CASCADE RECREATION AREA, PRELIMINARY GEOLOGY AND MINERAL POTENTIAL
(92H/2, 3, 6, 7)

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KEYWORDS: Regional geology, Cascade Recreation Area, mineral potential, Methow basin, stratigraphy, intrusions, economic geology, Punchbowl Lake, Granite-Scheelite.

INTRODUCTION

LOCATION AND ACCESS

The Cascade Recreation Area is located 30 kilometres southeast of Hope, in the Hozameen Ranges of the northern Cascade Mountains. The 167 square kilometre recreation area encompasses the headwaters of the Tulameen and Skaist rivers, and Snass Creek adjacent to the northwest boundary of E.C. Manning Provincial Park and the Skagit Valley Recreation Area (Figure 1-5-1).

Vehicle access to the southwest boundary is possible along Highway 3, to the north boundary via the Podunk Creek logging road into Whitecloud Creek and the upper Tulameen River, and along the east boundary via Whipsaw Creek and a seasonal four-wheel-drive road to Granite Mountain. In the recreation area a network of rehabilitated historic trails (Whatcom, Dewdney, Hope Pass) and former grazing trails provide excellent foot or horseback access along major valley bottoms. Valley Helicopters Ltd. in Hope provide the closest helicopter charter service.

PROJECT TERMS OF REFERENCE

The field component of a two-year mineral potential study of the Cascade Recreation Area was completed in 1991. The study is required under Section 19 of the *Mineral Tenure Act* to provide government and industry with detailed mineral potential information, and to initiate the time-limited exploration period prior to Cabinet decision on proceeding to park status.

The objectives of fieldwork in 1991 were:

- To complete geological mapping of the entire recreation area at a scale of 1:20 000.
- To examine, map and sample all known mineral occurrences, and prospect for new occurrences.
- To augment the 1990 stream-sediment survey with additional samples from unsampled drainages.
- To establish lithologic, stratigraphic and structural controls on mineralization.

This initial report on 1991 fieldwork includes a preliminary geological map, generalized rock descriptions and initial lithogeochemical analyses. Results of 1990 fieldwork were reported by Schmitt and Stewart (1990). Full descriptions of mineral occurrences and interpretation of stream-sediment geochemistry will be presented in the final report which is scheduled for publication in spring, 1992.

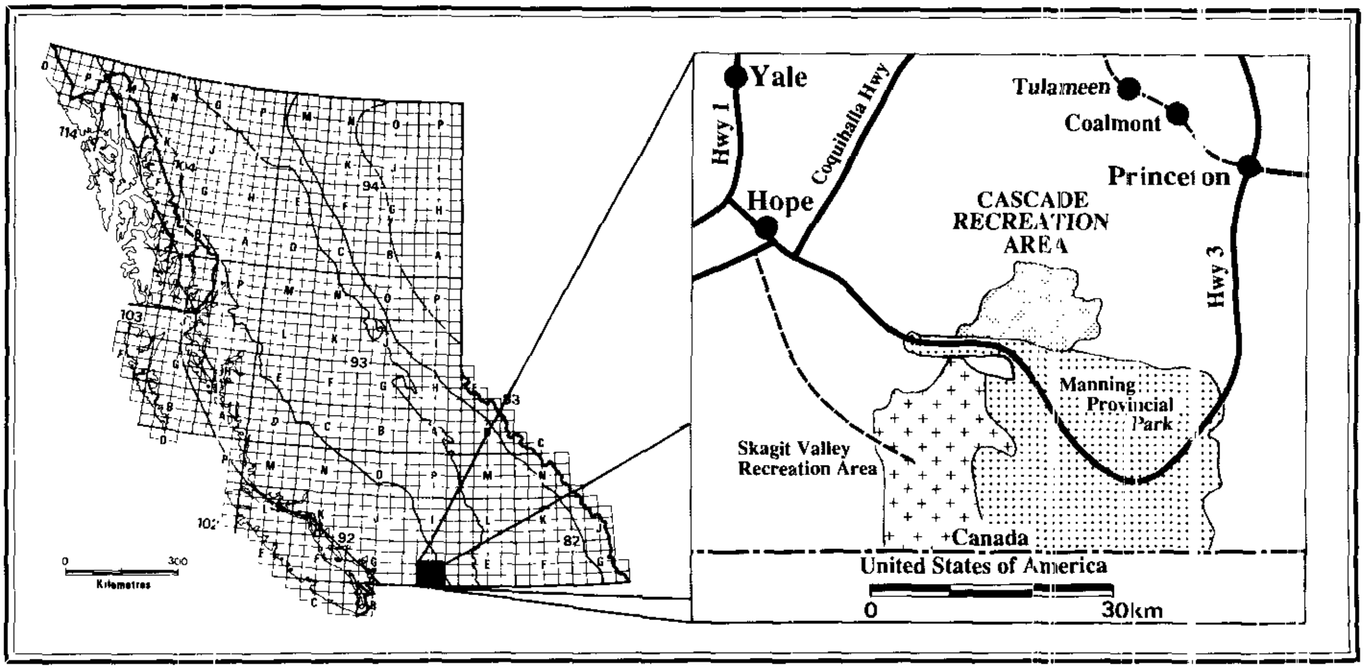


Figure 1-5-1. Location of Cascade Recreation Area, NTS 92H/2, 3, 6, and 7, in relation to Hope, Princeton, Manning Provincial Park and major transportation corridors.

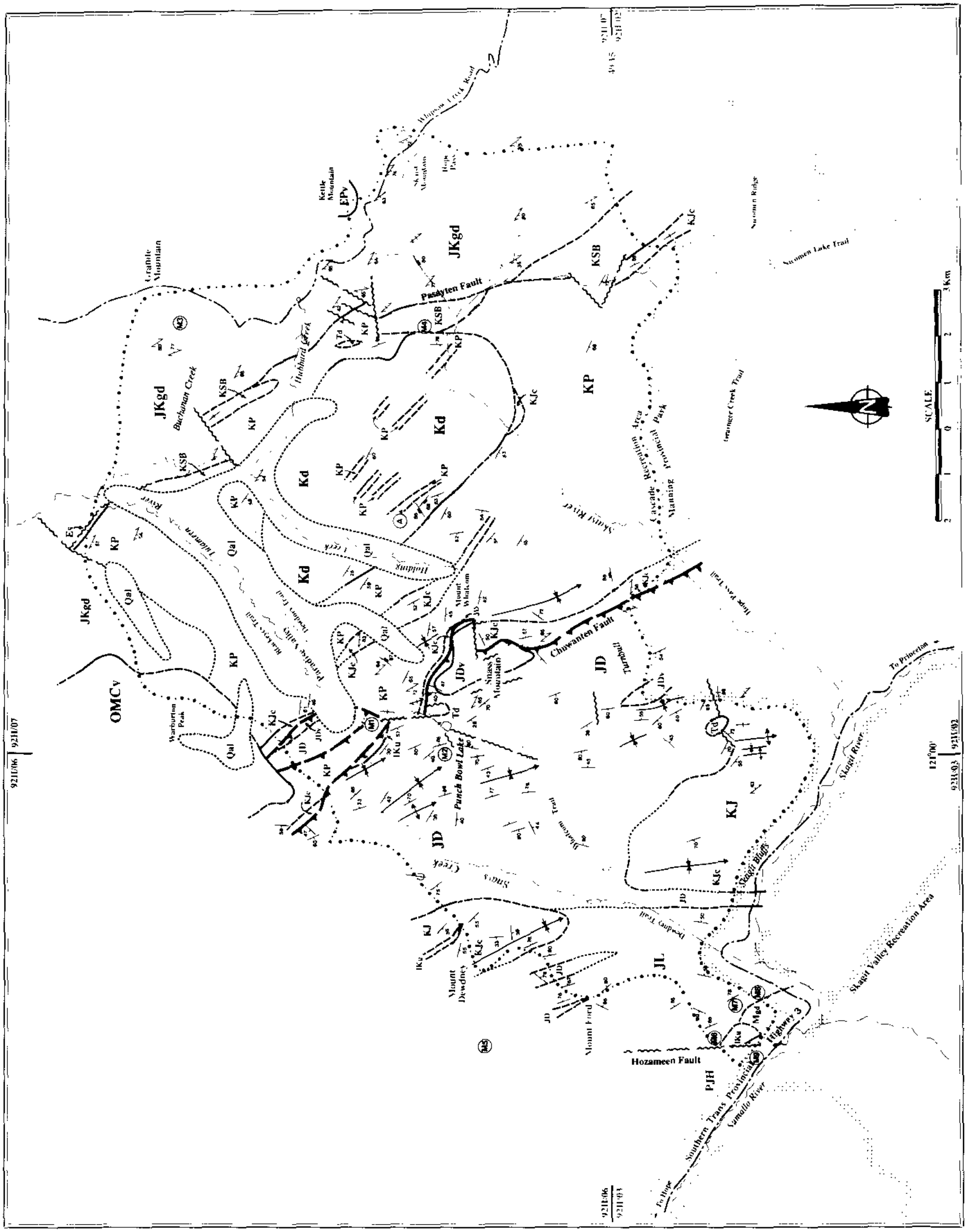


Figure 1-5-2. Geology and location of mineral occurrences in the Cascade Recreation Area, NTS 92H/2,3, 6, and 7.

LEGEND

LAYERED ROCKS

QUATERNARY

Qal *UNCONSOLIDATED GLACIAL TILL AND POORLY SORTED ALLUVIUM*

LATE OLIGOCENE TO EARLY MIOCENE

COQUIHALLA VOLCANICS

OMCv *HORNBLENDE ANDESITE, TRACHYTE, DACITE, BRECCIA, ASH FLOW TUFF*

EOCENE

PRINCETON GROUP

EPv *MAFIC TO INTERMEDIATE DIKES AND FLOWS, CHARACTERISTICALLY COARSE HORNBLENDE PHYRIC*

Es *PURPLE TO MAROON, QUARTZ-EYE LITHIC SANDSTONE*

LATE EARLY, EARLY LATE CRETACEOUS

PASAYTEN GROUP

KP *QUARTZ MUSCOVITE ARKOSE, MINOR SILTSTONE AND CHERT PEBBLE CONGLOMERATE, NONMARINE FACIES EQUIVALENT TO THE UPPER PART OF THE JACKASS MOUNTAIN GROUP*

LATE EARLY CRETACEOUS

SPENCES BRIDGE GROUP

KSB *INTERMEDIATE TO MAFIC, MAROON, PURPLE AND GREEN CRYSTAL-LAPILLI TUFFS AND FLOWS, VOLCANIC CONGLOMERATE, MINOR WACKE, SILTSTONE, SANDSTONE*

JACKASS MOUNTAIN GROUP

KJ *UNDIFFERENTIATED SANDSTONE, ARGILLITE, CONGLOMERATE, (KJc) GRANITIC-COBBLE CONGLOMERATE*

EARLY AND MIDDLE JURASSIC

LADNER GROUP

JL *ARGILLITE, SLATE, SILTSTONE, TYPICALLY RUSTY*

DEWDNEY CREEK FORMATION

JD *LAPILLI CRYSTAL TUFF, MINOR FOSSIL BEARING TUFFACEOUS ARGILLITE, SILTSTONE, SANDSTONE, CONGLOMERATE, RARE LIMESTONE, (JDv) HYDROCLASTIC BRECCIA, VOLCANICLASTICS, FLOWS, AGGLOMERATES, (JDs) FOSSIL BEARING TUFFACEOUS ARGILLITE, WACKE, (JDt) CRYSTAL, LITHIC AND LAPILLI TUFF*

PERMIAN TO JURASSIC

HOZAMEEN GROUP

PJH *UNDIFFERENTIATED CHERT, GREENSTONE, LIMESTONE*

INTRUSIVE ROCKS

TERTIARY

Td *PLAGIOCLASE-HORNBLENDE-BIOTITE DIORITE, GRANODIORITE, APLITE*

MIOCENE

Mgd *BIOTITE-HORNBLENDE GRANODIORITE (SUMALLO STOCK)*

LATE CRETACEOUS OR YOUNGER

lKu *ULTRAMAFIC ROCK, GABBRO*

LATE CRETACEOUS

Kd *PLAGIOCLASE-HORNBLENDE-BIOTITE PORPHYRITIC DIORITE (SKAIST RIVER STOCK)*

LATE JURASSIC AND EARLY CRETACEOUS

EAGLE PLUTONIC COMPLEX

JKgd *FOLIATED GRANITE, GRANODIORITE, QUARTZ-BIOTITE GNEISS, PEGMATITE, AMPHIBOLITE*

SYMBOLS

Potassium-argon isotopic age locality	Ⓐ
Mineral Showing or Prospect	(M1)
Cascade Recreation Area Boundary	•-•-•-•-•-•-•-•
Manning Provincial Park Boundary - Skagit Valley Recreation Area Boundary	░░░░░░
Trail	………………
Road	—·—·—·—

The Cascade Recreation Area was designated in 1987 to protect and manage heritage, wildlife and recreation values. A no-staking mineral reserve was placed over the area in 1987 as an interim measure until Cabinet provided further direction on mineral potential assessment and park designation. On September 3, 1991 the no-staking mineral reserve was removed, and the area became open to 4-post claim staking by application. Specific no-staking mineral reserves remain over parts of the Dewdney and Whatcom heritage trails and Punchbowl Lake basin

REGIONAL GEOLOGIC SETTING

The project area is located in the northern Cascade belt between the Coast Plutonic Complex to the west and the Intermontane Belt to the east. It is underlain mostly by the Methow basin containing Jurassic to Late Cretaceous sedimentary and volcanic rocks of the Ladner, Jackass and Pasayten groups deposited in a back-arc to nonmarine setting (Davis *et al.*, 1978; Anderson, 1976; Ray, 1990). The internal structure of the basin is dominated by northeast-directed thrusting of the Ladner Group onto younger rocks along the Chuwanten fault. The Methow basin is bounded on the west by the Hozameen fault which separates the basin from the Permian to Jurassic Hozameen Complex of the Bridge River Terrane, and on the east by the Pasayten fault which separates the basin from the Cretaceous Eagle Plutonic Complex of Quesnellia (Monger *et al.*, 1982; Monger, 1989; Greig, 1988; McGroder and Miller 1989; Whitney and McGroder, 1989). Eocene clastic rocks (Greig, 1988) and Oligocene to Miocene Coquihalla volcanic rocks (Berman and Armstrong, 1980) unconformably overlie the Methow basin, but are minor components of the project area.

Three periods of regional plutonism are tentatively recognized in the Cascade Recreation Area: Late Jurassic to late Early Cretaceous formation of the Eagle Plutonic Complex (Greig, 1988); Late Jurassic(?) to Early Tertiary emplacement of numerous mafic to felsic dikes, sills and stocks during crustal shortening, uplift, thrust faulting and folding; and Early Miocene intrusion of the dioritic Sumallo stock into the Hozameen fault (Armstrong *et al.*, 1987). Many of the dikes, sills and minor intrusions in the Ladner Group are of uncertain age, but probably post-Toarcian.

GEOLOGY OF THE RECREATION AREA

A preliminary geological map of the recreation area is shown in Figure 1-5-2. Seven lithostratigraphic units are recognized, including two previously unrecognized; a sandstone of presumed Eocene age (Greig, 1988; Monger, 1989), and a volcanic-epiclastic sequence tentatively assigned to the Cretaceous Spences Bridge Group. These two sequences occur along the west margin of the Eagle Plutonic Complex. In addition, a 20 square kilometre intrusion, named the Skaist River stock, was delineated in the east-central part of the recreation area. Isotopic dating of a hornblende separate is presently in progress. Detailed mapping has determined that both the Chuwanten and Pasayten faults are structurally complex with important implications for localizing intrusive activity and mineral potential. The following descriptions will be augmented by chemical. petrographic and paleontological analysis for the final mineral potential report.

STRATIFIED ROCKS

Stratified rocks range in age from Permian to Miocene. They generally strike northwest with moderate to steep southwest dips and, east of the Hozameen fault, record progressive infill and subsequent deformation of the Methow trough.

HOZAMEEN COMPLEX – UNIT PJH

The Permian to Jurassic Hozameen Complex is a deformed oceanic assemblage, which together with its northern faulted extension, the Bridge River Complex, comprise the Bridge River Terrane (Monger, 1970; Haugerud, 1985; Potter, 1986; Schiarizza *et al.,* 1989).

The Hozameen Complex underlies less than 100 hectares of the southwest corner of the recreation area, north of Highway 3. It consists of interlayered, massive light grey-buff to pinkish, black-streaked recrystallized chert, massive dark green hornblende-phyric greenstone and minor metasediments. Adjacent to the Hozameen fault these rocks are strongly deformed, commonly brecciated and have a prominent planar fabric oriented 160/75° west which parallels the strike of the fault. Pyrite is ubiquitous as narrow discontinuous stringers and disseminations in abundant fractures and small felsic segregations or dikes along the fault trace. Hozameen Complex rocks and the fault were intruded by the Early Miocene Sumallo stock but no obvious thermal overprinting is evident.

LADNER GROUP – UNITS JL, JD

Jurassic Ladner Group strata underlie most of the Snass Creek basin between the Hozameen and Chuwanten faults. They are the oldest sediments in the Methow basin (Ray, 1990) and are divisible in the recreation area into an Early Jurassic (Pliensbachian and Toarcian), marine clastic sequence (Unit JL), and an overlying Middle to Late Jurassic volcanic-rich sequence of the Dewdney Creek Formation (Unit JD). The contact between the two sequences is best exposed north of Mount Ford where it is represented by a gradual facies change from predominantly fine-grained turbiditic siltstones to tuffaceous sandstones and lapilli tuff interbedded with siltstones. This facies change marks the onset of Dewdney Creek Formation volcanic activity.

The Ladner Group distribution is currently shown on regional maps as two parallel, northwest-striking belts separated by a belt of Jackass Mountain Group sediments (Monger, 1989). New mapping information shows an uninterrupted stratigraphic interval of Ladner Group rocks, with the Jackass Mountain sediments in the northwest extension of the south-plunging Gibson Pass syncline. The syncline is completely eroded in its central part by Snass Creek, exposing the underlying Ladner Group. Further revisions to the distribution of Ladner Group rocks, and definitive recognition of the late Oxfordian to late Tithonian Thunder Lake sequence (Coates, 1974; O'Brien, 1986) may be possible with final age determinations of macrofossils collected from various localities. Ladner Group strata are thrust northeast onto both Jackass and Pasayten Group coarse to fine clastics along the Chuwanten fault.

Unit JL: Early Jurassic Ladner Group sediments crop out south of Mount Dewdney and west of Snass Creek where they comprise a section possibly 1500 metres thick that strikes north-northwest and dips 40° to 80° northeast. The easterly derived marine sediments were deposited as a west-facing prism of turbidites, submarine fan and related channel deposits (Ray, 1990). They consist of thinly laminated to medium-bedded, siliceous siltstones, slates, silty argillites, wackes and minor sandstones and chert-bearing grit to pebble conglomerates. Siliciclastic rocks fracture conchoidally and display slaty, bedding-parallel cleavage, or less commonly, well-developed pencil cleavage. The sediments range in colour from pale cream-buff to dark grey-brown with characteristic pale brown to gossanous weathering derived from ubiquitous oxidized, finely disseminated pyrite. Greenish and green-brown units with cherty and plagioclase-hornblende-phyric clasts predominate near the top of the sequence, marking progressive influx of Dewdney Creek Formation tuffaceous material.

Sedimentary structures include soft-sediment slumping, ripple marks, small-scale crossbedding and ball, pillow and flame features in thinly laminated silty units.

Regional deformation is manifest as well-developed foliation subparallel to bedding planes, and the presence of upright, tight to isoclinal folds, and local east-verging kink folds. Ladner sediments adjacent to the Hozameen fault and Sumallo stock exhibit intense small-scale folding and thermal metamorphism to quartz-biotite hornfels interbedded with a saccharoidal (re-crystallized?) cherty siltstone.

The presumed thickness of the Early Jurassic sequence is uncertain owing to few distinct marker units and the possibility of fold repetition. In the Coquihalla region Ray (1990) estimated the thickness of the Ladner Group to be 2000 metres, which is consistent with our observations in the recreation area.

A sequence of fine-grained clastic rocks with many lithological similarities to the Ladner Group Unit JL is exposed in a narrow belt in the hangingwall of the Chuwanten fault but is tentatively assigned to the Dewdney Creek Formation (Unit JDs below).

DEWDNEY CREEK FORMATION – UNITS JD, JDs, JDt, JDv

The upper part of the Ladner Group is represented by the Toarcian to Bajocian Dewdney Creek Formation (O'Brien, 1986; Coates, 1974; Cairnes, 1924). The formation is characterized by epiclastic volcanic and volcanic-derived marine sediments, tuffs and breccia developed during tectonic uplift of the immature Methow basin (O'Brien, 1986).

Dewdney strata underlie the central Snass Creek and east Snass Creek basins, southwest of the Chuwanten fault, and have a possible accumulated thickness of over 2000 metres, even accounting for fold repetition. A small duplex thrust slice of Dewdney rocks also underlies an area northwest of lower Punchbowl Creek.

In the recreation area, the Dewdney Creek Formation is divisible into at least four members: a lower fossiliferous, locally pyritic clastic sequence (Unit JDs); a distinctive volcanic-rich unit (Unit JDv); a massive crystal, lithic and lapilli tuff (Unit JDt); and an upper sequence of turbiditic and tuffaceous clastics, tuffs, and rare carbonate (Unit JD). The division between Units JDt and JD is poorly defined and is distinguished largely by the relative frequency of certain lithologic units. Units JDt and JD are intruded by basic to felsic sills and dikes. Cairnes (1924) originally recognized three distinct crystal-lithic tuff divisions in the Dewdney Creek type section in Dewdney Creek, which was revised by O'Brien (1986) to include tuffaceous strata in the Manning Park area. The Cascade Recreation Area may contain the most complete section of Dewdney Creek Formation yet recognized, with extensive representatives of both sections described earlier by Cairnes and O'Brien. On Figure 1-5-2 contacts between Units JD, JDs and JDt are omitted for clarity.

Unit JDs: An intensely folded sequence of fossiliferous argillites, tuffaceous siltstones and wackes is exposed in a north-tapering belt immediately above the Chuwanten fault from Punchbowl basin southeast. These rocks are locally pyritic, pale brown-buff to dark grey argillites. The unit has many lithological and structural similarities with the Ladner Group Unit JL but its stratigraphic position is uncertain pending further dating of the ammonite and bivalve fauna. Its stratigraphic contact with the overlying Unit JDv is mostly conformable but locally is unconformable, or faulted (Plate 1-5-1).

Unit JDv: Unit JDv crops out immediately north, east and southeast of Snass Mountain, and as minor belts north of Punchbowl Creek and west of Turnbull Lake. The unit is characterized by massive-weathering, medium to coarse-textured andesitic hydroclastic breccia, epiclastic flows, agglomerate, plagioclase-hornblende-phyric flows and subvolcanic intrusions(?), crystal-lithic tuff, minor tuffaceous wacke and rare limestone. Plate 1-5-2 shows an example of an andesitic hydroclastic breccia unit from Mount Whatcom. These rocks show *in situ* fragmentation textures considered to be diagnostic of non-explosive injection into wet sediments (Hanson, 1991). The textural and contact relationships of the various lithologies indicate a complex marine depositional environment close to one or more volcanic vents. The contact relationship with underlying strata is variable and is locally an unconformity, a fault or a possible disconformity. It is apparent that Unit JDv behaved in a structurally competent manner during thrusting along the Chuwanten fault, relative to underlying fine-grained sediments of Unit JDs. The deformation contrast between these two units may have been instrumental in the location and propagation of the Chuwanten fault in Ladner stratigraphy. Similar lithologic and field relationships exist for the volcanic breccia unit described on Blackwall Peak in Manning Park (Coates, 1974; O'Brien, 1986).

Unit JDt: Medium to thick-bedded crystal-lithic lapilli and crystal tuff, minor volcanic-pebble conglomerate and tuffaceous wacke crop out as prominent cliffs in a belt extending 5 kilometres from the headwaters of Snass Creek to the ridges west and south of Turnbull Lake. The rocks are predominantly medium green and light grey-green with subordinate brown colours, and are characterized by small (mm to 1 cm) ovoid to subangular cherty and feldspar-porphyritic lapilli and fine-grained lithic clasts of volcanic and argillaceous material set in a cherty tuffaceous matrix of quartz, feldspar and chlorite. Conglomerate and gritty tuffaceous wacke interbeds may represent periods of relative volcanic quiescence when reworking of lapilli-bearing units occurred.

The member is similar to the lower and intermediate Dewdney Creek series of Cairnes (1924), and the Dewdney Creek Formation rocks described by Ray (1990) in the central Sowaqua Creek drainage. If these units are correlative, then collectively they would indicate widespread volcanic activity in the Middle to Late Jurassic Methow basin.

Unit JD: Undivided Dewdney Creek Formation, Unit JD, contains a diverse assemblage of sparsely fossiliferous, turbiditic, thinly laminated to medium-bedded tuffaceous siltstone, argillite and wacke interbedded with coarser lapilli and lithic tuffaceous sediments, and most of the units described in Unit JDt. Most rocks exhibit bedding-parallel cleavage and a penetrative foliation striking 160°. A range of colours are present, from light green-grey to buff, brown and black. The beds exhibit a wide array of sedimentary structures, mostly indicating stratigraphic tops are up. Deformation is manifest as gentle warping and broad, upright open folds, to tight isoclinal and disrupted chevron folds, local shearing and block faulting. Fold axes typically plunge southeast and are generally difficult to trace for more than 2 kilometres along strike. The unit is intruded by a variety of aplite, diorite and gabbro dikes and sills, typically less than 5 metres thick and rarely exposed for more than 20 metres along strike.

JACKASS MOUNTAIN GROUP – UNIT KJ

Early Cretaceous Jackass Mountain Group marine sediments were mapped in three belts: from Mount Dewdney, southeast to Skagit Bluffs along Highway 3; and as the southwest and northeast limbs of a southeast-plunging syncline (proposed name – Turnbull Creek syncline) including a belt 50 to 500 metres wide with a strike length of 7 kilometres in the footwall of the Chuwanten fault, and a belt 100 to 500 metres wide extending over 8 kilometres from Paradise Meadows to upper Skaist River (Figure 1-5-2). In the recreation area the group is divisible into two members: a sequence of thin to medium-bedded fine to medium-grained wackes, sandstone, arkose and argillaceous clastics, with minor conglomerate (Unit 8 of Coates, 1974), and a massive polymictic cobble conglomerate with minor intercalated sandstone and siltstone beds (Unit 9 of Coates, 1974).

The western exposures of Jackass Mountain Group comprise a southeast-plunging syncline (possible northwest extension of Gibson Pass syncline of Coates 1974) which has been completely eroded in its central part by the deep valley of Snass Creek. The sequence includes wacke, arkose, siltstone, argillite and massive, fine to coarse-grained conglomerate containing subrounded to well-rounded granitic, gneissic, volcanic, chert and argillaceous clasts. The stratigraphically lowest part of this sequence, exposed on the north slopes of Mount Dewdney and north of Skagit Bluffs, contains fossiliferous arkose, siltstone,

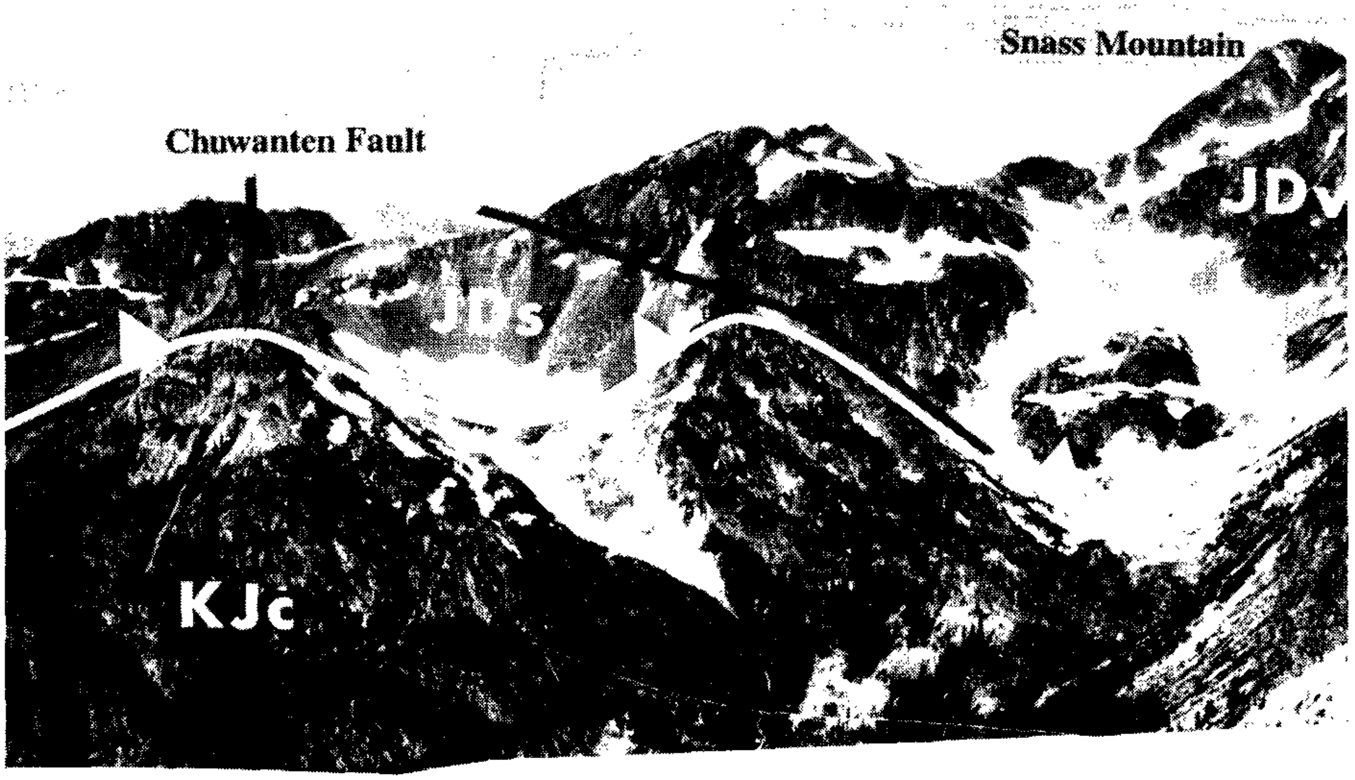


Plate 1-5-1. Photomosaic looking southwest at the Chuwanten fault; lower Dewdney Creek Formation Unit JDs and

argillite and rare limestone pods, and may be equivalent to the Dewdney Creek Formation of Coates (1974, Unit 3) and Thunder Lake sequence of O'Brien (1986) and Monger (1989). Age determinations of a sparse faunal collection from these rocks will hopefully help in stratigraphic interpretation.

Massive, granite-cobble conglomerate beds up to 100 metres thick are interbedded with minor sandstone, arkose and siltstone in the footwall of the Chuwanten fault. Plate 1-5-3 is an example of imbricate polymictic conglomerate from north of Snass Mountain. Similar conglomerates 1.7 kilometres to the southeast, contain locally abundant limestone clasts up to 30 centimetres across. A strongly sheared carbonate bed, 2 metres thick, is exposed in sheared polymictic conglomerate at possibly the same stratigraphic level, 1.5 kilometres northeast of Snass Mountain.

Jackass Mountain Group strata in the northeast limb of the Turnbull Creek syncline consist of polymictic conglomerate as above, but with volumetrically greater proportions of interbedded light green-brown sandstone, arkose and siltstone. The coarser strata exhibit abrupt facies changes indicative of channelized deposits. The beds are exposed intermittently for over 8 kilometres from Paradise Meadows to Skaist River. Their textural and lithological similarity, and stratigraphic position, may indicate time-stratigraphic equivalence with the adjacent nonmarine Pasayten Group sandstone and arkose (Coates, 1974). Unfortunately, most of the Jackass and Pasayten strata are characteristically unfossiliferous.

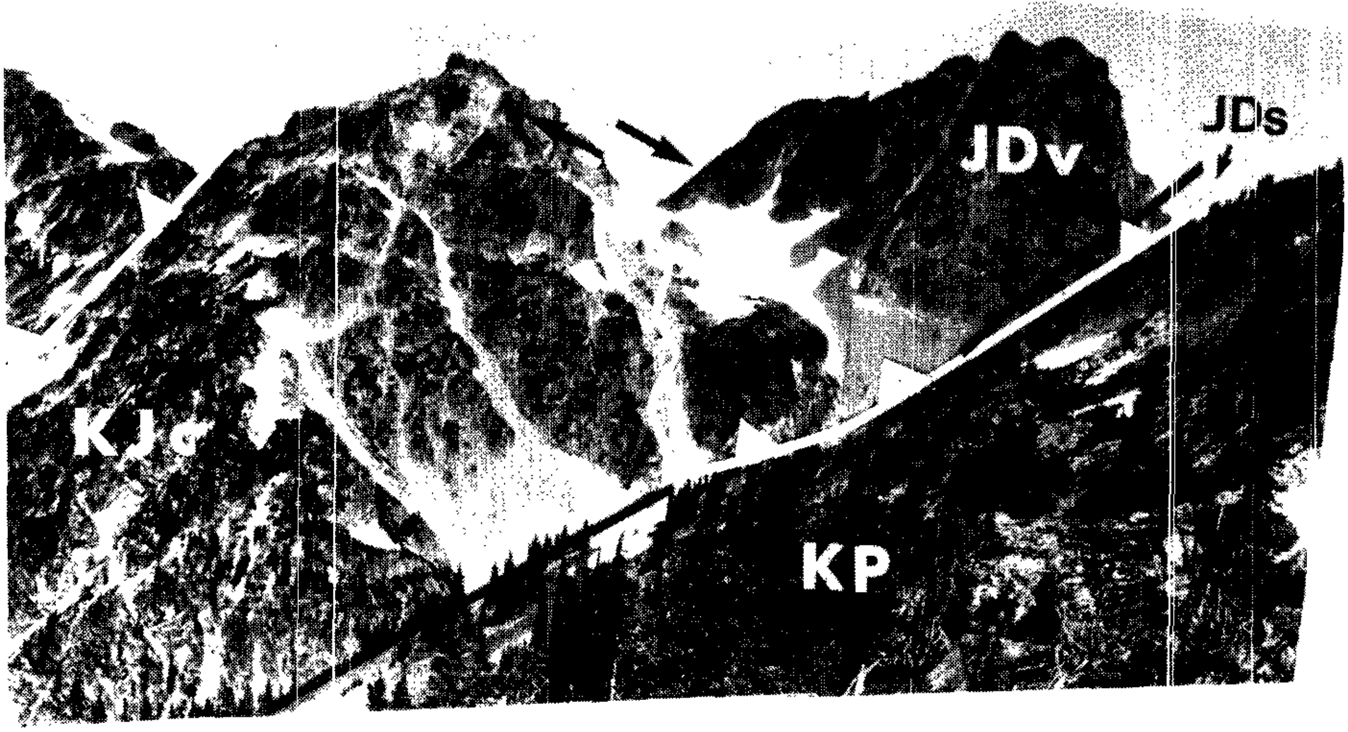
PASAYTEN GROUP - UNIT KP

The term Pasayten Group (Rice, 1947; Coates, 1974) has been used to describe predominantly nonmarine sandstones and siltstones of Albian age which overlie, and are partly time-stratigraphic equivalents of the upper Jackass Mountain Group. We recognize Pasayten Group rocks as a broad belt striking northwest and generally dipping moderately southwest, underlying the central and east-central parts of the recreation area.

Two broad divisions of the Pasayten Group are distinguishable. The lower sequence consists of predominantly thin to thick-bedded quartz-muscovite-biotite sandstone, arkose, siltstone and argillite, with minor wacke and tuffaceous beds. The upper sequence consists almost entirely of massive, light grey-buff, well-indurated quartz-muscovite-biotite sandstone with minor arkose, siltstone, and minor argillite and polymictic conglomerate. The lowermost, predominantly eastern member is equivalent to Coates' uppermost Jackass Mountain Group, Unit 10, whereas our uppermost member is correlative with Coates' entire Pasayten Group. Our definition parallels more recent usage (Monger, 1989) which restricts the Pasayten Group to areas east of the Chuwanten fault, and the Jackass Mountain Group to areas west of the fault.

SPENCES BRIDGE GROUP - UNIT KSB

A northwest-trending belt of previously unmapped volcanic and related epiclastic and sedimentary rocks, up to 1 kilometre wide, is exposed almost continuously over a



volcanic Unit JDv are thrust towards the viewer over Jackass Mountain Group massive cobble conglomerate, Unit KJc.

strike length of 11 kilometres along the west margin of the Eagle Plutonic Complex. The belt consists of green-brown and purple amygdaloidal basaltic(?) and dark green, crowded plagioclase-phyric flows, varicoloured green and maroon epiclastic units with angular to subrounded clasts up to 30 centimetres across, tuffaceous wacke, cherty tuff, argillite and minor basic intrusions. The volcanic flows exposed at the Manning Park boundary are weakly magnetic and contain numerous microfractures and shears with propylitic, quartz-chlorite-epidote alteration and minor veinlets. These rocks strike mostly northwest and have steep southwest dips, whereas north of the Skaist River north-south oriented beds dip steeply east, and north of Hubbard Creek, northwest-striking beds are near vertical. Beds may be locally overturned as evidence for stratigraphic tops is not equivocal.

The Pasayten fault marks the belt's eastern contact against the Eagle Plutonic Complex; evidence of intense shearing and quartz-sericite alteration along this contact is exposed 1.5 kilometres north of the Skaist River. The belt is apparently terminated by a northeast-trending Tertiary(?) fault south of Buchanan Creek. The contact between this unit and the Albian(?) sediments to the west is partly faulted in the south, but appears to be unconformable elsewhere. Exposures of wacke and volcanic sandstone along the west margin in the southern segment of the belt locally contain muscovite and biotite, whereas adjacent Albian(?) arkosic strata locally contain rare purple lithic fragments. The lithologic evidence implies at least some synchronous deposition of the two units.

The foregoing contact relationships and regional comparisons suggest a pre-Santonian, post-Jurassic age. Immediately north of the Skaist River the volcanic unit is intruded by the early Late Cretaceous (Santonian?) Skaist River stock (Unit Kd, described below). By comparison with recent studies of Thorkelson and Rouse (1989), and McGroder (1989), we conclude that the unit most closely resembles the Pimainus Formation of the Albian Spences Bridge Group.

In the Cascade Recreation Area, Spences Bridge Group rocks were apparently deposited in a narrow, north-tapering structural depression marginal to the Eagle Plutonic Complex, possibly extending discontinuously southeast into Washington State (Monger, 1989; McGroder, 1989). These rocks provide intriguing new evidence for mid-Cretaceous volcanic activity west of the Mount Lytton – Eagle Plutonic Complex, possibly related to down-dropping along the Pasayten fault (Monger, 1989, marginal notes).

PRINCETON GROUP – UNITS Es; EPv

Limited exposures of Eocene Princeton Group occur immediately west of the Tulameen River, and on the peak of Kettle Mountain.

The northern exposure (Unit Es) consists of reddish to maroon, quartzose lithic sandstone about 100 metres thick, in fault contact with the Eagle Plutonic Complex. Similar rocks have been described and palynologically dated as Eocene at Vuich Creek, 15 kilometres to the northwest (Greig, 1988) and 60 kilometres to the north in the Pig Lake

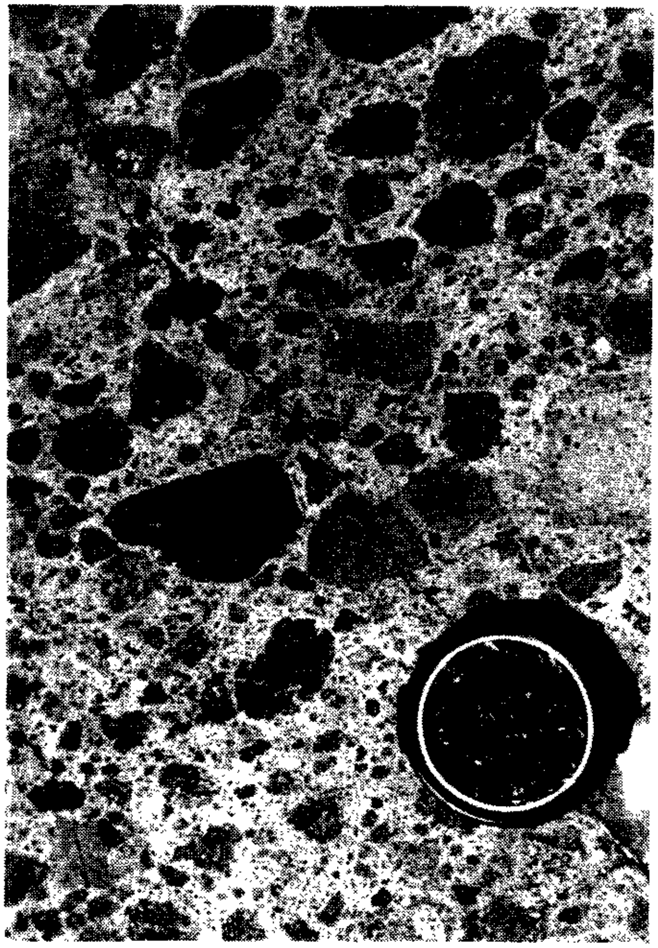


Plate 1-5-2. Dewdney Creek Formation andesitic hydroclastic breccia (Unit JDv) located above the Chuwanten fault 1.5 kilometres northeast of Snass Mountain. Fragmentation and resorption textures developed during non-explosive intrusion into marine sediments.

Plate 1-5-3. Jackass Mountain Group polymictic cobble conglomerate (Unit KJc) from 1 kilometre north of Snass Mountain, adjacent to dextral fault offsetting Chuwanten thrust fault (*see* Figure 1-5-2).

graben along the Coldwater fault system (Thorkelson, 1988).

Kettle Mountain is underlain by a prominent subcircular body of dark greenish black hornblende augite(?) basalt porphyry (Unit EPv). Columnar fracture patterns suggest that the rock was intruded into the surrounding Eagle plutonic rocks although a talus apron conceals the contact area. Intrusives of similar age were mapped by Preto (1972) in the Copper Mountain area, and small dikes of similar appearance occur in the headwaters of Buchanan Creek. The intrusive is an interesting physiographic feature, comprising a roche moutonnée covered by scattered glacial erratics of the Eagle Plutonic Complex.

COQUIHALLA VOLCANICS - UNIT OMCv

The north-central boundary of the recreation area, in the vicinity of Mount Warburton, is underlain by Oligocene to Miocene volcanics of the Coquihalla Volcanic Complex. The dominant rock type is a fresh, pale green-grey trachytic hornblende andesite that forms prominent, unstable cliffs and a large talus apron. The Coquihalla volcanics were investigated in detail by Berman and Armstrong (1980) who concluded that they are part of the Pemberton volcanic belt formed in response to subduction of the Juan de Fuca plate.

QUATERNARY DEPOSITS - UNIT QAL

Paradise Valley and the lower reaches of Holding and Hubbard creeks are infilled with unconsolidated glacial deposits of clay to cobble-sized material, and mantled by organic deposits. Partly stratified drumlinoid ice-contact deposits are found along the margins of these areas. Although not indicated on the geology map, the bottoms of other narrow valleys, such as the Skaist River and Snass Creek, are also filled with discontinuous deposits of similar material, locally mantled by distal parts of postglacial colluvium and talus aprons.

A thin veneer of locally derived glacial till, colluvium and immature soils covers most slopes and rounded ridge crests. Glacial erratics are widely deposited on all exposed ridges. The source of ultramafic erratics near Snass Mountain is thought to be the Tulameen Ultramafic Complex, indicating that a minimum 22 kilometres of southwest-directed ice transport has occurred.

INTRUSIVE ROCKS

Prior to this mapping project only two intrusive bodies and several dikes of uncertain age were indicated on published regional maps of the recreation area: the Miocene Sumallo stock, the Cretaceous Eagle Plutonic Complex, and the Lightning Creek intrusions (Cairnes, 1920, 1944; Rice, 1947; Monger, 1989). Exploration work in the Punchbowl Lake area had delineated small diorite bodies, and Monger (1989; personal communication, 1990) reported diorite dikes northeast of Snass Mountain for which he had determined an early Late Cretaceous date. This project has delineated: a large (20 square kilometres) diorite stock that intrudes the Pasayten Group sediments and is referred to as the Skaist River stock; several 50 to 100-hectare diorite plugs, and numerous gabbro, diorite and minor ultramafic and felsic dikes and sills.

EAGLE PLUTONIC COMPLEX – UNIT JKgd

The late Jurassic(?) to Cretaceous Eagle Plutonic Complex underlies the eastern part of the recreation area in a belt ranging from 1 to 3 kilometres wide, and forms the core of the Skaist, Kettle and Granite Mountain uplands. Its western boundary is in fault contact with Pasayten, Spences Bridge and Princeton groups along the Pasayten fault and later Tertiary faults.

Greig (1988) recognized three major units in the complex; muscovite granite, gneissic granodiorite and heterogeneous gneiss. In the recreation area, foliated hornblende biotite granodiorite and heterogeneous amphibolitic to granitic gneiss are the dominant units, however, in the Granite Mountain area, the proportions of pegmatite and muscovite granite increase. Foliations and planar fabrics strike mostly northwest with steep to moderate southwest dips, although in some sections dip reversals are numerous. Deformation is manifest as tight isoclinal and ptygmatic folding, boudinaging of quartz veins and pegmatites, and possibly mylonitization. In the Pasayten fault and related cross-faults, the plutonic rocks are present as well-developed quartz sericite schists. North of the recreation area and immediately south of Cunningham Creek, alongside the Podunk Creek road, Eagle plutonic rocks were forcefully intruded by the Coquihalla Volcanic Complex to form a breccia zone 500 metres wide. Angular fragments of Eagle complex up to 0.5 metre across, and smaller fragments of Cretaceous sediments, are preserved in a pinkish brown vitrophyric ash-rich matrix displaying fiammé textures.

SKAIST RIVER STOCK – UNIT Kd

A plagioclase-hornblende-biotite-porphyritic diorite stock (Plate 1-5-4) has been delineated between the northern bend of the Skaist River and the ridge east of Paradise Valley (Figure 1-5-2). The body is elliptical in outline, with a northwest elongation, and has a maximum width of 3.8 kilometres and maximum exposed length of 7 kilometres. Where the contact with enveloping sediments is observed it is generally sharp and steeply dipping with only minor hornfelsing or shearing apparent. Thin to medium-bedded Cretaceous sediments, up to 200 metres thick and traceable along strike for up to 2 kilometres, are preserved at high elevations in the central parts of the stock, and less commonly in the low-elevation exposures west of the Skaist River.

The stock exhibits considerable uniformity in internal structure, texture and composition. It is generally light grey-buff to light green-buff and contains equant to stubby lath-shaped plagioclase and fresh to weakly chloritized hornblende phenocrysts averaging 3 to 5 millimetres in length, and subhedral to euhedral 1 to 4-millimetre biotite in a fine-grained light olive-buff groundmass. The most common texture is a weakly trachytic crowded porphyry, with local gradations to less crowded and less trachytic varieties. Along its eastern margins, a possible weak zonation is discernible, with biotite phenocrysts increasing at the expense of hornblende.

The stock was sampled for isotopic dating of hornblende and a separate has been prepared and submitted to The University of British Columbia. Monger (1989) reported a Santonian age (85.7 Ma; K-Ar) for hornblende from a diorite "dike" which appears to have been collected along the south-central margin of the stock, close to where we collected our sample. Thus, intrusion may have occurred shortly after final deposition of the Albian Pasayten Group sediments during a period of crustal thickening resulting from northeast-directed thrusting (McGroder, 1989; Haugerud *et al.*, 1991). It is interesting to note that a lithologically similar dike dated at 84.8 Ma (Monger, 1989) is exposed in a roadcut 16 kilometres to the northwest, near Vuich Creek, suggesting that early Late Cretaceous magmatism in the northern Methow basin may be more widespread than previously recognized. Petrological and chemical analyses are in progress on these rocks.

Unit lKu: Diorite, gabbro and ultramafic dikes and sills intrude Jurassic and Early Cretaceous strata primarily in the western half of the study area. These are generally less than 5 metres wide but may extend for many tens of metres. Four notable exceptions are described.

Adjacent to the Hozameen fault a locally serpentinized, medium to coarse pyroxenitic gabbro with dimensions of 300 by 500 metres, is exposed as a fault-bounded(?) sliver which was tectonically emplaced, or intruded into the Ladner Group sediments. The rock is dark green-brown and contains clusters of radiating clinopyroxene and sporadic concentrations of pyrite and pyrrhotite. Its margins are variably sheared, serpentinized and silicified, however the actual contact with the Ladner Group was not observed.

Northwest of Punchbowl Creek a medium-grained hornblende gabbro sill, up to 20 metres thick and over 1 kilometre in length, intrudes Dewdney Creek Formation tuffaceous sediments in the hangingwall of the Chuwanten fault. The eastern end of the sill strikes into the Punchbowl Creek fault zone, whereas the northwest end crosses upper Snass Creek and may be related to a similar body which crops out 500 metres northwest of the recreation area boundary. Intrusion of the sill was accompanied by shearing, silicification and pyritization of surrounding sediments; traces of chalcopyrite were noted.

A hornblende gabbro dike 5 metres wide by over 50 metres long intrudes Jackass Mountain siltstone, argillite and sandstone 3 kilometres east of Skagit Bluffs. The western contact of the dike is weakly serpentinized adjacent to a

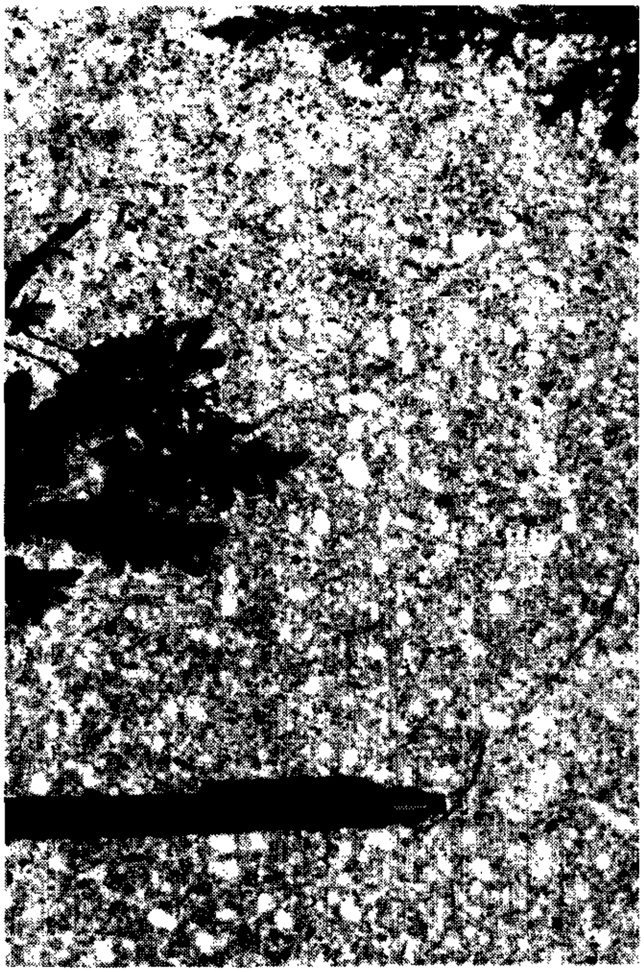


Plate 1-5-4. Skaist River stock plagioclase-hornblende-biotite diorite illustrating typical crowded porphyritic texture.

listwanitic zone of quartz-carbonate veining and brecciation 0.2 to 0.5 metre wide. Adjacent sediments are pyritic. The dike apparently intruded a minor fault zone which was active subsequent to intrusion and veining.

On the northeast slopes of Mount Dewdney several gabbroic to ultramafic sills have intruded Jackass Mountain Group sediments, causing sporadic pyritization. The largest sill is up to 50 metres thick and appears to extend for over 1 kilometre along strike, into the upper Sowaqua Creek drainage. It is dark greenish black and varies from fine to coarse grained, suggesting cumulate textures.

SUMALLO STOCK - UNIT Mgd

A massive hornblende biotite granodiorite stock, exposed over an area of 100 hectares, intrudes the Hozameen fault, Hozameen complex, Ladner Group and the ultramafic unit 1 kilometre north of the confluence of the Sumallo and Skagit rivers. The contact of the stock with most of these rocks is concealed although there is some evidence for sharp and irregular contacts with some diking and quartz veining. The stock was first dated by Coates (in Wanless *et al.*, 1967) who determined a 84 Ma age, but was recently redetermined by Armstrong *et al.* (1987) to be 19.9 to 22 Ma (Early Miocene). Several mineral occurrences are associated with the Sumallo stock.

OTHER INTERMEDIATE TO FELSIC INTRUSIONS - UNIT Td

Several small intrusive bodies of dioritic to granitic composition were mapped in the recreation area. These include: two hornblende diorite bodies adjacent to Punchbowl Lake; an equigranular hornblende granodiorite of unknown dimensions (possibly several hundred metres across) underlying the headwaters of east Snass Creek, and a smaller, but similar body on the ridge between lower Whatcom and Dewdney trails; and several prominent granodiorite to aplite dikes west of Snass Mountain and east of Mount Dewdney.

STRUCTURE

The dominant structural fabrics and elements of the recreation area trend northwest and reflect late Mesozoic, northeast tectonic convergence and crustal shortening. All stratified rocks, except for Unit OMCv, and most intrusive rocks, have northwest-trending planar foliations and lineations.

Folding is best developed in rocks west of the Chuwanten fault and typically occurs as northeast-verging upright to inclined isoclinal and chevron folds. Folding intensity increases adjacent to the fault. Two broad, shallow southeast-plunging synforms are developed in Cretaceous strata: the northwest extension of the Gibson Pass syncline (Coates, 1974) which underlies Mount Dewdney and the slopes northeast of Skagit Bluffs; and a similar feature, referred to as the Turnbull Creek syncline, that occurs northeast and parallel to the Chuwanten fault. Strongly deformed, gently south-dipping strata, including thin, boudined limestone beds in the nose of this syncline, were mapped 1.75 kilometres northeast of Snass Mountain.

The principal faults in the Cascade Recreation Area are the northwest-trending Hozameen, Chuwanten and Pasayten faults. East to northeast-striking Tertiary normal faults are found in many areas and may control the physiographic depressions drained by the Skaist and upper Tulameen rivers, and Snass Creek.

The Hozameen fault trends across the southwest corner of the recreation area where it separates Hozameen complex from Ladner Group sediments and is intruded by the Miocene Sumallo stock. The steep west-dipping fault is characterized by a zone of high strain and brecciation, and its development may have been accompanied by tectonic emplacement of the adjacent ultramafic body, analogous to the Coquihalla River area (Ray, 1990). Precise timing of the fault movement is uncertain, however, Ray concluded that its regional importance as a gold exploration target is related to a long period of recurrent movement, mainly during the Cretaceous.

The Chuwanten thrust fault strikes northwest through the central part of the recreation area. Along its length the Ladner Group is thrust northeast over Early Cretaceous Jackass Mountain and Pasayten Group sediments. Field evidence suggests that the fault propagated along a detachment zone defined by the brittle-ductile contrasts between thin-bedded argillaceous and massive volcanic units in the Ladner Group.

The thrust zone is complex as shown on Figure 1-5-2. It changes from a simple, steep southwest-dipping planar geometry in the southeast, to a segment of steep and northeast dips east of Snass Mountain, complicated by dextral shear along east-trending wrench faults. It eventually splays into a system of imbricate thrust sheets northwest of Paradise Valley. Deformation in the lower hangingwall of the thrust is manifest as tight east-verging to upright and partly overturned isoclinal drag folds, shearing, locally intense stretching and pencil lineations, and development of coplanar quartz and carbonate veins. The thrust has localized a number of intrusions including gabbro to diorite dikes and sills and the Punchbowl Lake area diorite. Pronounced quartz-pyrite alteration is present in sediments and intrusions adjacent to the thrust in the Punchbowl Creek area.

The fault is traceable for more than 80 kilometres southeast into Washington State where it becomes the Canyon Creek thrust fault and terminates in the Canyon Creek tear fault (McGroder, 1989). It is also traceable for over 75 kilometres northwest to Boston Bar, where it terminates in the Fraser fault system. The regionally significant Treasure Mountain lead-silver-zinc-copper-gold deposit occurs in a splay of the fault (Meyers and Hubner, 1989).

The third major fault in the recreation area is the Pasayten fault which places the Cretaceous Eagle Plutonic Complex against the Methow basin stratigraphy. The fault trace lies up to 1.5 kilometres northeast of its previously indicated position on regional maps (Monger, 1989). It is best exposed southeast of Hubbard Creek where pale buff to grey-green quartz sericite schists and stongly fractured, quartz-sericite-pyrite-carbonate-altered sediments characterize the fault zone. The Pasayten fault has been disrupted by east to northeast-trending Tertiary(?) faults.

GEOCHEMISTRY

Information on the distribution of trace elements in bedrock and surficial materials is an integral component in determining prospective metallogenic environments. The geochemical sampling component of this mineral potential study included the following:

- Detailed drainage-sediment (moss mat and silt) and water geochemistry, with an average density of one sample per 1.5 square kilometres.
- Lithogeochemical sampling of known and newly located mineral occurrences, alteration and shear zones.
- Collection of representative rock types for major and trace element determinations.

The initial drainage-sediment sampling conducted under contract in 1990 resulted in collection of samples from 74 sites. Chemical analyses for the standard Regional Geochemical Survey (RGS) suite of trace elements were visually interpreted and assisted in guiding mapping and prospecting in 1991. In-fill sampling during mapping resulted in the collection of an additional 72 samples. Representative samples of mineralized and altered zones, and common lithologies, were collected during mapping, for chemical analysis and to assist with interpretation of the silt and moss-mat geochemical data. The final project report will include sample location maps, multi-element plots highlighting anomalous drainages and data interpretation

ECONOMIC GEOLOGY

The tectonostratigraphic setting of the Cascade Recreation Area contains metallogenic environments typical of deformed, convergent terrane margins. Mineral deposit types recognized include:

- Base and precious metal veins associated with regional and local faults.
- Gold-bearing base metal veins, disseminations and listwanite(?) associated with ultramafic and gabbro intrusions.
- Precious and/or base metal veins, disseminations and skarns associated with mafic to felsic intrusions.
- Polymetallic quartz veins in metamorphosed granitoids and supracrustals.
- Base metal sulphides in pyritic sediments.

Table 1-5-1 summarizes the mineral occurrences in the recreation area, and is based on field examination and literature review. A number of minor occurrences and zones of quartz-carbonate alteration, shearing and pyritization which are not documented in the table will be described in the final report. Three key areas of mineralization are described below.

Punchbowl Lake Area (Minfile 92HSW151, and Undocumented)

Mineralization in the Punchbowl Lake area was discovered by R. Rabbitt in 1984 and preliminary exploration was carried out until 1987 when the recreation area was designated and no further exploration permitted. Two areas of mineralization reported by Cardinal (1986a, b) and Kallock (1987) were geologically mapped and resampled (Figure 1-5-3). To date neither of these prospects has been geophysically surveyed or drilled.

The Punchbowl Creek occurrence (M1 – Figure 1-5-2) is located approximately 1 kilometre north of Punchbowl Lake and 500 metres south of Paradise Meadows where the creek has deeply incised the lower valley. The area is underlain by thin to medium-bedded Pasayten Group siltstones, argillite and arkose intruded by altered hornblende diorite dikes or plugs. There are few exposures of the intrusive(s) away from the creek so dimensions are uncertain. Structures are dominated by a zone of high strain parallel to the creek. It appears to have caused dextral offset of the main Chuwanten fault trace, and may be the terminus for a zone of imbricate thrust faulting to the northwest (*see* Figure 1-5-2). Sediments along the creek strike north with steep to vertical dips, compared to northwest strikes and moderate southwest dips away from the creek. Sediments are sheared, intensely fractured and pervasively silicified and pyritized for over 200 metres along the creek. Adjacent to the main intrusive body, bedding-parallel and cross-cutting shears contain narrow, discontinuous quartz veins with variable amounts of pyrite and arsenopyrite, and trace amounts of chalcopyrite, sphalerite and galena. Trace element analyses of the samples plotted in Figure 1-5-3 indicate anomalous concentrations of gold, zinc, lead, copper, arsenic and tungsten (Table 1-5-2). Pyrite veinlets in silicified Unit KP contain up to 267 ppb gold, 0.1 per cent zinc, and 5200 ppm lead.

The Punchbowl Fault occurrence (M2 – Figure 1-5-2) is located 500 metres west of Punchbowl Lake on the ridge crest at the head of a prominent gully. The gully follows an east-trending fault which splays into several minor faults on the ridge, where it is intruded by two small, irregular shaped hornblende diorite plugs. The hostrocks are thin-bedded Dewdney Creek tuffaceous argillite, sandstone and lapilli tuff, which have been moderately hornfelsed and weakly pyritized up to several metres away from the diorite contact. A prominent northwest fault splay has localized a quartz-ankerite vein 30 centimetres wide which can be traced for 200 metres along strike. Trenching on the vein has exposed irregular blebs, streaks and disseminations of pyrite, chalcopyrite, galena, sphalerite and arsenopyrite. Samples plot-

TABLE 1-5-1
SUMMARY OF MINERAL OCCURRENCES IN THE CASCADE RECREATION AREA

MAP NO.	MINFILE NAME	COMMODITIES	REFERENCE	UTM Zn 10 EAST	UTM Zn 10 NORTH	DESCRIPTION
M1	Punch Bowl	Zn,Ag,Au,Pb,Cu	Schmitt and Stewart, 1991	646432	5461859	hornblende diorite intrudes Pasayten Group sediments; py, cpy, gn and sp occur as blebs and disseminations in qtz veins, shears and fractures.
M2	Punch Bowl Fault K.C.M.	Au,Ag,Cu,Pb,Zn	Schmitt and Stewart, 1991; Cardinal, 1985	645550	5460500	qtz veins are developed along the faulted contact between several diorite dikes and Dewdney Creek Formation fine-grained volcaniclastics; py, gn, cpy and sp occur in qtz veins and hornfelsed Dewdney Creek rocks.
M3	Granite Scheelite	Au,Ag,Cu,Zn,Pb	this report, Brown, 1980	654966	5467408	mineralized qtz occurs along the contact of qtz-albite-muscovite pegmatite and hornblende-biotite amphibolite in the Eagle Plutonic Complex; mineralization consists of disseminated py, gn, sp and cpy; assays returned elevated Au, Ag, Cu, Pb and Zn values.
M4	Skaist River	Cu	this report	654469	5461147	semimassive and disseminated py and cpy occur in sheared and altered Spences Bridge Group volcaniclastics near the contact with the Skaist River diorite stock.
M5	Ford	Au,Ag	Barde, 1984	639295	5459572	qtz veins up to 15 cm in width cut Hozameen Group sediments and return trace Ag, Au, Cu, Pb and Zn values.
M6	Forks	Ni	M.M. ANN RPT 1938	639585	5454512	a serpentinized ultramafic body intrudes Hozameen Group rocks east of the Hozameen fault; po is disseminated throughout; significant Ni values are reported.
M7	Dingo	Ag,Cu,Au,Mo	M.M. ANN RPT 1927	640446	5454101	a Miocene granodiorite stock intrudes Ladner Group sediments east of the Hozameen fault; small sheared zones within the intrusion contain mo and cpy mineralization; assays returned significant Ag and Cu values and trace Au.
M8	Silver Queen	Ag,Pb,Zn,Au,Cu	M.M. ANN RPT 1915	640559	5453641	Ladner sediments east of the Hozameen fault are intruded by a Miocene granodiorite stock; nodules and narrow stringers of gn, cpy, py and po in qtz are hosted by the intrusive; assays returned Au, Ag, Cu, Pb and Zn values.
M9	Mammoth	Ni,Ag,Au,Cu,W,Mo	EMPR Property Files	639266	5453546	a 15-metre-wide zone of altered limestone of the Hozameen Group near the Hozameen fault hosts disseminated po, py, aspy and cpy mineralization; a 0.9-metre calcsilicate vein hosts scheelite and po mineralization with minor amounts of sp, pyr and mo.

Abbreviations:

Ag - silver, ANN RPT - annual report, As - arsenic, aspy - arsenopyrite, A.R. - assessment report, Au - gold, cpy - chalcopyrite, Cu - copper, EMPR - Energy, Mines and Petroleum Resources, gn - galena, M.M. - Minister of Mines, mo - molybdenite, Mo - molybdenum, Ni - nickel, Pb - lead, po - pyrrhotite, py - pyrite, pyr - pyrolusite, qtz - quartz, sp - sphalerite, W - tungsten, Zn - zinc ted on Figure 1-5-3 are anomalous in base and precious metals (Table 1-5-2). The highest concentrations of metals occur in quartz veins in the fault splay. Hornfelsed sediments contain anomalous tungsten and slight enrichments in zinc. A recent assessment report documents a broad zone of anomalous zinc and arsenic in soils, suggesting the possible presence of additional mineralized structures (Kallock, 1987).

GRANITE SCHEELITE (MINFILE 92HSE101 – M3 FIGURE 1-5-2)

Gold-silver mineralization has been explored and evaluated at the Granite-Scheelite prospect intermittently since about 1942 (Stevenson, 1942; Brown, 1980). The mineralized vein system is well exposed for 175 metres along strike, in a series of trenches and an adit on upper Buchanan Creek. In 1969 Silver Tip Explorations Ltd. advanced an adit 50 metres along the vein system and conducted a milling test of 132 tonnes of ore, the results of which are unknown (*Geology, Exploration and Mining in British Columbia 1969*, p. 282). Detailed surface sampling of trenches and a five-hole drilling program were carried out by Long Lac Mineral Exploration Ltd. in 1980 to test the gold and silver potential of the vein system under option from Northern Lights Resources Ltd. (Brown, 1980). Long Lac relinquished the option after concluding that there was limited economic potential. Apart from limited interest in tungsten during the war years there is no record of base metal geochemical analyses from this property despite recognition of chalcopyrite, galena and sphalerite mineralization.

The prospect is underlain by chloritized hornblende, biotite and garnet-bearing amphibolites of the Eagle Plutonic Complex which have been intruded by one or more quartz-albite-muscovite pegmatite dikes, and later diabase dikes of possible Princeton Group affinity (Figure 1-5-4). A series of parallel and bifurcating mineralized quartz veins up to 1 metre wide are parallel to the contact zone of the pegmatite and amphibolite and locally offset by minor faults. The main vein system strikes 150° and dips steeply northeast. All rocks have undergone high strain, with development of schistose and fine-grained recrystallized equivalents.

Mineralization occurs as blebs, small lenses and disseminations of pyrite, galena, sphalerite and chalcopyrite, principally in the quartz veins but also disseminated in adjacent amphibolites and quartz-sericite schists. Sulphide concentrations are erratic along the strike length of the main vein system. Table 1-5-3 lists our preliminary analyses of selected vein samples. High gold values of 60 grams per tonne and silver values of nearly 2000 grams per tonne occur in narrow quartz veins carrying chalcopyrite, sphalerite and galena. Mineralization has an interesting polymetallic signature, including anomalous antimony, cadmium and bismuth, which may reflect a volcanic origin of the amphibolitic unit (Nelson *in* Brown, 1980) and offer new possibilities for regional exploration in similar amphibolitic units in the Eagle Plutonic Complex.

SKAIST RIVER

A previously undocumented mineral occurrence was found during mapping in 1991 along the southeast contact of the Skaist River stock, 500 metres north of the Skaist River (Figure 1-5-2, M4). The main stock and satellite dikes of hornblende biotite diorite intrude thin to medium-bedded tuffs and tuffaceous siltstone, wacke and argillite of the Cretaceous Spences Bridge Group. Mineralization consists of a sheared quartz vein 15 to 30 centimetres wide by 1.5 metres long with massive to banded pyrite and trace chalcopyrite. The exposure is on a steep, outcrop and talus-covered slope. Down slope, along strike, the volcaniclastics are pervasively hornfelsed and pyritized. From the air a weakly gossanous zone can be seen to extend to the east and up slope, suggesting potential for additional alteration and mineralization. Chemical analyses of mineralization are in progress.

SUMMARY

A two-year mineral-potential field study of the Cascade Recreation Area was completed in 1991. The 16 780 hectare recreation area was mapped at a scale of 1:20 000, prospected and geochemically sampled in order to provide a comprehensive mineral potential database for private industry and government decision makers. Publication of the final report and interpretation of this study, scheduled for early 1992, will initiate a further minimum 10 year exploration period in the recreation area. Exploration during this period will be jointly administered by the Ministries of Energy, Mines and Petroleum Resources and of Environment, Lands and Parks.

The Cascade Recreation Area is underlain by a thick succession of Mesozoic marine and nonmarine sedimentary and volcaniclastic rocks of the Methow basin between the Hozameen Complex (Bridge River Terrane) to the west and Eagle Plutonic Complex to the east. Accretionary tectonics and associated plutonism during the Late Jurassic and throughout the Cretaceous resulted in the development of a number of intrusion and structure-associated metallogenic environments. The area's mineral potential has been substantially upgraded through: delineation of the Skaist River stock; recognition of a belt of previously unmapped Spences Bridge Group volcanics and derived clastics definition of the structural complexity and intrusive activity along the Chuwanten fault, mapping of mafic and ultramafic bodies along the Hozameen and Chuwanten faults and within Ladner Group sediments; and an improved geochemical database.

Potential for the following mineral deposit types is recognized: quartz-carbonate veins containing gold, silver, copper, lead and zinc, associated with regional (Hozameen, Chuwanten, Pasayten) and related minor faults, with mineralization hosted by various rock types; quartz veins, disseminations, and skarns containing a variety of base and precious metals associated with intrusive rocks ranging from diorite to pegmatite; and veins and disseminations of nickel and gold-bearing sulphides associated with gabbro and ultramafic rocks.

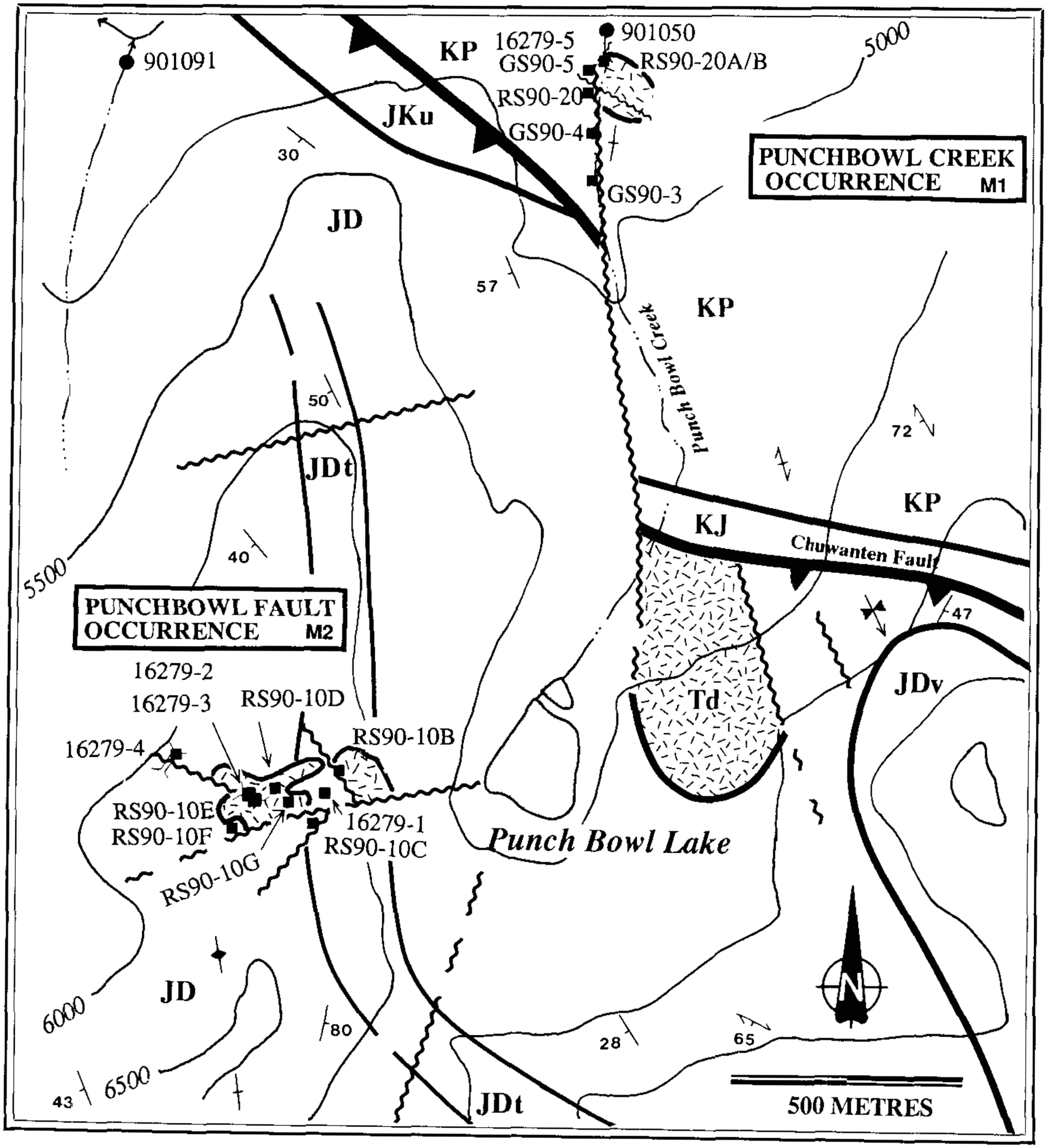


Figure 1-5-3. Geology, location and lithogeochemical sample sites at Punchbowl Creek and Punchbowl Fault occurrences (M1 and M2, Figure 1-5-2). Sample analyses and descriptions in Table 1-5-2.

ACKNOWLEDGMENTS

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REFERENCES

Anderson, P. (1976): Oceanic Crust and Arc-trench Gap Tectonics in Southwestern British Columbia; *Geology*, Volume 4, pages 443-446.

Armstrong, R.L.A., Greig, C.J., Harakal, J. and Runkle, D. (1987): Isotopic Age Date for Sumallo Stock; Geochronology Files, *The University of British Columbia.*

Berman, R.G. and Armstrong, R.L.A. (1980): Geology of the Coquihalla Volcanic Complex, Southwestern British Columbia; *Canadian Journal of Earth Sciences,* Volume 17, pages 985-995.

Barde, B. (1984): Geological and Geochemical Report, Ford 1, 2, 3, 4, 5, and 6 Mineral Claims New Westminster Mining Division, NTS 92H/3W; *B.C. Ministry of Energy, Mines and Petroleum Resources,* Assessment Report 13270, 13 pages.

Brown, R.F. (1980): Long Lac Mineral Exploration Diamond Drilling Report, Gransil Claims I and II, Granite-Scheelite 1, Granite Mtn. Area, Similkameen Mining District, NTS 92H/7W; *B.C. Ministry of Energy, Mines and Petroleum Resources,* Assessment Report 8503, 25 pages.

TABLE 1-5-2
SELECTED TRACE ELEMENT ANALYSES OF PUNCHBOWL FAULT AND PUNCHBOWL CREEK MINERALIZATION

Sample Number	Au (ppb)	Ag	Cu	Pb	Zn	As	Sb	W	Ni
PUNCHBOWL FAULT OCCURRENCE:									
RS90C-10B	<5	<0.6	44	<3	51	65	1.0	2[illegible]0	140
RS90C-10C	<5	<0.6	59	3	122	8	2.2	[illegible]8	120
RS90C-10D	<5	<0.6	31	6	116	54	2.0	1[illegible]0	<50
RS90C-10E	624	406	440	970	0.36%	130	100	1[illegible]0	<50
RS90C-10F	<5	<0.6	34	<3	207	71	2.1	[illegible]6	<50
RS90C-10G	5	<0.6	76	6	88	14	0.6	[illegible]8	280
16279-1	5	1.2	54	73	165	53			
16279-2	215	>100	310	7200	770	1100			
16279-3	190	>100	118	1700	600	5700			
16279-4	10	0.2	35	9	206	73			
PUNCHBOWL CREEK OCCURRENCE:									
GS90-3	<5	<0.6	31	5	58	9	0.6	[illegible]2	<50
GS90-4	<5	<0.6	99	<3	58	4	0.4	[illegible]4	<50
GS90-5	267	4	60	43	420	1600	0.9	[illegible]0	<50
RS90C-20	19	2	94	35	136	14	1.3	1[illegible]0	<50
RS90C-50N	13	1	59	11	130	42	0.8	1[illegible]0	<50
RS90C-50NA	126	8	36	12	0.10%	310	4.5	[illegible]9	110
RS90C-50NB	14	2	28	11	169	45	1.4	[illegible]6	<50
RS90C-60N	5	0.6	2	<3	290	14	0.7	1[illegible]0	63
16279-5	*85*	*13*	*253*	*5200*	*>10,000*	*160*			

All values in ppm unless otherwise indicated
Au, As, Ni, Sb and W determined by instrumental neutron activation analyses (INAA)
Ag, Cu, Pb and Zn determined by atomic absorption spectrometry (AAS)

Sample descriptions:

RS90C-10B; sheared Unit JDt at diorite contact
RS90C-10C; sheared Unit JDt with disseminated pyrite
RS90C-10D; hornfelsed tuffaceous siltstone Unit JD
RS90C-10E; sulphide-bearing quartz vein in fault zone
RS90C-10F; 10-metre chip sample pyritic hornfelsed Unit JDt
RS90C-10G; pyritic hornblende diorite Unit Td
GS90-3; pyritic silicified siltstones Unit KP
GS90-4; pyritic silicified siltstones Unit KP
GS90-5; pyrite veinlets in silicified siltstones Unit KP
RS90C-20; pyritic, propylitic altered diorite Unit Td
RS90C-50N; pyritic siltstones Unit KP
RS90C-50NA; pyrite vein in silicified siltstone Unit KP
RS90C-50NB; pyrite veins in silicified Unit KP
RS90C-60N; pyrite veins in silicified Unit KP

Samples reported in Kallock (1987):

16279-1; lapilli tuff Unit JDt
16279-2; quartz-galena float near fault
16279-3; mineralized quartz vein in fault zone
16279-4; quartz-limonite veinlets in Unit JDt, average of 4 samples across 10 metres
16279-5; pyrite veinlets in silicified Unit KP sediments

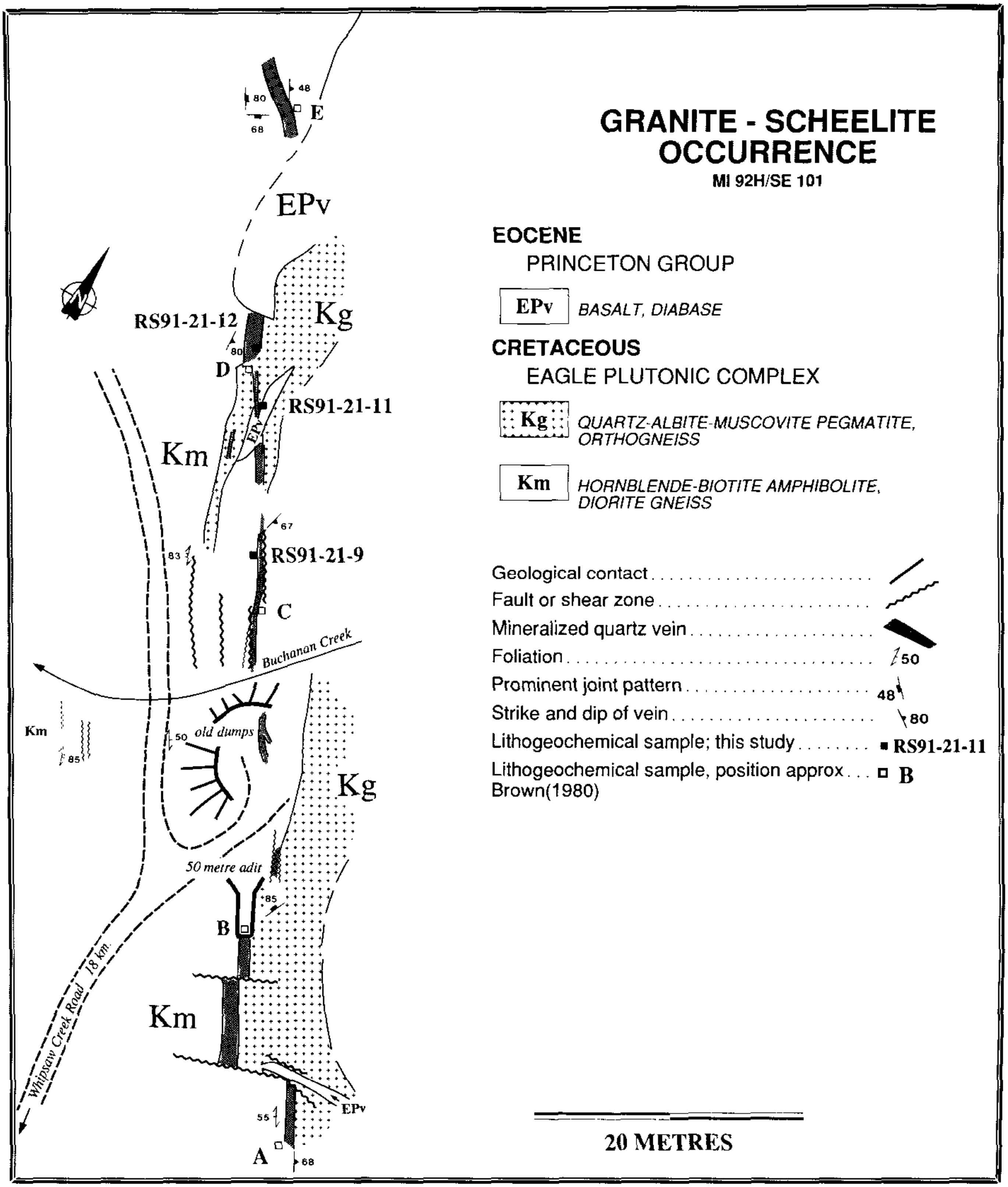

Figure 1-5-4. Geology and lithogeochemical sample sites at the Granite-Scheelite occurrence (MINFILE 92HSE101 and M3, Figure 1-5-2). Sample analyses and descriptions in Table 1-5-3.

Cairnes, C.E. (1920): Dewdney Trail between Beaver Lake and Nine-mile Creek; *Geological Survey of Canada*, Summary Report, Part A, pages 108A-123A.

Cairnes, C.E. (1924) Coquihalla Area, British Columbia; *Geological Survey of Canada*, Memoir 139, 187 pages.

Cairnes, C.E. (1944): Hope; *Geological Survey of Canada*, Map 737A, 1:253 440.

Cardinal, D.G. (1985): A Preliminary Geological Report on the K.C.M. Claim Group, Similkameen and New Westminster Mining Divisions, NTS 92H/6E, 7W; *B.C. Ministry of Energy, Mines and Petroleum Resources*, Assessment Report 14693, 14 pages.

Cardinal, D.G. (1986a): Reconnaissance Geochemical and Geological Assessment Report on the Punch Bowl Claim Group, Similkameen and New Westminster Mining Divisions, NTS 92H/6E, 7/W; *B.C. Ministry of Energy, Mines and Petroleum Resources*, Assessment Report 15146, 13 pages.

Cardinal, D.G. (1986b): Reconnaissance Geochemical and Geological Assessment Report on the K.C.M. Claim Group, Similkameen and New Westminster Mining Divisions, NTS 92H/6E, 7/W; *B.C. Ministry of Energy, Mines and Petroleum Resources*, Assessment Report 15212, 14 pages with maps.

Coates, J.A. (1974): Geology of the Manning Park Area, British Columbia; *Geological Survey of Canada*, Bulletin 238, 177 pages.

Davis, G.A., Monger, J.W.H. and Burchfield, B.C. (1978): Mesozoic Construction of the Cordilleran "Collage", Central British Columbia to Central California; *in* Mesozoic Paleogeography of the Western United States, Howell, D.G. and McDougall, K.A., Editors, *Society of Economic Paleontologists and Mineralogists, Pacific Section*, Pacific Coast Paleogeography Symposium 2, pages 1-32.

Greig, C.J. (1988): Geology and Geochronometry of the Eagle Plutonic Complex, Hope Map-area, Southwestern British Columbia; *in* Current Research, Part E, *Geological Survey of Canada*, Paper 88-1E, pages 177-183.

Hanson, R.E. (1991): Quenching and Hydroclastic Disruption of Andesitic to Rhyolitic Intrusions in a Submarine Island-arc Sequence, Northern Sierra Nevada, California; *Geological Society of America Bulletin*, Volume 103, pages 804-816.

Haugerud, R.A. (1985): Geology of the Hozameen Group and the Ross Lake Shear Zone, Maselpanik Area, North Cascades, Southwest British Columbia; *University of Washington*, unpublished Ph.D. thesis, 263 pages.

Haugerud, R.A., Van der Heyden, R., Tabor, R.W., Stacey, J.S. and Zartman, R.E. (1991): Late Cretaceous and Early Tertiary Plutonism and Deformation in the Skagit Gneiss Complex, North Cascade Region, Washington and British Columbia; *Geological Society of America Bulletin*, Volume 103, pages 1297-1307.

TABLE 1-5-3
SELECTED TRACE ELEMENT ANALYSES OF GRANITE-SCHEELITE OCCURRENCE

Sample Number	Au (ppb)	Ag	Cu	Pb	Zn	As	Sb	W	Cd	Mo	Bi
RS91-21-9[a]	56 900	2000			7450	8	78	<4		<5	
RS91-21-9[b]		>100	5870	>10 000	6710			120	104	12	144
RS91-21-11[a]	112	10			463	29	2	9		130	
RS91-21-11[b]		6.2	833	50	382			10	1	155	2
RS91-21-12[a]	7850	56			19 600	6	3.8	<4		<5	
RS91-21-12[b]		60	3840	390	>10 000			30	246	3	50
A-A (0.46m)	16 930	464									
A-B (0.3m)	1440	9.9									
B-A (0.94m)	7130	146									
B-B (1.5m)	3290	37									
C-A (0.46m)	63 350	123									
C-B (1.22m)	5420	22.5									
D-A (0.76m)	19 680	107									
D-B (1.07m)	2060	45									
E-A (0.76m)	25 780	111									
E-B (0.9m)	3570	42.5									

All values in ppm unless otherwise indicated

[a] analyses by instrumental neutron activation (INAA)

[b] analyses by inductively coupled plasma emission spectroscopy (ICP) following total digestion

Sample descriptions:

RS91-21-9; 15 cm quartz vein with galena, chalcopyrite and pyrite
RS91-21-11; sheared pyritic amphibolite adjacent to quartz vein
RS91-21-12; 0.6 m wide quartz vein with sphalerite, pyrite, chalcopyrite and minor galena

Samples collected by Phendler, 1979 (A series) and Hogan, 1980 (B series) as reported in Brown (1980, Assessment Report 8503)
Sample locations approximately the same, analytical method not reported.

A; mineralized quartz in shear zone
B; mineralized quartz vein in adit face
C; mineralized quartz veins in trenches
D; quartz veins in trench
E; quartz vein in exposed face, north end of vein

Kallock, P. (1987): Geological and Geochemical Investigations, Punch West, Puch East, K.C.M. West and K.C.M. East Mineral Claims, Snass Creek – Tulameen River Area, Hope, B.C., Similkameen and New Westminster Mining Divisions, NTS 92H/6E 7W; *B.C. Ministry of Energy, Mines and Petroleum Resources*, Assessment Report 16279, 14 pages.

McGroder, M.F. (1989): Structural Geometry and Kinematic Evolution of the Eastern Cascades Fold-belt, Washington and British Columbia; *Canadian Journal of Earth Sciences*, Volume 26, pages 1586-1602.

McGroder, M.F. and Miller, R.B. (1989): Geology of the Eastern North Cascades; *in* Geologic Guidebook for Washington and Adjacent Areas, N.L. Joseph *et al.*, Editors, *Washington Division of Geology and Earth Resources*, Information Circular 86, pages 97-118.

Meyers, R.E. and Hubner, T.B. (1990): Preliminary Geology of the Treasure Mountain Silver-Lead-Zinc Vein Deposit; *in* Exploration in British Columbia 1989, *B.C. Ministry of Energy, Mines and Petroleum Resources*, pages 95-103.

Monger, J.W.H. (1970): Hope Map-area, West-half, British Columbia; *Geological Survey of Canada*, Paper 69-47, 75 pages.

Monger, J.W.H. (1989): Geology, Hope, British Columbia; *Geological Survey of Canada*, Map 41-1989, 1:250 000, Sheet 1 to 4 and accompanying notes.

Monger, J.W.H., Price, R.A. and Templeman-Kluit, D.J. (1982): Tectonic Accretion and the Origin of the Two Major Metamorphic and Plutonic Welts in the Canadian Cordillera; *Geology*, Volume 10, pages 70-75.

O'Brien, J. (1986): Jurassic Stratigraphy of the Methow Trough, Southwestern British Columbia; *in* Current Research, Part B, *Geological Survey of Canada*, Paper 86-1B, pages 749-756.

Potter, C.J. (1986): Origin, Accretion, and Post-accretionary Evolution of the Bridge River Terrane, Southwestern British Columbia; *Tectonics*, Volume 5, pages 1027-1041.

Preto, V.A. (1972): Geology of Copper Mountain; *B.C. Ministry of Energy, Mines and Petroleum Resources*, Bulletin 59, 87 pages plus plates and maps.

Ray, G.E. (1990): The Geology and Mineralization of the Coquihalla Gold Belt and Hozameen Fault System, Southwestern British Columbia; *B.C. Ministry of Energy, Mines and Petroleum Resources*, Bulletin 79, 97 pages plus maps.

Rice, H.M.A. (1947): Geology and Mineral Deposits of the Princeton Map-area, British Columbia; *Geological Survey of Canada*, Memoir 243, 136 pages.

Schiarizza, P., Gaba, R.G., Glover, J.K. and Garver, J.I. (1989): Geology and Mineral Occurrences of the Tyaughton Creek Area (92O/2, 92J/15, 16); *in* Geological Fieldwork 1988, *B.C. Ministry of Energy, Mines and Petroleum Resources*, Paper 1989-1, pages 115-130.

Schmitt, H.R. and Stewart, G.G. (1990): Preliminary Geology and Mineral Potential of the Cascade Recreation Area, (92H/2, 3, 6, 7); *in* Geological Fieldwork 1990, *B.C. Ministry of Energy, Mines and Petroleum Resources*, Paper 1991-1, pages 47-55.

Stevenson, J.S. (1942): Tungsten Deposits of British Columbia; *B.C. Ministry of Energy, Mines and Petroleum Resources*, Bulletin 10, page 116.

Thorkelson, D.J. (1988): Eocene Sedimentation and Volcanism in the Fig Lake Graben, Southwestern British Columbia; *Canadian Journal of Earth Sciences*, Volume 26, pages 1368-1373.

Thorkelson, D.J. and Rouse, G.E. (1989): Revised Stratigraphic Nomenclature and Age Determinations for Mid-Cretaceous Volcanic Rocks in Southwestern British Columbia; *Canadian Journal of Earth Sciences*, Volume 26, pages 2016-2031.

Wanless, R.K., Stevens, R.D., Lachance, G.R. and Edmonds, C.M. (1967): Age Determinations and Geological Studies, K-Ar Isotopic Ages, Report 7; *Geological Survey of Canada*, Paper 66-17.

Whitney, D.L. and McGroder, M.F. (1989): Cretaceous Crustal Section through the Proposed Insular-Intermontane Suture, North Cascades, Washington; *Geology*, Volume 17, pages 555-558.