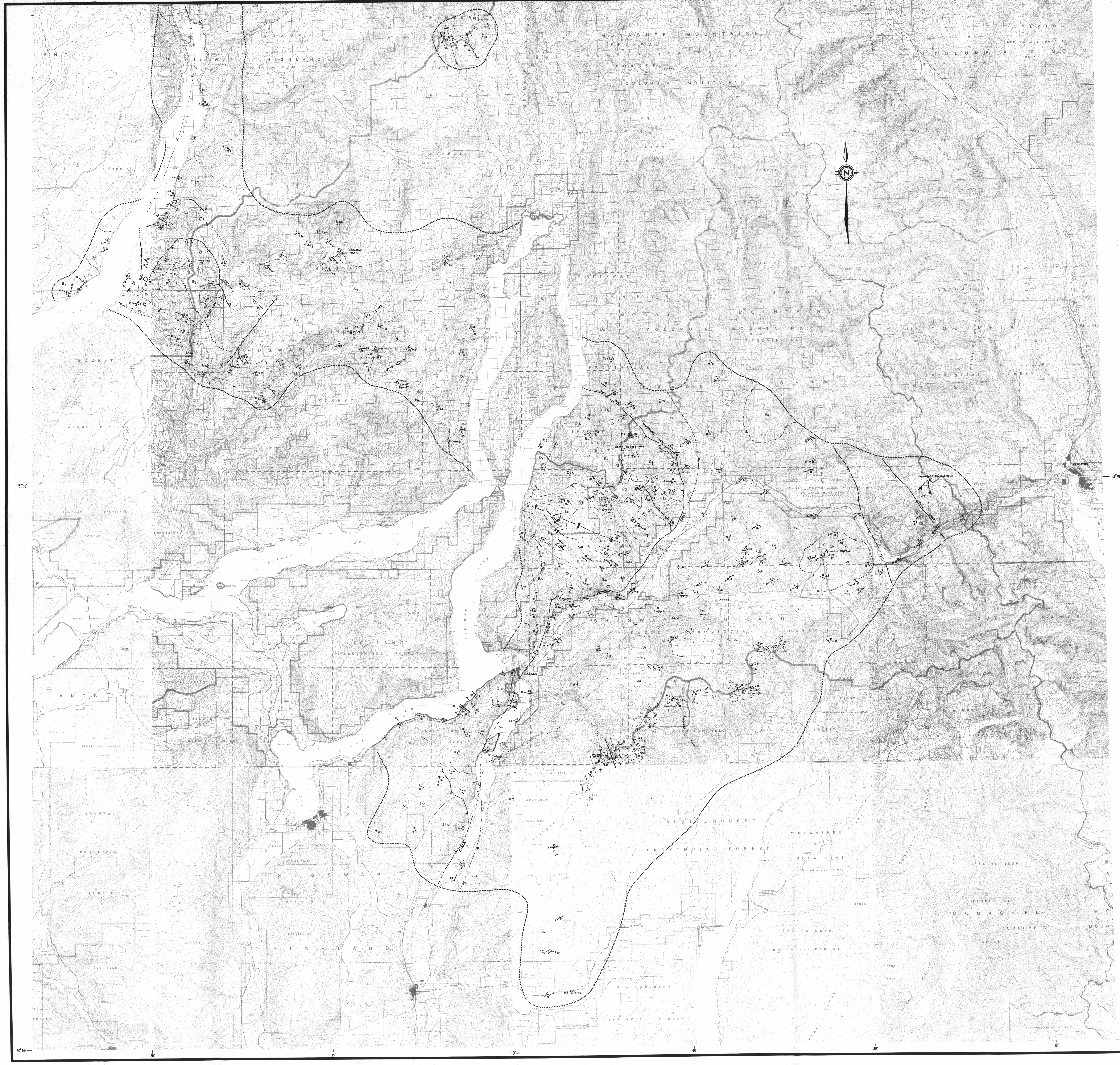
Hadrynian - Paleozoic:

Eagle Bay assemblage

Ec Calc-silicate schist; marble; chloritic, sericitic, calcareous and graphitic phyllites; metasiltite; mafic schist; minor quartzite. **Ecm** dominated by calc-silicate schist, grey fine-grained marble and phyllitic marble. **Ecp** dominated by phyllite and metasiltite. **Eca** dominated by epidote-biotite-amphibole-chlorite schist and quartz-sericite-chlorite phyllite.

Em White to medium grey marble.

Eq Light brown, greenish grey, and white quartzites and micaceous quartzites; (staurolite-



BC Ministry of Energy, Mines and Petroleum Resources

British Columbia Geological Survey

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Devonian:

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Eagle Bay assemblage

Ec	Calc-silicate schist; marble; chloritic, sericitic, calcareous and graphitic phyllites; metasiltite; mafic schist; minor quartzite. **Ecm** dominated by calc-silicate schist, grey fine-grained marble and phyllitic marble. **Ecp** dominated by phyllite and metasiltite. **Eca** dominated by epidote-biotite-amphibole-chlorite schist and quartz-sericite-chlorite phyllite.
Em	White to medium grey marble.
Eq	Light brown, greenish grey, and white quartzites and micaceous quartzites; (staurolite-garnet-) biotite-quartz-muscovite schists; minor feldspathic granule conglomerate; locally abundant epidote-biotite-amphibole-chlorite schist and quartz-sericite-chlorite phyllite.

Mount Ida assemblage

Isc	Sicamous Formation: grey, fine-grained, phyllitic marble and calcareous phyllite.
Ita	Tsalkom Formation: epidote-chlorite-amphibole schist, massive metabasalt, chloritic phyllite.
Isq	Silver Creek Formation: pelitic to semipelitic (garnet-biotite-)quartz-muscovite schist, micaceous quartzite, minor calc-silicate and mafic schists. Intruded by abundant aplite and pegmatite.

Shuswap assemblage

Su	Undifferentiated quartzofeldspathic gneiss, feldspathic psammite, semipelitic and pelitic schists, amphibolite, calc-silicate gneiss, marble, minor quartzite. Extensively intruded by sheets and dikes of Mesozoic to Tertiary pegmatite. **Sus, Suc, Sua** and **Suh** are dominated by rocks like those of units **Ss, Sc, Sa** and **Sh**, respectively.
Sh	Garnet-hornblende-biotite-quartz-feldspar gneiss, biotite-hornblende granodiorite to tonalite gneiss.
Ss	Semipelitic to pelitic biotite-feldspar-quartz and garnet-sillimanite-biotite(-muscovite) schists, feldspathic psammite, minor quartzite, local garnet-hornblende-biotite gneiss and amphibolite
Sa	Diopsidic amphibolite, semipelite, feldspathic psammite, garnet-hornblende-biotite-quartz-feldspar gneiss, minor pelite and marble.
Sc	Diopsidic calc-silicate gneiss, marble, diopsidic amphibolite, rusty weathering semipelite, minor psammite and pelite.
Sm	Light brown to light grey diopsidic marble and calcite marble, diopsidic calc-silicate gneiss, minor amphibolite and semipelite.

Aphebian - Cambrian(?):

Monashee complex

Mu	Garnet-kyanite-sillimanite-biotite schist, quartzite, calc-silicate gneiss, marble, biotite-hornblende-quartz-feldspar gneiss.

Geological contact (defined; approximate; inferred)

S_0S_1 and, unless shown by another symbol, S_2.

S_0S_1 where graded beds indicate right-way-up.

S_2 where attitude differs from S_0S_1.

S_3 crenulation cleavage.

Mineral lineation, stretching lineation.

Stretching lineation in mylonitic rocks where west-directed shear sense is indicated.

Stretching lineation in mylonitic rocks where east-directed shear sense is indicated.

L_2 intersection lineation ($S_0S_1 \wedge S_2$).

L_3 intersection lineation ($S_0S_1 \wedge S_3$).

F_3 antiform; synform.

F_2 synform.

Normal fault.

Thrust fault.

Isograds (positions approximate; ornament on high-temperature sides):

Muscovite out

Garnet in

Tremolite out