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MINERAL RESOURCES DIVISION
Geological Survey Branch

THE GEOLOGY AND MINERALIZATION OF THE COQUIHALLA GOLD BELT AND HOZAMEEN FAULT SYSTEM, SOUTHWESTERN BRITISH COLUMBIA

By Gerald E. Ray

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SUMMARY

This bulletin and the accompanying maps describe the geology, gold deposits and mineral occurrences adjacent to the Hozameen fault system and Coquihalla serpentine belt in southwestern British Columbia. The map area covers 170 square kilometres within parts of the Hope (92H/6), Spuzzum (92H/11) and Boston Bar (92H/14) map sheets.

The northerly trending Hozameen fault is associated with both the Coquihalla serpentine and Coquihalla gold belts, and separates two distinct crustal units. East of the fault are greenstones of the Early Triassic(?) Spider Peak Formation which forms a basement for the Jurassic to Middle Eocene turbidite and successor basin deposits of the Methow-Pasayten trough. The Jurassic Ladner Group, the oldest sedimentary rocks in the trough, unconformably overlies the Spider Peak Formation and contains a locally developed basal coarse clastic unit that hosts many of the mineral occurrences in the Coquihalla gold belt, including the Carolin deposit. Recently discovered Late Jurassic Buchia fossils in the Ladner Group succession suggest the group extends beyond its formerly accepted age of Early to Middle Jurassic. West of the Hozameen fault, the Permian to Jurassic Hozameen Group is interpreted as a highly deformed, dismembered ophiolite suite comprising ultramafic rocks of the Petch Creek serpentine belt at the base, stratigraphically overlain in turn by volcanic greenstone and chert units. Volcanic greenstones on either side of the Hozameen fault are geochemically distinguishable. Those in the Spider Peak Formation represent sodic, ocean-floor, subalkaline basalts probably formed in a spreading-ridge environment, while the volcanic rocks in the Hozameen Group include both arc tholeiites and oceanic island–seamount subalkaline basalts.

Farther west, the major, northerly trending and easterly dipping Petch Creek fault separates the Hozameen Group from the Custer-Skagit gneiss. This fault is associated with the lowest recognized stratigraphic section of the Hozameen Group, the Petch Creek serpentine belt, and is believed to be a northern extension of the Ross Lake fault in Washington State.

The evolution of, and relationships between, the Hozameen Group, the Spider Peak Formation and the Methow-Pasayten trough are still controversial. One possibility is that they were all deposited within a single long-lived basin that evolved from a multi-rifted, marine back-arc basin into a narrow, nonmarine trough. Alternatively, it can be argued that the contrasting geochemical signatures of the volcanics in the Spider Peak Formation and the Hozameen Group suggest they were not closely associated prior to Middle Jurassic time.

The relationship between the Hozameen Group and the Custer-Skagit gneiss to the west is also uncertain, primarily because of transcurrent and vertical movements along the Petch Creek fault. Closure of the Methow-Pasayten trough during Cretaceous to Middle Eocene time resulted in easterly overthrusting of the Hozameen Group onto the Methow-Pasayten strata along a westerly dipping thrust plane that was a precursor to the Hozameen fault. Upthrust ultramafic material from beneath the Spider Peak Formation now forms the Coquihalla serpentine belt. Both the thrust and ultramafic belt were later tilted into their present subvertical attitudes. Together the Coquihalla serpentine belt and Spider Peak Formation represent steeply inclined or overturned basement to the Methow-Pasayten trough.

The Petch Creek and Coquihalla serpentine belts are dissimilar and unrelated. The Petch Creek belt mainly comprises olivine-bearing serpentinite and is not associated with gold or listwanites. The much wider and extensive Coquihalla serpentine belt is an ophiolite that is spatially associated with gold mineralization; it includes early serpentinite, later gabbroic intrusions and minor tectonic slices of listwanite. Textures suggest both serpentine belts were derived from ultramafic cumulates.

A felsic dyke swarm, possibly related to the Middle Eocene Needle Peak pluton, intrudes the rocks of the Methow-Pasayten trough, but is absent in the Hozameen Group. It is postulated that this is due to later offset by regional dextral strike-slip movement along the Hozameen fault.

The Coquihalla gold belt shows similarities in its geological setting, mineralogy and alteration assemblages to the Bridge River camp of British Columbia and the Mother Lode district of California. It comprises five past-producing mines (Carolin, Emancipation, Aurum, Pipestem and the Ward mine) as well as at least 25 minor gold occurrences. Total production from the belt was 1473 kilograms of gold from just over 800 000 tonnes of ore mined, although over 90 per cent of this came from the Carolin mine. Three forms of epigenetic mesothermal gold-bearing mineralization are recognized:

(1) Fracture-related quartz-carbonate vein systems that host the majority of the minor occurrences as well as the mineralization at the Emancipation and Pipestem mines.

(2) Sulphide-rich albite-quartz-carbonate-gold mineralization within folded sedimentary rocks in the basal portion of the Ladner Group. The Carolin deposit is representative of this type.

(3) Native gold hosted in talcose shears adjacent to the faulted eastern margin of the Coquihalla serpentine belt. The only documented example of this type is the Aurum mine.

The source and age of the gold mineralization in the belt is unknown. The Hozameen fault probably played an important role as a conduit for ore-forming fluids; most of the occurrences are hosted by the Ladner Group and lie close to the Hozameen fault. However some gold mineralization is hosted by the Spider Peak Formation or is associated with a suite of small sodic felsic intrusions of uncertain age that cut the Ladner Group. Significant spatial relationships exist between gold mineralization, the Hozameen fault, ultramafic rocks of the Coquihalla serpentine belt and the basal Ladner Group unconformity. Over 99 per cent of the gold production from the belt took place to the east and within 200 metres of the Hozameen fault, the serpentinite and the unconformity.

Limited isotopic and fluid inclusion data suggest the ore-forming fluids in the Coquihalla gold belt were highly evolved meteoric waters that were greatly enriched in ^{18}O during deep circulation. Mineralization is believed to have occurred at temperatures of 350 to 380°C, at pressures of 750 to 1250 bars, and at depths of 1 to 3 kilometres (Nesbitt *et al.*, 1986).

There is potential for the discovery of more auriferous mineralization in the Coquihalla gold belt, particularly deposits of the Carolin type. Other mineral potential in the district includes volcanogenic massive sulphide mineralization in the Hozameen Group and base metal and gold-bearing systems associated with the intrusion of the Needle Peak pluton. The reported occurrence of placer platinum in Sowaqua Creek raises intriguing possibilities that the Coquihalla serpentine belt represents an exploration target for platinum-group elements.

INTRODUCTION

The Coquihalla mapping project was begun in June 1981 at a time when Carolin Mines Ltd. had announced production plans for the Idaho zone gold orebody, located approximately 20 kilometres northeast of Hope (Plate 1). At that time very little was known about the geological controls, type of gold mineralization or morphology of the orebodies. However, the announcement caused excitement in the exploration community and led to increased interest in the Hozameen fault system and the associated Coquihalla serpentine and Coquihalla gold belts.

The project extended over three field seasons (1981, 1982 and 1983) and resulted in the geological mapping of a 55-kilometre-long, 170-square-kilometre area, adjacent to the Hozameen fault system. Mapping covered parts of NTS map sheets 92H/6, 11 and 14 and extended from near the confluence of the Anderson and Fraser rivers, southwards to Sowaqua Creek (Figure 1) approximately 18 kilometres east of Hope. Mapping was completed at a scale of 1:20 000 (Figure 1). However, the central part of the area, between Spider Peak and the Coquihalla River, which contains the Emancipation, Aurum, Carolin and Pipestem mines and numerous minor gold occurrences, was mapped at 1:6000 scale (Figure 1); these more detailed maps were published separately from this report as Open File 1986-1 (Ray, 1986a).

In addition, more detailed mapping was completed around the Emancipation, Carolin and Pipestem mines, and the McMaster Zone gold occurrence. Numerous mineralized and unmineralized rock samples were collected from throughout the Coquihalla gold belt and analysed for major and trace elements. A detailed program of surface lithogeochemical sampling at Carolin mine revealed that the gold deposit is associated with various mineralogical alteration and geochemical enrichment and depletion envelopes. Geochemical studies were also completed on drill-core samples from the Carolin deposit.

Another study was undertaken to compare the geochemistry of the volcanic rocks on either side of the Hozameen fault system. This, together with the structural and stratigraphic studies, enabled a comprehensive geological history of the area to be postulated.

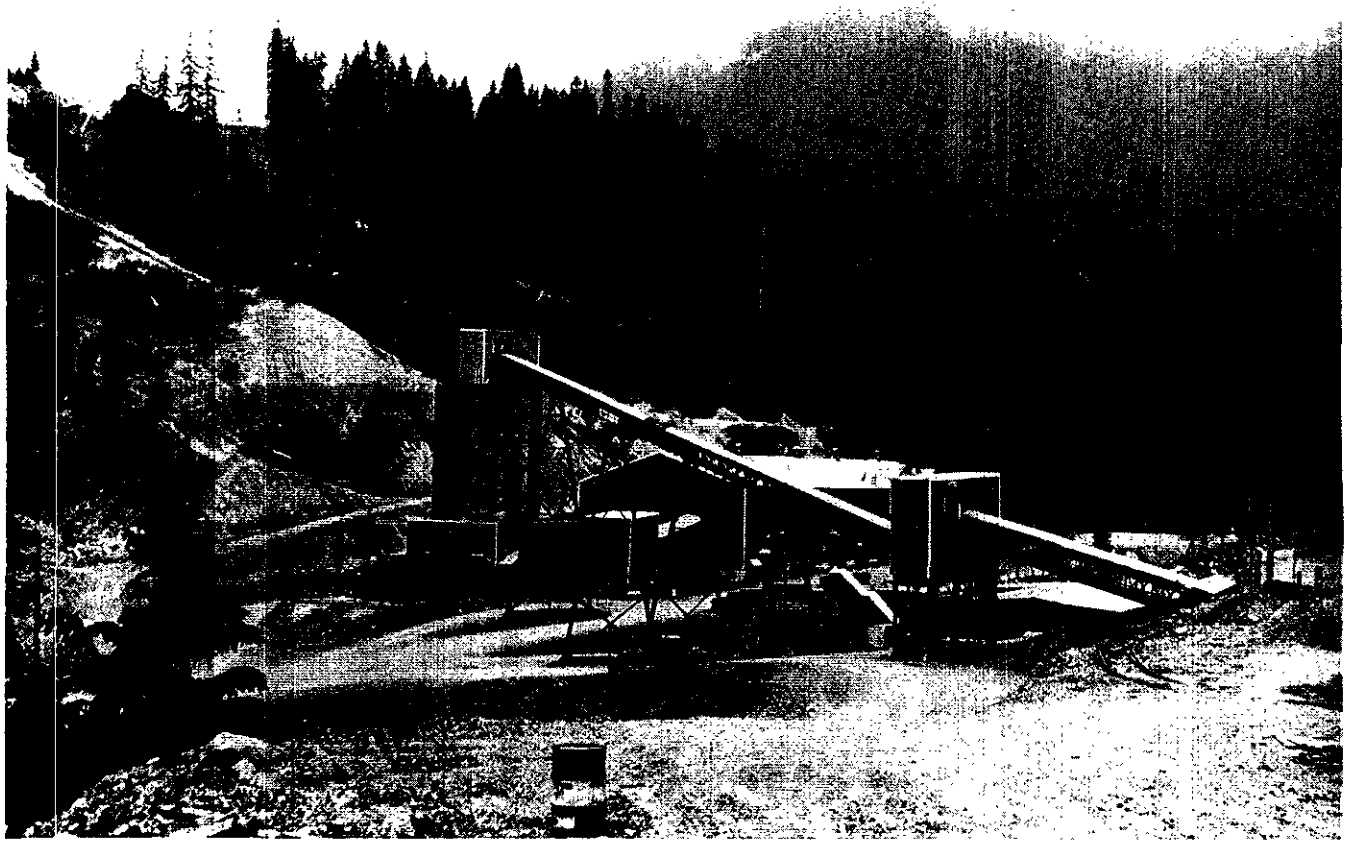


Plate 1. Carolin mine looking southwestwards up Ladner Creek. The tailings pond lies behind the bare ridge in the upper left. Photo taken in June 1986 after the mine had closed.

LOCATION AND ACCESS

The study area is situated approximately 130 kilometres east and northeast of Vancouver, in the Hope–Boston Bar area of southwestern British Columbia (Figure 1). It lies east of the Fraser River valley, and access is provided by numerous roads that branch eastwards off the TransCanada Highway (Highway No. 1). In the south, logging roads leading from the old Hope–Merritt road along the Coquihalla valley (now replaced by the multilane Coquihalla Highway) give access to Ladner, Dewdney and Sowaqua creeks, as well as the Carolin, Emancipation and Pipestem mine properties.

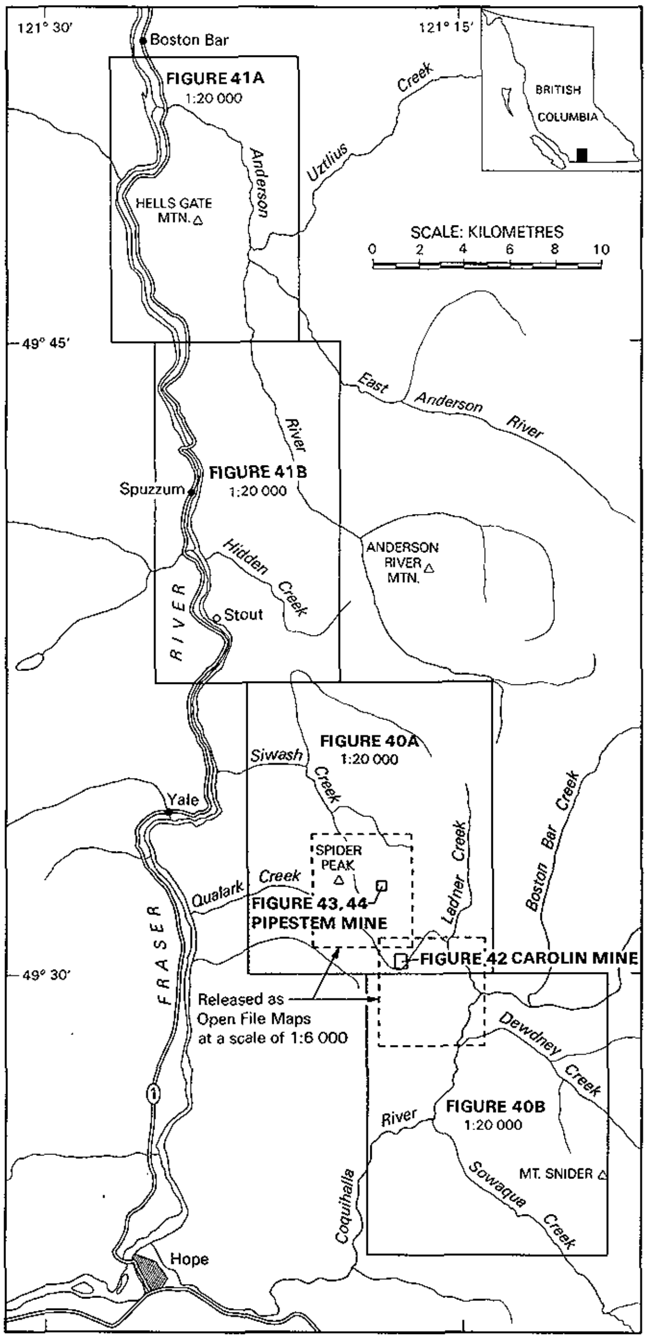


Figure 1. Location and scale of geological maps described in this bulletin.

Farther north, entry to the Gilt, Hidden and Upper Siwash Creek valleys is by a logging road which joins the Trans-Canada Highway a few hundred metres north of Alexandra Bridge, 1.5 kilometres north of Spuzzum. In 1984, and subsequent to the field mapping program, this logging road system was extended southwards toward Spider Peak. In the northern part of the map area, access to the Anderson River valley is by a gravel road system that joins the TransCanada Highway approximately 1 kilometre north of the Anderson River bridge, 1.5 kilometres south of Boston Bar.

HISTORY OF EXPLORATION

Attention was first drawn to the mineral potential of the region in the 1850s when placer gold was discovered along the Fraser River. This resulted in a rapid population increase in the townships of Hope and Yale. In 1868, the first Crown-granted claim in mainland British Columbia was awarded; this covered the Eureka and Van Bremer silver mines located on Silver Peak, approximately 9 kilometres south of Hope. By the turn of the century, several gold-bearing quartz veins had been discovered adjacent to the eastern edge of what was later called the Coquihalla serpentine belt (Cairnes, 1929); one property on Siwash Creek, the Ward, had minor gold production in 1905 and 1911 (Bateman, 1911). Exploration activity increased after the opening of the Kettle Valley railway along Coquihalla River valley in 1910. About this time, a series of adits were driven at the gold occurrence on the Emigrant property (*Minister of Mines, B.C.*, Annual Report, 1917) on the south fork of Siwash Creek.

The Emancipation property, located approximately 2.5 kilometres southeast of Carolin mine, was originally staked in 1913. Gold production occurred intermittently from 1916 to 1941, and prior to the opening of Carolin mine in the 1980s, Emancipation mine was the major producer in the Coquihalla gold belt. Mineralization is hosted in quartz-carbonate veins that cut volcanic greenstones close to their faulted contact with the Coquihalla serpentine belt (Cairnes, 1924; Ray *et al.*, 1983).

In 1926-27, the Aurum deposit was discovered in the Ladner Creek valley, approximately 450 metres south of the Carolin mine orebodies. Spectacular free gold was found in a talcose shear within the East Hozameen fault zone, along the eastern margin of the Coquihalla serpentine belt (Cairnes, 1929).

The Pipestem property (also known as the Home Gold mine), situated approximately 2 kilometres east-southeast of Spider Peak (Figure 2), was first staked in 1922, but was mainly explored and worked in the middle to late 1930s. Extensive underground workings were driven on four levels and a mill was built.[1] Mineralization is hosted in veins of quartz breccia that cut fractured Ladner Group fossiliferous wackes and tuffs of Late Jurassic age (Ray, 1986b).

Very little exploration was done in the Coquihalla gold belt for several decades after World War II. However, interest was revitalized in the 1970s, following a major increase in the price of gold; this activity included a re-examination of the

[1] Due to the initiative of J.W.T. Shearer, with assistance from the Hope Historical Society, the original Pipestem mill has been renovated and is on display at the Hope Mining Museum.

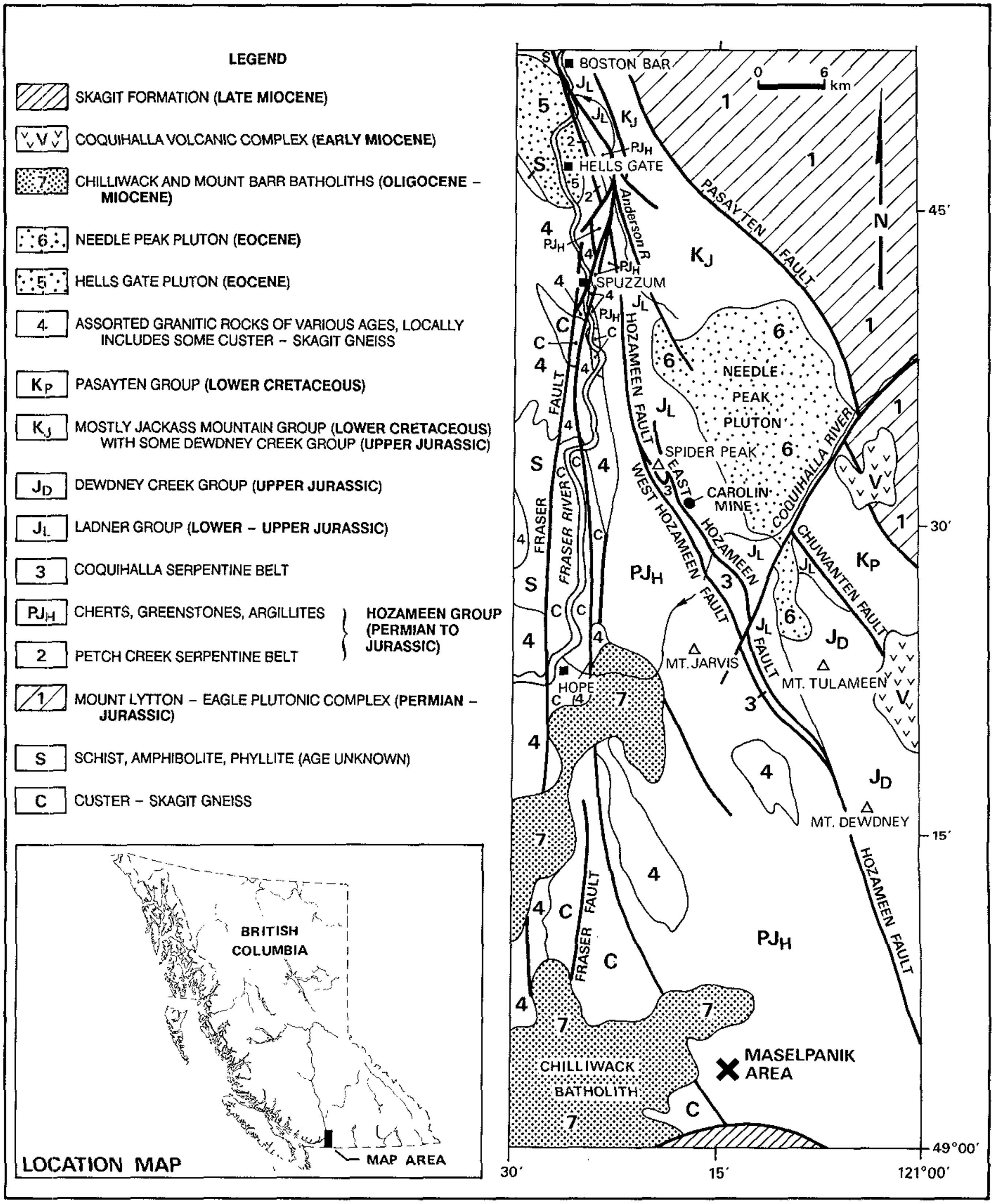


Figure 2. Regional geology of the Hope–Boston Bar area (adapted from Monger, 1970; Ray, 1986b).

abandoned Aurum, Pipestem and Emancipation mines. One major result of the exploration activity was the opening of the Carolin gold mine, which operated between 1982 and 1984.

The Carolin mine claims (originally called the "Idaho claims") were first staked in 1915 by T. De Angelis, J. O'Connell and A. McLean. The outcrops of the "Idaho zone", the gold deposit which later became the Carolin orebody, were originally described by Cairnes (1929). In 1945 and 1946, eight shallow diamond-drill holes tested the zone; they intersected mineralization, averaging 5.4 metres wide, grading 5.8 grams gold per tonne. In 1966, trenching by Summit Mining Ltd. extended the surface showings for a strike length of 75 metres. In 1973, the Ladner Creek property was purchased by Carolin Mines Ltd. which conducted a major exploration and drilling program and, by the end of 1974, the mining potential of the Idaho zone was realized. Underground diamond drilling and bulk sampling of the zone were carried out from an exploration decline in 1977 and 1978, and the mill, with a 1360 tonne-per-day design capacity, was completed in 1981 (Plate 1). Milling began in December 1981 and the first doré bar was poured in February 1982. Mining was by open-stope blast-hole methods taking vertical slices from longhole rings placed 1.5 metres apart. Further details on the initial mining methods and milling procedures are given by Samuels (1981). During its three years of operation, Carolin mine produced a total of 1354 kilograms of gold from 799 119 tonnes of ore; the annual mining and gold production statistics are given in Appendix 10. Throughout the mining operation there were several periods of shutdown caused by environmental concerns and poor gold recoveries. These difficulties resulted in the closure of the mine at the end of 1984.

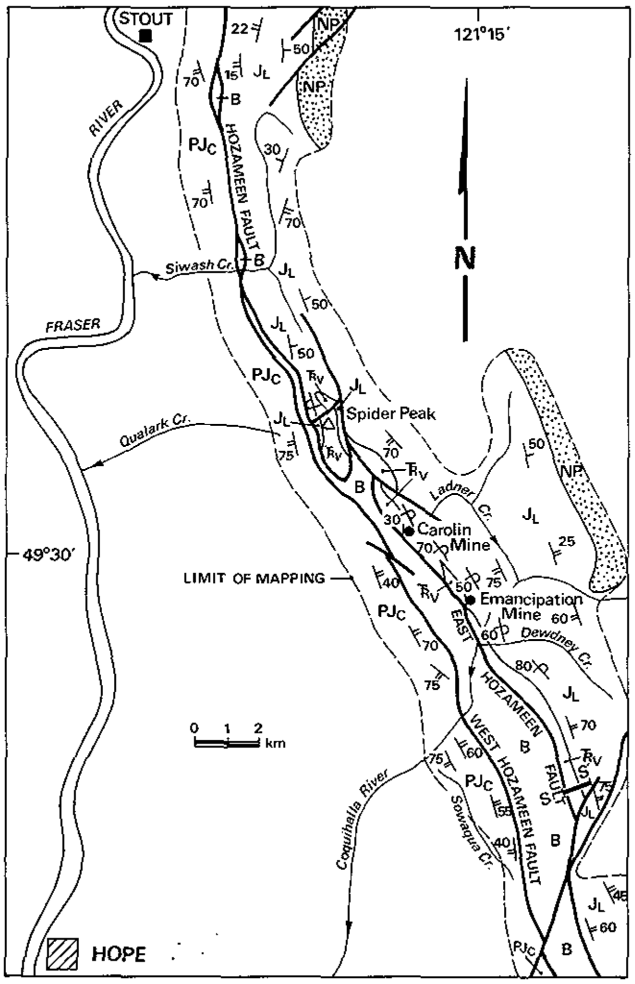


Figure 3. The geology adjacent to the Hozameen fault between Stout and the Coquihalla River.

PREVIOUS GEOLOGICAL WORK

The first important geological description of the area was given by Dawson (1879) who traversed the Coquihalla River valley in 1877. Later, Bateman (1911) described some gold properties in the Siwash Creek area (Figure 3), approximately 7 kilometres east-northeast of Yale, and Camsell (1919), working along the Coquihalla valley, examined some gold properties in the "Ladner slate belt" (now part of the Ladner Group). A major contribution to the geological knowledge of the area was made by Cairnes (1920, 1924, 1929, 1944) who mapped and described the Coquihalla serpentine belt and the Ladner and Dewdney Creek groups. Cairnes also described some gold properties in the area, including the Aurum, Emancipation and Pipestem mines.

Both Osborne (1966) and McTaggart and Thompson (1967) described Hozameen Group rocks in the Hope region adjacent to the Hozameen fault, while Haugerud (1985) dated these rocks in the Maselpanik area (Figure 2), south of Hope, as being Permian to Middle Jurassic in age on the basis of microfossil evidence.

Monger (1970) completed a geological compilation of the Hope (west half) map sheet and first named the Needle Peak pluton. The sedimentary rocks in the Methow-Pasayten trough in the Manning Park area southeast of Hope were mapped and described by Coates (1970, 1974), and regional tectonic and sedimentation studies on rocks of the Methow-Pasayten trough were subsequently presented by Kleinspehn (1985), Trexler and Bourgeois (1985), and O'Brien (1986a, 1986b, 1987). Other recent publications relevant to either the tectonism or plutonism of the region include those by Greig (1989), Whitney and McGroder (1989), Haugerud (1989), McGroder and Miller (1989), Miller *et al.* (1989) and Haugerud *et al.* (in preparation).

Following renewed interest in the Coquihalla gold belt in the 1970s, several studies of the Hozameen fault and the associated gold properties were undertaken; these included a three-year mapping project by the British Columbia Ministry of Energy, Mines and Petroleum Resources (Ray, 1982, 1983, 1984, 1986a, 1986b, 1986c). The geology and geochemistry of the Carolin gold deposit were described by Shearer and Niels (1983) and Ray *et al.* (1986). Other publications concerning either the Hozameen fault, or properties in the Coquihalla gold belt, include those by Cochrane *et al.* (1974), Anderson (1976), Cardinal (1981, 1982) and Wright *et al.* (1982).

GENERAL GEOLOGY

REGIONAL GEOLOGY

This bulletin describes the geology, geochemistry, mineralization and inferred geological history of an area adjacent to the Hozameen fault between Mount Tulameen, approximately 20 kilometres east of Hope, and Boston Bar (Figures 2, 3, and 4). In places this structure is associated with ultramafic rocks of the Coquihalla serpentine belt (Cairnes, 1929; Ray, 1984) and with sporadic, but widespread gold mineralization (Ray, 1983) including the Carolin orebody (Shearer and Niels, 1983).

The Hope–Boston Bar area lies within the Cascade Mountains physiographic unit (Holland, 1976), at the southern end of the Coast plutonic complex close to its boundary with the Intermontane Belt. The Hozameen and Pasayten faults (Figure 2) mark the western and eastern boundaries of the northwest-trending Pasayten trough (Coates, 1970) which is a northerly continuation of the Methow basin in Washington State and a probable southeasterly extension of the Tyaughton trough (Monger, 1977, 1985; Kleinspehn, 1985). Turbidite and successor basin sedimentary deposits predominate in the trough; these range in age from Early Jurassic to Middle Eocene (Coates, 1974; Greig, 1989) and have an estimated maximum thickness of between 9000 and 12 000 metres (Figure 5B).

Northeast of the Pasayten fault, the Mount Lytton–Eagle plutonic complex (Figure 2) contains deformed remnants of the Triassic Nicola Group (Monger and Preto, 1972; Preto, 1979) together with both younger and older granitic rocks. Potassium-argon and zircon dates from the complex range from 250 Ma (Monger, personal communication, 1984) to 100 Ma (Monger and Preto, 1972; Monger and McMillan, 1984, Greig, 1989).

Unconformably underlying the Pasayten trough, and forming the basement to it, is a volcanic greenstone sequence, the Spider Peak Formation of possible Early Triassic age (Ray, 1986a and b). This unit is best developed in the Spider Peak–Coquihalla River area where it forms a narrow discontinuous strip that generally separates the Ladner Group to the east from the Hozameen fault and Coquihalla serpentine belt to the west (Figure 3).

The stratigraphy in the Methow-Pasayten trough is shown in Figure 5B. Marine siltstones, argillites and wackes of the Lower to Upper Jurassic Ladner Group are the oldest sedimentary rocks in the trough. They rest unconformably on volcanic rocks of the Spider Peak Formation. The upper part of the Ladner Group probably passes laterally across a facies change into marine argillites, tuffs and wackes of the Upper Jurassic Dewdney Creek Group[2] (Cairnes, 1924; Coates, 1974); these rocks are overlain in turn by a 4000-metre-thick sequence of coarse clastic, shallow-water marine sediments of the Lower Cretaceous Jackass Mountain Group. The youngest rocks in the trough include Early Cretaceous, coarse clastic, nonmarine sediments of the 3000-metre-thick Pasayten Group (Coates, 1974), as well as some Middle Eocene sediments (Greig, 1989).

West of the Hozameen fault, the Hozameen Group (Daly, 1912) represents a highly deformed oceanic assemblage of chert, greenstone, argillite, serpentinite and rare limestone (Cairnes, 1924; McTaggart and Thompson, 1967; Monger, 1970, 1975; Ray, 1984, 1986a and b) of Permian to Middle Jurassic age (Haugerud, 1985). Farther west, it is in fault contact with para- and orthogneisses of the Custer-Skagit gneiss, and granitic rocks that range from 35 to 103 Ma in age (Baadsgaard *et al.*, 1961; Monger, 1970; Richards and White, 1970; Wanless *et al.*, 1973; Figure 2). Work by Tabor *et al.* (1989), Haugerud (1989) and Miller *et al.* (1989) suggests that the protolith of the Custer-Skagit gneiss is in part Triassic, and that the orthogneisses, which make up the bulk of the complex, are largely Late Cretaceous and Early Tertiary in age. Many of the potasium feldspar rich granitic intrusions, including several deformed bodies, are Middle Eocene in age. At or after 45 Ma (Middle Eocene) the Custer-Skagit gneiss underwent ductile northwest-southeast extension (Haugerud *et al.*, in preparation).

The nature of the tectonic contact between the Hozameen Group and the Custer-Skagit gneiss varies along strike from a single sharp fault to a wide, poorly defined fracture zone. In northern Washington the contact is represented by the Ross Lake fault (Misch, 1966), while southeast of Hope, McTaggart and Thompson (1967) noted a "transition zone" marked by a sharp westerly increase in metamorphic grade and migmatization. This zone, which contains at least one fault within sillimanite-grade rocks (Haugerud, 1985), is crosscut and intruded by the Chilliwack batholith dated at 16 to 35 Ma (Richards and White, 1970). Northeast of Hope, easterly dipping mylonites separate the gneisses from the structurally overlying Hozameen Group (Read, 1960), while farther north, east of Hells Gate (Figure 4), the two are in fault contact (Ray, 1984). There, the low-grade Hozameen Group rocks to the east are separated from cataclastic, garnetiferous, sillimanite-bearing gneisses and younger granitic rocks to the west by the east-dipping Petch Creek fault, in which mylonite is developed locally.

The Hozameen fault, which separates the Hozameen Group from the rocks of the Methow-Pasayten trough, is a major, steeply dipping, north-northwest-trending fracture system that exceeds 100 kilometres in length in southwestern British Columbia (Figure 2). To the south, it extends into Washington State where it appears to truncate the low-angle Jack Mountain thrust (Tabor *et al.*, 1989), and is apparently cut and intruded by the Eocene (50 Ma) Golden Horn batholith (McGroder, 1988, McGroder and Miller, 1989). To the north of the Coquihalla River area the Hozameen fault is cut off by the younger Fraser faults (McTaggart and Thompson, 1967; Monger and McMillan, 1984). The northwesterly continuation of the system beyond the Fraser faults is uncertain; McTaggart and Thompson considered its poss-

[2] O'Brien (1986b, 1987) recommends that the Upper Jurassic rocks of Coates' Dewdney Creek Group be renamed the Thunder Lake sequence and that the term Dewdney Creek Formation be retained for a Middle Jurassic succession of tuffs, sediments and newly recognized volcanics. The discovery, during this survey, of Upper Jurassic fossils within the Ladner Group succession at Pipestem mine suggests that the group is in part time-equivalent to the Upper Jurassic Thunder Bay sequence.

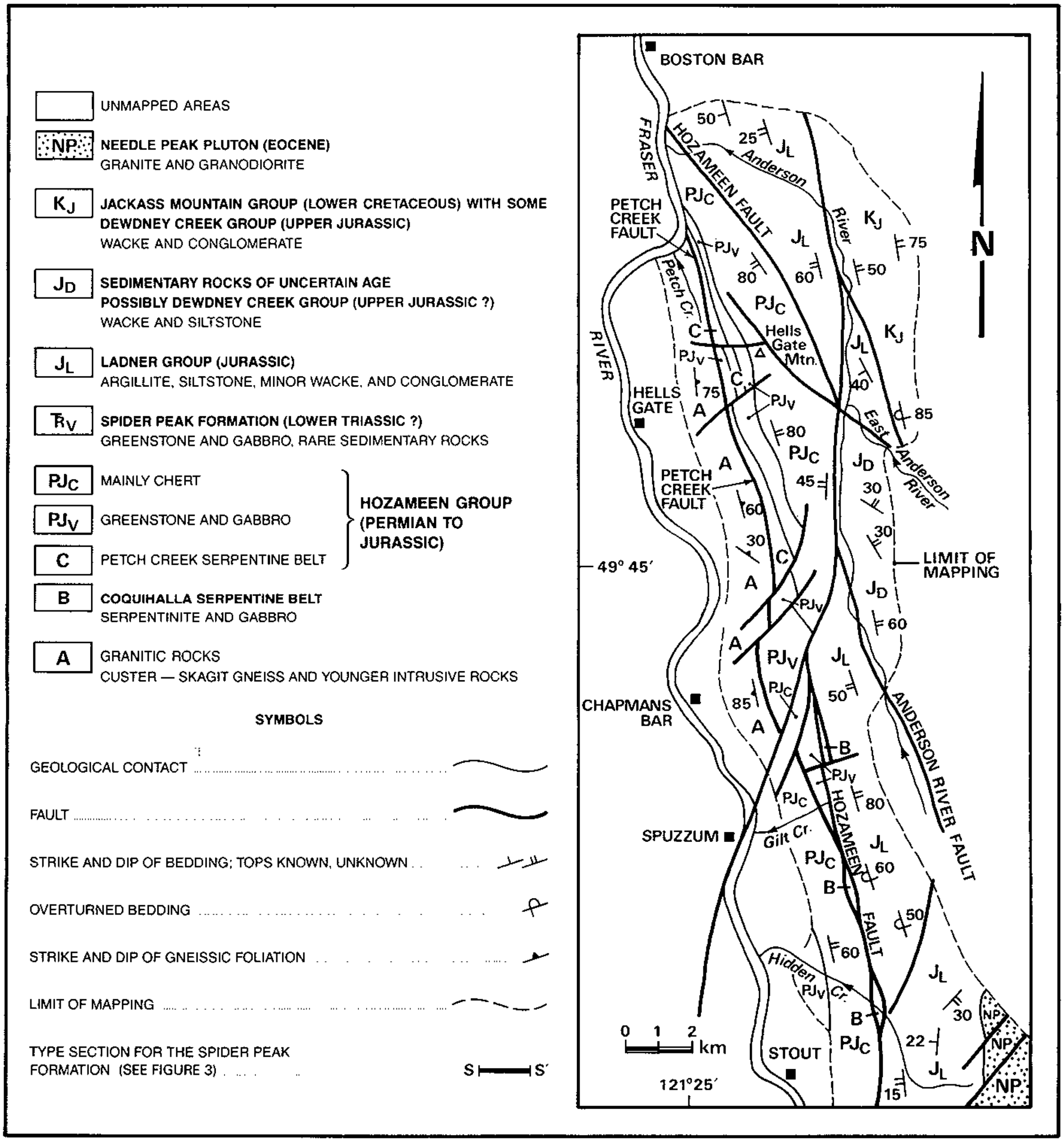


Figure 4. Simplified geology adjacent to the Hozameen and Petch Creek faults between Boston Bar and Stout.

ible extension to follow a prominent ultramafic zone exposed approximately 20 kilometres northwest of Boston Bar, while Monger (1985) believes the 300-kilometre-long Yalakom fault, northwest of Lillooet, represents the offset continuation of the Hozameen fault.

The dip of the Hozameen fault varies along strike. In northern Washington it is represented by an original low-angle structure that was subsequently refolded into a synformal feature (Misch, 1951, 1952, 1966). Near the United States border the fault dips steeply west (Rice, 1947) while farther north, in the Boston Bar–Coquihalla River area, dips are generally steep to the east. Both Misch, and McTaggart and Thompson, suggested that this regional change in attitude is due to later refolding of the fracture; this study supports their interpretation.

North of Mount Dewdney (Figure 2), the Hozameen fault encloses the Coquihalla serpentine belt (Cairnes, 1929), which forms an elongate, steeply dipping ultramafic unit that exceeds 50 kilometres in discontinuous strike length and locally reaches 2 kilometres in outcrop width (Figures 2 and 3). The margins of the belt are sharply defined by two major fractures (Figures 2 and 24), the East and West Hozameen faults, which underwent recurrent vertical and horizontal movements (Ray, 1983). At Carolin mine (Figures 2 and 24), the Coquihalla serpentine belt separates the Hozameen Group to the west from rocks of the Spider Peak Formation and Ladner Group to the east. Both to the north and south, however, the ultramafic belt gradually thins until the Hozameen and Ladner groups are either in direct fault contact, or are separated by narrow lenses of fault-bounded serpentinite less than 100 metres wide (Figures 3 and 4). With gradual thinning of the serpentine belt, the eastern and western bounding fractures merge into a single tectonic feature, the Hozameen fault (Figure 2).

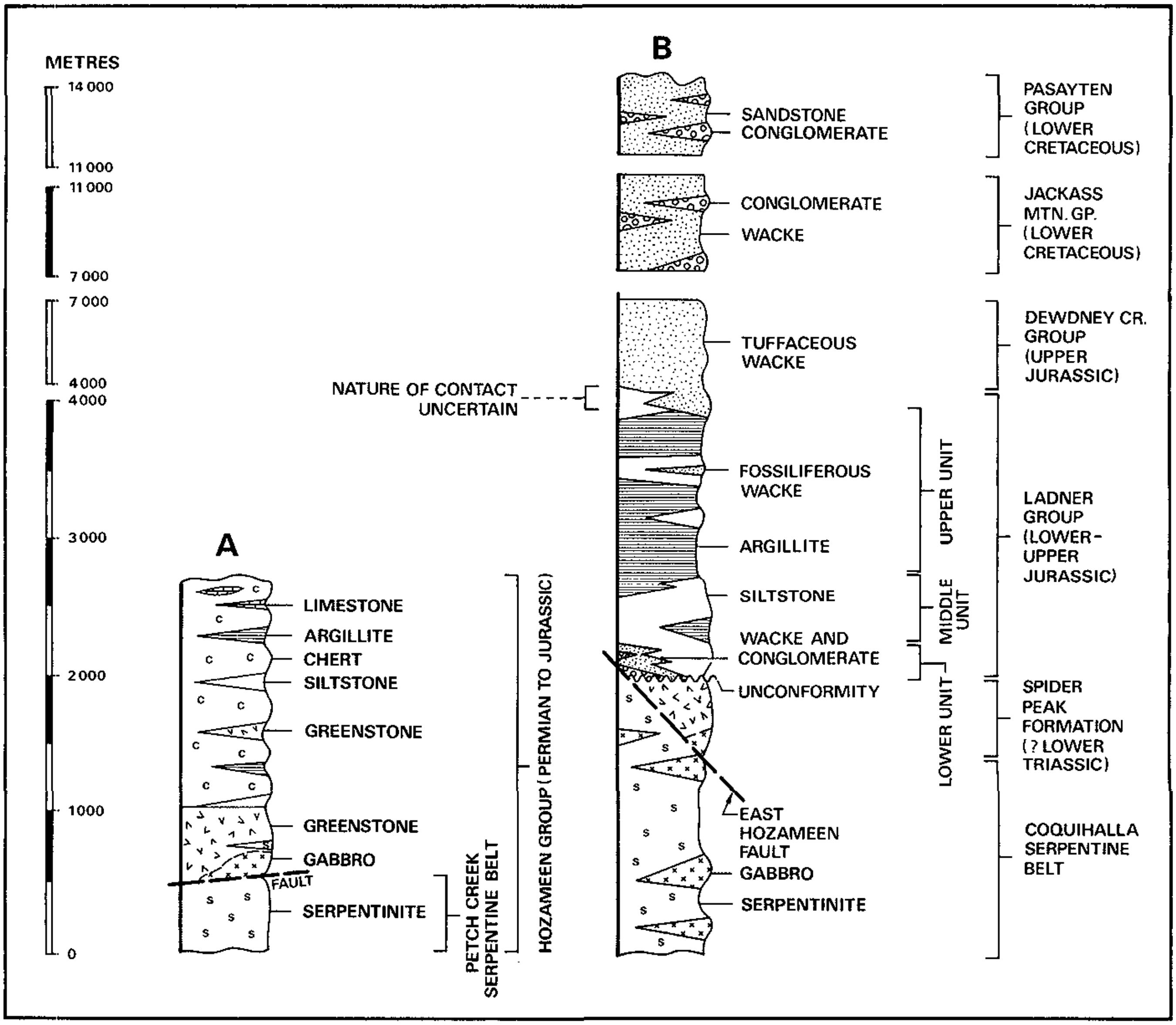


Figure 5. Schematic stratigraphic columns: (A) Hozameen Group succession east of Hells Gate; (B) Pasayten trough sedimentary rocks and underlying basement in the Coquihalla River area. (Data on the Pasayten, Jackass Mountain and Dewdney Creek groups after Cairnes, 1924, 1944; and Coates 1970, 1974).

TABLE 1.
COMPARISON BETWEEN THE PETCH CREEK AND COQUIHALLA SERPENTINE BELTS

Petch Creek serpentine belt	Coquihalla serpentine belt
Lies along the western tectonic margin of the Hozameen Group.	Lies along the eastern tectonic margin of the Hozameen Group.
Associated with the Petch Creek fault.	Associated with the Hozameen fault.
Has an 8 km strike length and a maximum outcrop width of 500 m.	Has a 50 km discontinuous strike length and a maximum outcrop width of 2 km.
Comprises serpentinite with no gabbros or "listwanite" rocks.	Comprises serpentinite with gabbroic sheets up to 250 m thick: includes some fuchsite-bearing "listwanite" rocks.
Contains some remnant olivine. Is not associated with gold mineralization.	Remnant olivine rarely seen. Is regionally associated with gold mineralization of the Coquihalla gold belt.
Represents a basal portion of the Hozameen Group succession.	Represents basement material upthrust from beneath the Spider Peak Formation.

The northern segment of the Hozameen fault, between Gilt Creek and the confluence of the Anderson and Fraser rivers (Figures 4 and 41), is not associated with serpentinite and the Hozameen and Ladner groups are in fault contact. However, a prominent serpentinite unit can be traced from Petch Creek southward to the area northeast of Chapmans Bar, a distance of 8 kilometres (Figure 4). This serpentine belt occupies the western tectonic margin of the Hozameen Group, and separates these rocks from the Custer-Skagit gneiss and younger intrusive granodiorites farther west. Thus, the Coquihalla serpentine belt, which was formerly regarded as a single, discontinuous but related unit (Cairnes, 1929; Osborne, 1966; Monger, 1970; Ray, 1983), is separable into dissimilar northern and southern segments. These two ultramafic units have contrasting structural and stratigraphic characteristics (Table 1) and exhibit petrographic differences. Consequently, the term 'Coquihalla serpentine belt' is hereafter restricted to the southern unit, and the northern unit is formally named the 'Petch Creek serpentine belt'. The apparent regional on-strike position of the two belts is coincidental, and is caused by a 6 to 8-kilometre right-lateral offset of the Hozameen fault along a set of younger, oblique faults that trend from Spuzzum north-northeastward to the Anderson River, where they merge with the Anderson River fault (Figures 2, 4 and 41).

The sedimentary rocks in the Methow-Pasayten trough are cut by a variety of small intrusive bodies ranging in composition from gabbro through granodiorite to syenite (Cairnes, 1924; Ray, 1982) as well as one major intrusion, the Needle Peak pluton (Monger, 1970). This granite-granodiorite intrusion exceeds 200 square kilometres in area (Figure 2); it was originally dated at 40 Ma by potassium-argon methods (Wanless *et al.*, 1967; Monger, 1970) but has recently been dated at 46 Ma by uranium-lead methods (Greig, 1989). It is spatially associated with swarms of felsic sills and dykes; these include several suites of varying texture and composition, including a porphyritic, sodium-rich phase originally mapped as 'syenite porphyry' by Cairnes (1924, 1929). These felsic sills and dykes are common within Ladner Group rocks, but are absent west of the Hozameen fault. Thus, they probably predate the last major transcurrent movement along this structure.

The rocks of the Coquihalla volcanic complex (Cairnes, 1924) are the youngest in the area (Figure 2). They comprise a calcalkaline acid to intermediate extrusive and intrusive suite with potassium-argon ages averaging 21 Ma (Berman and Armstrong, 1980). These rocks rest unconformably upon both the Mount Lytton plutonic complex[3] and sedimentary rocks of the Pasayten trough, and the eruptive centres appear spatially related to the Pasayten and Chuwanten faults (Figure 2).

ROCKS WEST OF THE HOZAMEEN FAULT SYSTEM

CUSTER-SKAGIT GNEISS AND YOUNGER INTRUSIVE ROCKS (UNIT G)

A narrow, 11-kilometre-long strip underlain by Custer-Skagit gneiss (Daly 1912; Misch 1952, 1966; McTaggart and Thompson, 1967, Tabor *et al.*, 1989; Haugerud *et al.*, in preparation) and younger intrusive rocks was mapped between Petch Creek and the area northeast of Spuzzum during this study (Figures 4 and 41); these rocks are separated from the Hozameen Group farther east by the Petch Creek fault. They include both massive (Unit Gd) and foliated or gneissic (Unit Gf) rocks all of which vary considerably in texture, colour and mineralogy. The moderately to intensely foliated paragneisses and orthogneisses are medium to coarse-grained, equigranular to porphyroblastic, leucocratic to melanocratic rocks. The garnet-sillimanite-bearing varieties (Unit Ggs) are grey, medium-grained, gneissic to schistose rocks that contain 50 to 60 per cent plagioclase and 15 to 20 per cent quartz; both the quartz and feldspar crystals are elongated along the foliation. Many of these rocks have undergone intense ductile and brittle deformation and the quartz crystals exhibit ribbon textures, undulatory extinction and sutured margins (Plate 2). Biotite comprises between 5 and 10 per cent by volume and forms unaltered, red-brown flakes up to 0.2 millimetre in length. It has generally ragged irregular margins and is orientated subparallel to the foliation.

The pale red garnets form rounded to subhedral crystals up to 0.5 millimetre in diameter and are commonly associated with pressure shadows filled with biotite and plagioclase. Some garnets show evidence of partial rotation and they

[3] The southern portion of the Mount Lytton complex is now renamed the Eagle plutonic complex (Monger 1989; Greig 1989).

usually contain abundant small inclusions of quartz with lesser amounts of plagioclase, biotite and apatite (Plate 3). The euhedral nature of the small quartz crystals within the garnets contrasts with the anhedral, irregular form of the larger quartz crystals in the rock groundmass (Plate 3). The larger garnets are cut by numerous parallel fractures orientated normal to the foliation.

Sillimanite (fibrolite) generally forms less than 2 per cent of these rocks and occurs as bundles and sheafs oriented subparallel to the foliation and intergrown with the biotite, quartz and feldspar. Accessory minerals include apatite, chlorite, sericite, pyrite, ilmenite and zircon.

The orthogneisses range in composition from quartz monzonite through granodiorite to quartz diorite. The foliated granodiorites generally contain 5 to 20 per cent hornblende and/or 5 to 10 per cent biotite, although in the more mafic varieties these minerals total more than 40 per cent by volume. The other principal minerals are plagioclase, potassium feldspar and quartz, with traces of chlorite, epidote, apatite, sphene, zircon and opaque minerals. The original porphyritic rocks are now represented by augen or flaser gneisses containing large, flattened plagioclase and potassium feldspar augen up to 1.5 centimetres in length. Many of these augen comprise an older, partially altered core containing deformed twin planes and perthitic textures, rimmed by numerous small crystals of fresh secondary feldspar and quartz (Plate 2). Some augen exhibit evidence of partial rotation.

The granodiorite gneisses outcropping approximately 2.5 kilometres southeast of Hells Gate contain a thin (less than 20 metres) unit of grey, highly deformed marble (Unit Gm) which is at least 300 metres in strike length. Contacts between the marble and the foliated granodiorite are sharp and sheared. In its southern part the marble unit contains numerous pink, angular, deformed, matrix-supported clasts of white to pale pink leucogranite and aplite up to 20 centimetres in diameter (Plate 4).

The younger plutonic rocks that intrude the gneisses are generally grey to pale pink, massive to weakly foliated leucocratic rocks ranging from granodiorite to quartz monzonite in composition (Unit Gd). They include both equigranular and porphyritic varieties, and locally are cut by randomly oriented aplite veins and dykes.

Both the gneisses and younger plutonic rocks adjacent to the Petch Creek fault were subjected to early ductile and later brittle movements. Ductile deformation resulted in the formation of thin mylonite zones as well as small-scale, rootless isoclinal folds and elongate, ribbon-textured quartz crystals. In some areas immediately adjacent to the fault, ductile movements have transformed the original feldspar-porphyritic rocks into augen and flaser gneisses (Plate 2). The mylonites are well-layered rocks forming bands generally less than 2 metres thick; they consist largely of an exceedingly fine grained, granulated, silicified groundmass containing occasional larger crystals or trails of relict altered plagioclase, hornblende or epidote.

Several subsequent episodes of brittle deformation along the Petch Creek fault resulted in pervasive cataclasis and the development of mortar textures, faulting and slickensiding. In thin section, brittle deformation is evidenced by the formation of granulated margins around the larger quartz and feldspar crystals, by the shredding and buckling of biotite, and by the development of incipient microshears around the larger hornblende and feldspar crystals. Sporadic postcataclastic silicification and the crystallization of fresh quartz are seen in the groundmass of some previously sheared gneisses.

Hozameen Group (Unit PJH) [Including the Petch Creek Serpentine Belt]

The Hozameen Group in British Columbia is a highly deformed suite of oceanic rocks with metamorphic grades varying from prehnite-pumpellyite to amphibolite facies (Haugerud, 1985; Haugerud personal communication, 1989). It forms an elongate crustal unit more than 20 kilometres wide near the International Boundary, but northwards, toward Boston Bar, it steadily narrows (Figure 2). To the east the Hozameen Group is bounded by the Hozameen fault system, while to the west it is faulted against the Custer-Skagit gneiss and various intrusive and schistose rocks (Figure 2); this western boundary, the Petch Creek fault, is probably a northern continuation of the Ross Lake fault in Washington State.

The Hozameen Group in the Maselpanik area of British Columbia (Figure 2) and Jack Mountain area of Washington State contains cherts ranging from Permian to Middle Jurassic in age, as well as basaltic sequences probably erupted during Permian and Late Triassic time (Haugerud, 1985). Farther north, however, between Boston Bar and Mount Tulameen (Figure 2), the ages of Hozameen Group sedimentation and volcanism are unknown; attempts to extract microfossils from Hozameen rocks in this area have been unsuccessful. Hozameen rocks immediately adjacent to the Hozameen fault include highly deformed cherts interlayered with lesser amounts of greenstone and phyllitic argillite. East of Hells Gate, between Spuzzum and Boston Bar (Figure 4), the sequence attains a thickness of approximately 2500 metres (Figure 5A). There are three major divisions: a structurally lower ultramafic unit comprising the Petch Creek serpentine belt (Unit PJHu), a middle mafic unit composed mainly of volcanic greenstone (Unit PJHg), and an upper sedimentary unit in which cherts predominate (Unit PJHc). Despite lack of fossil control, these divisions are tentatively considered to be a tectonically attenuated stratigraphic succession; they probably represent oceanic layers 1, 2 and 3 respectively (Cann, 1974), and the Hozameen Group is believed to be a dismembered ophiolite suite.

The Petch Creek serpentinites (Unit PJHu) are probably the oldest Hozameen rocks exposed in this area; they form a continuous unit, 8 kilometres long, with a maximum true thickness of 450 metres (Figure 5A). The serpentinite is exposed in small outcrops along the Trans-Canada Highway just north of Petch Creek, and can be traced southward to an area 5 kilometres northeast of Chapmans Bar (Figures 4 and 41). The belt reaches its maximum thickness at its southern end, where it is truncated by younger north-northeast-trending faults. Continuation southward beyond these faults is unproven, but a narrow serpentinite layer, reportedly exposed along a Canadian National Railway cutting less than 1.6 kilometres north of Stout (Cairnes, 1929), may represent

Plate 2. Ductile deformation in the Custer-Skagit gneiss. Photomicrograph (X nicols) of augen gneiss with rotated, deformed K-feldspar megacrysts within a matrix of ribbon-textured quartz crystals. Sample taken from a biotite-sillimanite-bearing gneiss (Unit Ggs) adjacent to the Petch Creek fault, 2 kilometres east of Hells Gate tunnel.

Plate 3. Custer-Skagit gneiss (Unit Ggs). Photomicrograph (PPL) of biotite-garnet-sillimanite gneiss with partially rotated garnet porphyroblast containing abundant inclusions of quartz, plagioclase, biotite and apatite. Sample taken 2 kilometres east of Hells Gate tunnel.

Plate 4. Custer-Skagit gneiss (Unit Gm). Thinly layered, deformed marble containing angular clasts of leucogranite and aplite. 2.5 kilometres east-southeast of Hells Gate.

an attenuated extension of the belt. The belt generally lies along the westernmost boundary of the Hozameen Group (Figures 4 and 41); it is fault bounded and dips between 40 and 70° eastward. Along its western margin the serpentinite is marked by intense ductile and brittle shearing; the presence of gently plunging mylonitic lineations suggests some major transcurrent movement. This ultramafic belt differs from the Coquihalla serpentine belt farther south (Table 1) in that it contains no gabbroic intrusions, has no regional association with gold mineralization or listwanites, and contains olivine-rich material in which primary igneous textures are recognizable (Osborne, 1966). However, both the Petch Creek and Coquihalla serpentinites are believed to have been largely derived from ultramafic cumulates, and there is no evidence that they represent mantle tectonites.

In outcrop, the Petch Creek serpentinites are massive to highly schistose, dark-coloured rocks that locally contain remnant olivine and pyroxene crystals, and are cut by narrow chrysotile veinlets. Major rock-forming minerals are serpentine, olivine, enstatite and bastite with variable but lesser amounts of talc, chlorite and opaque minerals. The olivine content varies from trace amounts up to more than 50 per cent by volume and Osborne (1966) reports that it has a composition of 90 ± 2 mol per cent forsterite. It generally occurs as fractured, anhedral crystals, up to 1 centimetre long, that show varying degrees of replacement by serpentine, magnetite and other opaque alteration minerals. Locally the serpentinites contain up to 30 per cent enstatite as anhedral to subhedral crystals up to 1.5 centimetres in length that are partially altered to bastite. Bastite pseudomorphs after enstatite are common, and locally the rocks are enriched in talc. Other minor constituents include chromite, magnetite, magnesite, chrome spinel, chalcopyrite, millerite, actinolite-tremolite and augite. The chrome spinels are partially altered and surrounded by opaque rims, while the augite occupies exsolution lamellae within the enstatite. Chromite generally forms anhedral to subhedral grains up to 2 millimetres in diameter and Osborne (1966) notes that the proportion of magnetite to chromite increases as serpentinization intensifies. Unlike the Coquihalla serpentine belt, no fuchsite-mariposite-bearing listwanites or gabbroic rocks were observed within the Petch Creek serpentine belt (Table 1).

To the east, the Petch Creek serpentine belt is in fault contact with, and structurally overlain by, a thick sequence of greenstone which forms the middle unit of the Hozameen Group (Figure 5A). This unit has an average thickness of 500 metres (Figure 5A), but east of Chapmans Bar (Figure 4) it is more than 1100 metres thick. It consists largely of altered, black to light green basaltic greenstones (Unit PJHg) with some gabbro (Unit PJHG) toward the base; contacts between the greenstones and the gabbroic rocks are generally gradational. The greenstones are typically massive, but rare pillowed structures are present near the top of the unit. Locally, southwest of Hells Gate, the greenstones contain thin tectonic slices of serpentinite generally less than 25 metres thick.

The mineralogy of the greenstones is variable, depending on the degree of alteration. The freshest contain between 25 to 50 per cent augite which generally forms anhedral, partially altered crystals up to 1.0 millimetre in diameter. Ophitic textures are common and the plagioclase laths reach 0.3 millimetre in length and are highly altered to clinozoisite, zoisite and chlorite. The plagioclase composition in these rocks is difficult to determine due to the ubiquitous alteration, although oligoclase-andesine (An_{25-45}) and some minor secondary albite were recorded. Tremolite-actinolite, which is widespread and forms up to 40 per cent of the rock by volume, often rims and replaces the augite crystals. Accessory minerals include quartz, skeletal ilmenite, epidote, carbonate, sphene, apatite, pyrite and magnetite. Osborne (1966) reports the presence of stilpnomelane in the greenstones in the Gilt Creek area. Many of these rocks are cut by irregular veins of black, highly sheared chlorite and veinlets of weakly altered, finely twinned albite.

In addition to the major greenstone sequence which overlies the Petch Creek serpentine belt, greenstone flows up to 200 metres thick are present higher in the Hozameen Group succession (Figure 5A); these are most common northeast and southeast of Hells Gate Mountain where they are interlayered with cherts and argillites. Despite alteration and shearing, they exhibit remnant pillow structures and some amygdules. One volcanic flow outcropping 4 kilometres south-southeast of Hells Gate Mountain is unique in being dark maroon to brick-red in colour and possessing possible accretionary lapilli features, suggesting a subaerial origin. This rock is characterized by altered plagioclase laths (An_{34}) up to 0.1 millimetre long, some of which are deformed and bent. The ferromagnesian minerals in the groundmass are completely replaced by chlorite and opaque minerals, and the rocks are cut by abundant calcite veins.

Whole-rock and trace element analyses on 16 greenstone samples (Unit PJHg) collected from the Hozameen Group (Appendix 1) indicate they represent a geochemically heterogeneous, subalkaline basaltic suite (Figures 6A, 7B and 9B) with a wide variation in titanium content. Various plots were made to establish the environment of the Hozameen volcanism (Figures 10B, 11A, 11B, 12B, 13B, 14B and 15B) which is believed to include two geochemically distinct volcanic suites represented by within-plate and plate-boundary basalts (Figure 10B); the latter possess some arc affinities (Figures 11A, 11B, 12B, 13B and 14B). The within-plate suite is interpreted to be basalt developed in an oceanic island–seamount environment, while discriminatory plots for the nine samples outlined as plate-boundary rocks on Figure 10B suggest that they represent island arc tholeiites (Figures 11A and 11B).

It is noteworthy that the arc tholeiites and ocean island–seamount basaltic samples in the Hozameen Group were collected from two different areas. Arc tholeiite samples predominate in the area northeast of Spuzzum and along Gilt Creek, while the seamount-type basalt samples are most common along Hidden Creek (Appendix 1; Figure 4). Although the stratigraphic position of some Hozameen greenstones sampled in this study is uncertain, the tholeiitic arc samples (GR 316, 330, 331, 332 and 342; Appendix 1) were collected from the thick greenstone unit that immediately overlies the Petch Creek serpentine belt (Figure 5A), while the within-plate basalt samples (GR 338, 339, 340, and 341; Figure 10B) were taken from flows within the cherts higher in the sequence. This geochemical bimodalism in the Hozameen Group, which has also been noted by Haugerud (1985), may reflect sampling of two different stratigraphic units represented by arc tholeiites in the lower part of the sequence and ocean island or seamount basalts higher in the succession. The wide-ranging titanium values in the Hozameen volcanic rocks resemble those determined from greenstones in the Bridge River complex, approximately 125 kilometres northwest of Boston Bar (Potter, 1983). Monger (1977, 1985) and Haugerud (1985) correlate the Hozameen

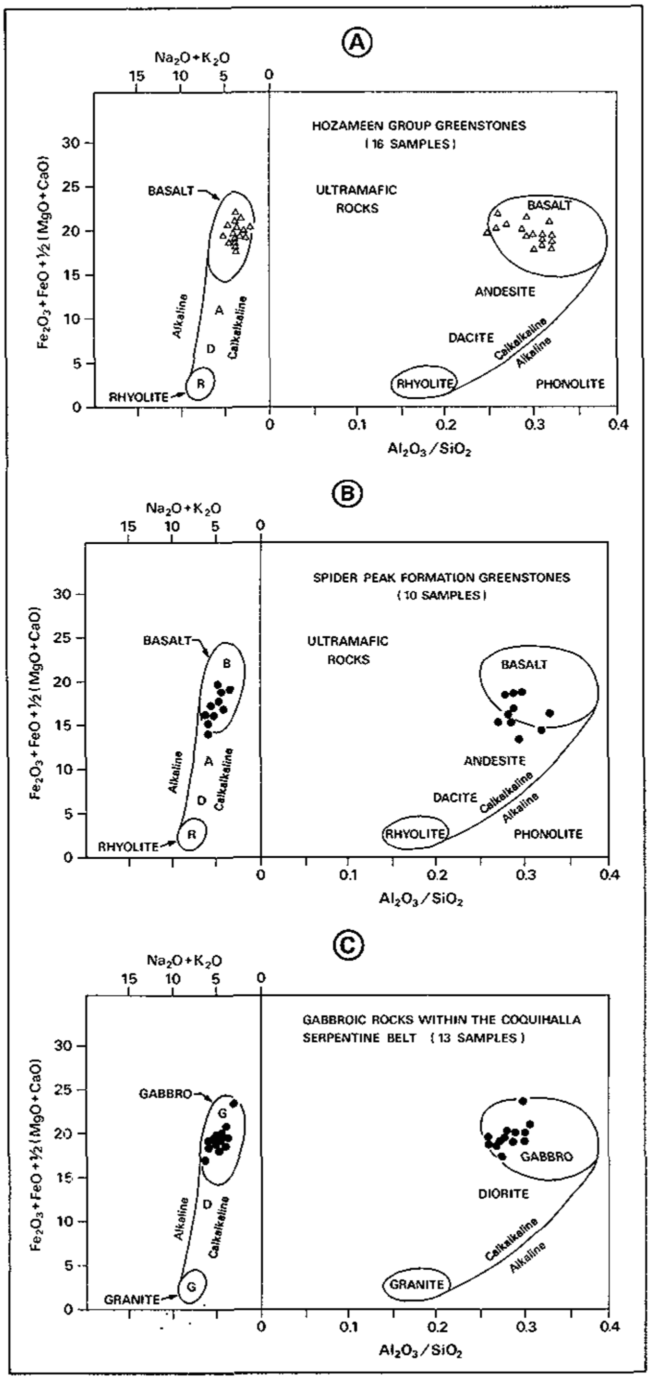


Figure 6. Triaxial oxide plots (after Church, 1975): (A) Hozameen Group greenstones; (B) Spider Peak Formation greenstones; (C) gabbroic rocks within the Coquihalla serpentine belt.

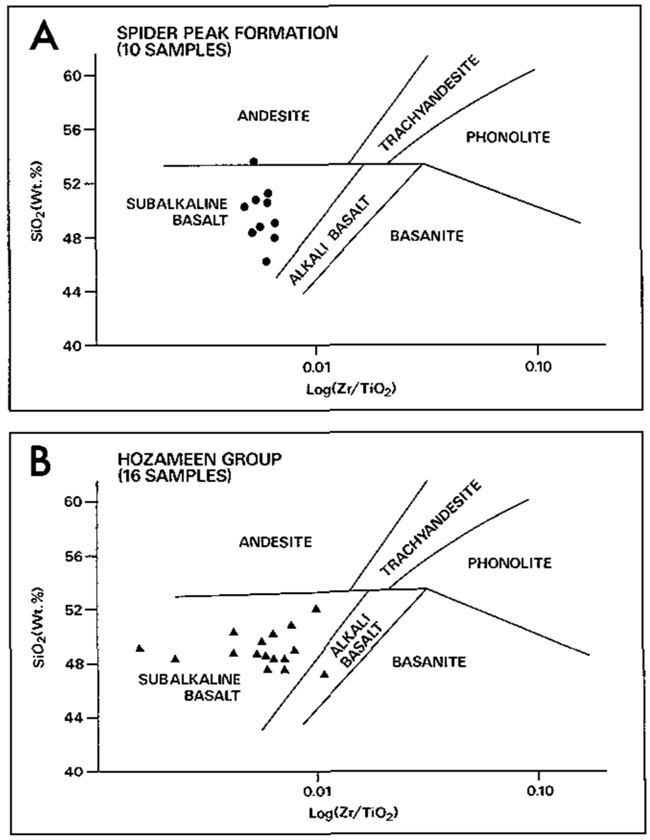


Figure 7. Plots of SiO_2 versus log Zr/TiO_2 (after Floyd and Winchester, 1978) illustrating the subalkaline basalt composition of the Spider Peak Formation (A) and Hozameen Group (B) volcanic rocks.

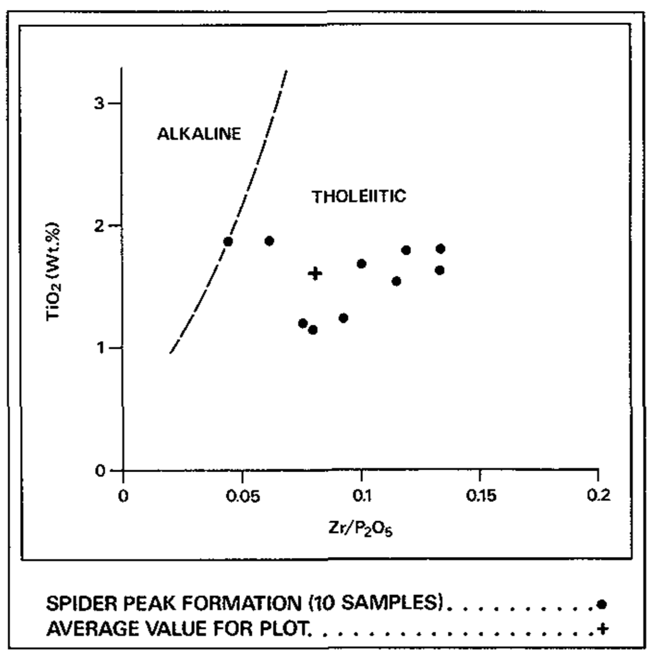


Figure 8. Plots of TiO_2 versus Zr/P_2O_5 (after Floyd and Winchester, 1975), illustrating the tholeiitic character of the Spider Peak Formation greenstones.

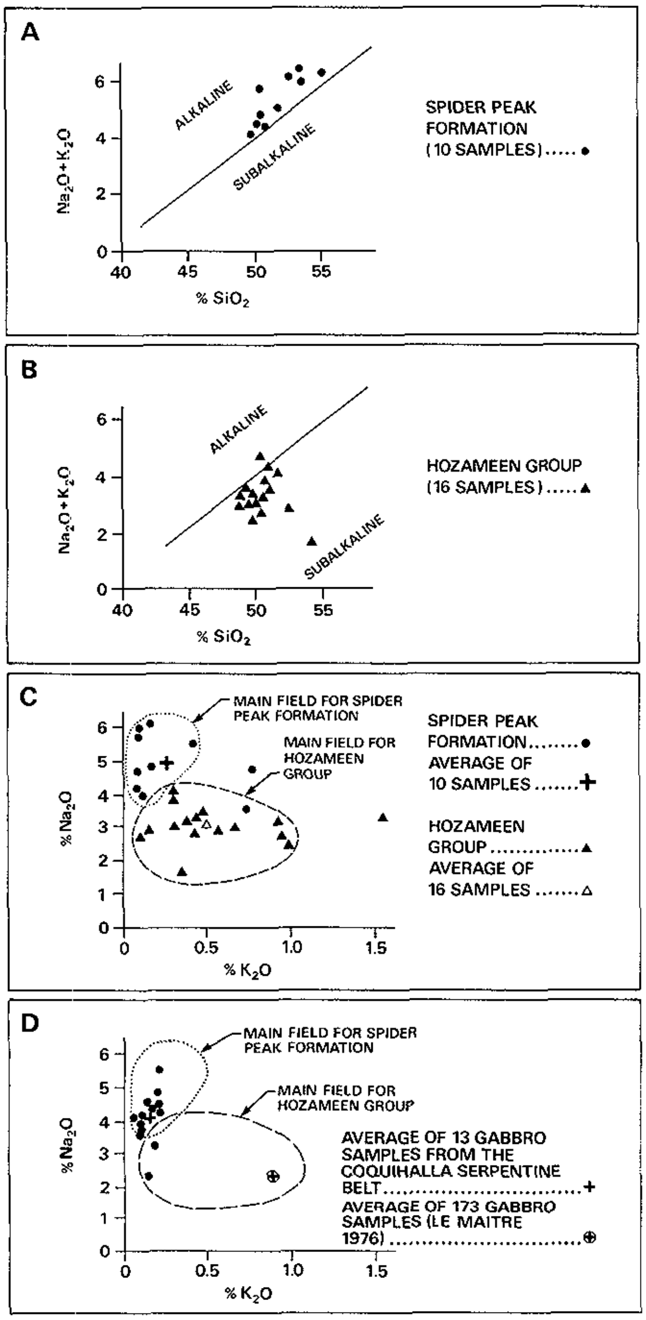


Figure 9. (A, B) Alkali-silica plots (after MacDonald, 1968; Irvine and Baragar, 1971) illustrating the differences between greenstones in the Spider Peak Formation (A) and Hozameen Group (B). The volcanic rocks in the Spider Peak Formation fall in the alkali field as a result of spilitization. (C) Sodium-potassium plots illustrating the different Na_2O/K_2O fields determined for greenstones in the Spider Peak Formation (dots) and Hozameen Group (triangles). (D) Sodium-potassium plots of gabbroic rocks (dots) from the Coquihalla serpentine belt illustrating their similarity to the Spider Peak Formation greenstone field and dissimilarity to the Hozameen Group greenstone field. Note their enrichment in Na_2O and depletion in K_2O compared with "average" gabbroic rocks as determined by Le Maitre (1976).

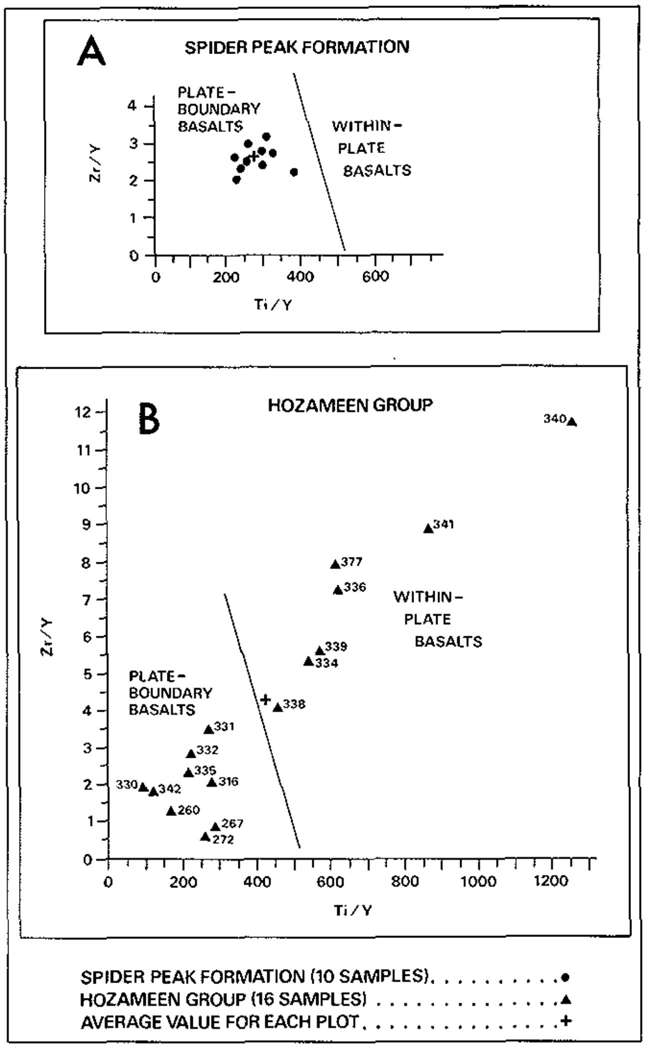


Figure 10. Plots of Zr/Y versus Ti/Y (after Pearce, 1975). The Spider Peak Formation (A) comprises "plate-boundary basalts", whereas the Hozameen Group volcanic rocks (B) include both "within-plate" and "plate-boundary basalts". Numbers refer to Hozameen Group sample numbers listed in Appendix 1.

Group and Bridge River complex on lithological grounds; the similar titanium geochemistry of the volcanic rocks in both areas lends support to this correlation.

The gabbros (Unit PJHG) associated with the greenstones (Unit PJHg) are massive, medium to coarse-grained rocks with a maximum grain size of 2.5 millimetres; most are intensely altered although ophitic textures are recognizable. They mainly comprise strongly altered plagioclase, hornblende, tremolite-actinolite and chlorite with variable amounts of clinozoisite, epidote, augite and carbonate. Accessory minerals include sphene, apatite, magnetite and pyrite and some outcrops are cut by veins of chlorite.

The upper part of the Hozameen Group succession (Figure 5A) is 1600 metres thick and is dominated by deformed cherts (Unit PJHc) (Plate 5) interlayered with thinner bands of argillite (Unit PJHa), greenstone (Unit PJHg), strongly altered volcaniclastic rocks (Unit PJHs) and limestone or

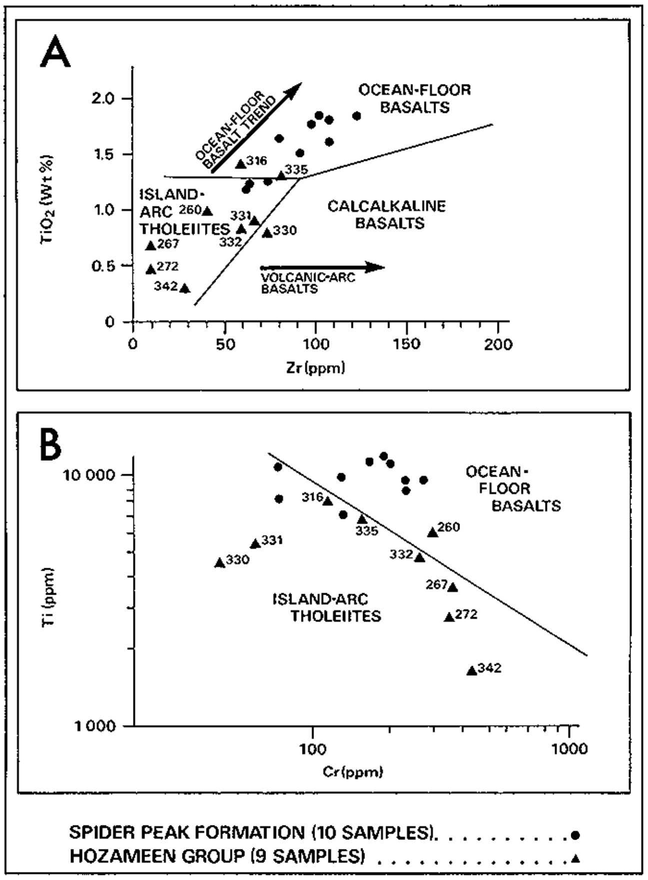


Figure 11. (A) Plots of TiO_2 versus Zr (after Pearce and Cann, 1973; Garcia, 1978); (B) Plots of Ti versus Cr (after Pearce, 1975) illustrating the ocean-floor basalt character of the Spider Peak Formation greenstone (dots) and the arc tholeiitic character of the Hozameen Group (trianges). Numbers refer to the Hozameen Group "plate-boundary basalts" sample number shown in Figure 10B.

marble (Unit PJHl). Cherts are dark to very light grey to cream in colour and vary from massive to well-layered ribbon cherts; the latter comprise beds between 1 and 10 centimetres thick separated by thin interlayers of schistose argillite generally less than 0.5 centimetre thick (Plate 5). In thin section the cherts are seen to consist mostly of an exceedingly fine grained mosaic of quartz crystals and chalcedony, with minor amounts of sericite and chlorite. Sporadic traces of feldspar, magnetite, biotite and carbonate, pyrite and pyrrhotite, and fine-grained carbonaceous materials are also present. Crosscutting quartz veins are common.

Argillites are common in the upper part of the succession, and are often interbedded with the cherts as layers generally less than 25 metres thick. The argillites are strongly deformed and bedding is rarely seen. However, some horizons contain deformed, dark, argillitic clasts up to 5 centimetres in diameter which are presumed to represent sedimentary clasts. Argillites in the Hozameen Group are medium-grained, well-cleaved rocks that vary from slaty to phyllitic in appearance. They comprise mainly fine-grained quartz, chlorite and altered plagioclase, with lesser, variable amounts of sericite, biotite, calcite, prehnite, pumpellyite, tremolite-actinolite and hornblende. Traces of epidote, sphene, albite and pyrite or pyrrhotite are seen and some horizons contain graphite.

Marbles and limestones are extremely rare in the Hozameen Group in the Hope–Boston Bar area; they are mostly confined to an area approximately 5 kilometres southeast of Hells Gate, apparently within the upper part of the Hozameen succession (Figure 5A). They generally form layers less than 20 metres thick that are interbedded with the cherts and argillites. In outcrop they are grey, massive to finely layered, intensely sheared and cleaved rocks. The well-foliated outcrops commonly exhibit a mineral lineation and locally these rocks are intensely fractured and cut by calcite veins. The veins comprise over 90 per cent carbonate which forms mostly small, fresh crystals up to 0.2 millimetre in diameter, with some coarser crystals up to 1 millimetre in length. Accessory minerals include quartz, chlorite, sericite, plagioclase and sporadic traces of graphite. The intense defor-

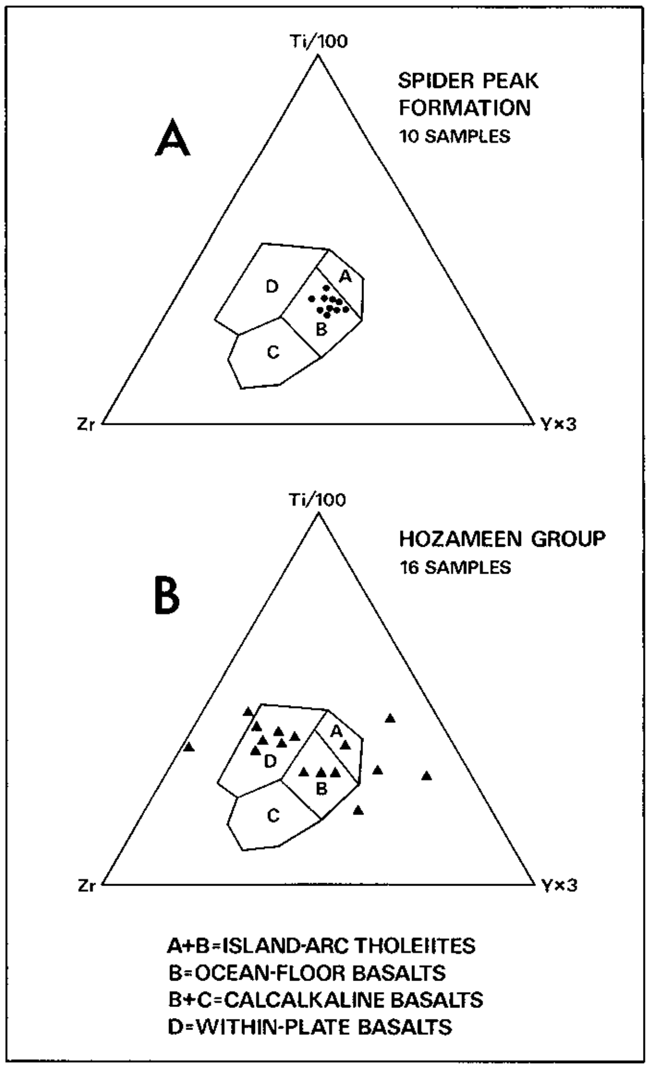


Figure 12. Zr-Ti-Y ternary plots (after Pearce, 1975); (A) Spider Peak Formation greenstones; (B) Hozameen Group volcanic rocks.

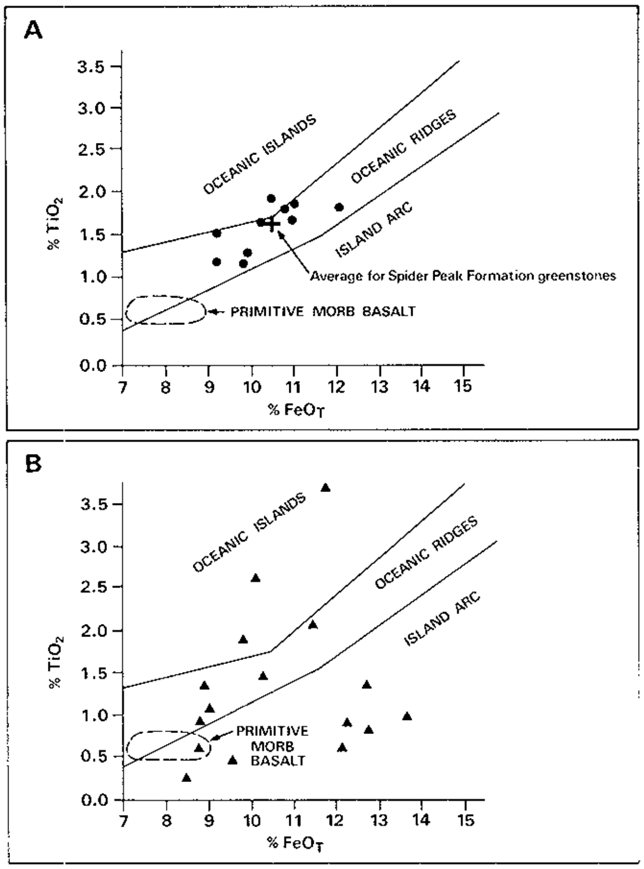


Figure 13. Plots of TiO_2 versus total iron (after de Rosen-Spence, 1976): (A) Spider Peak Formation greenstones; (B) Hozameen Group volcanic rocks.

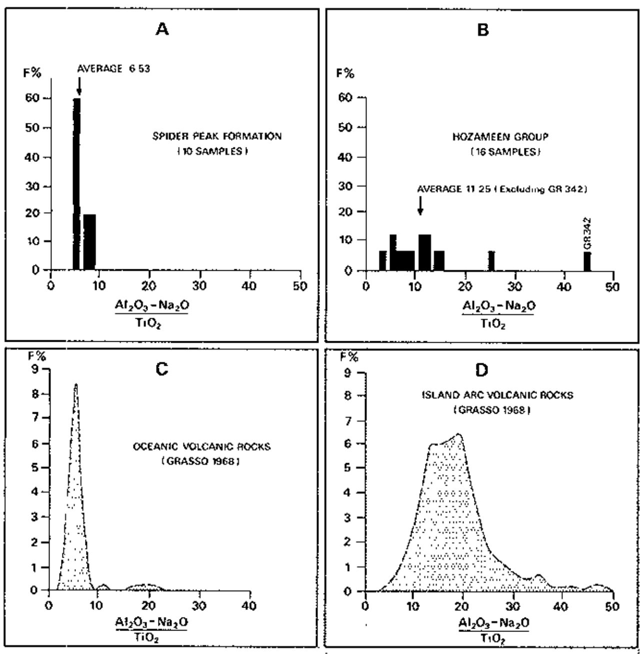


Figure 14. Al_2O_3 minus Na_2O/TiO_2 frequency plots A = Spider Peak Formation, B = Hozameen Group greenstones, C&D = Oceanic volcanic and island arc volcanic rocks respectively (after Grasso, 1968).

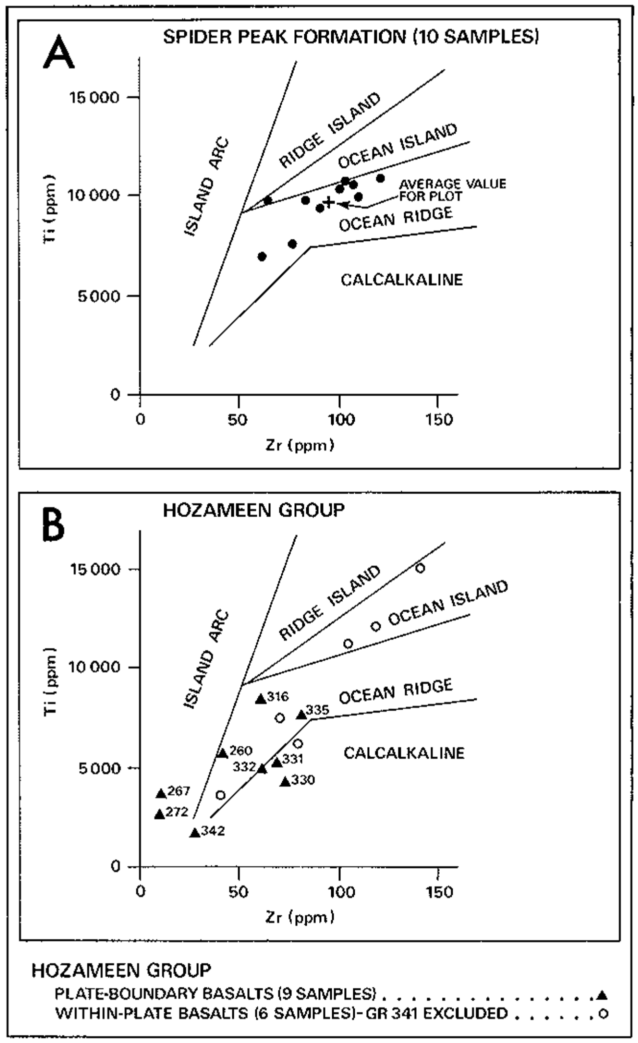


Figure 15. TiO_2 versus Zr plots (after Pearce and Cann, 1971, 1973; Muller, 1980); (A) = Spider Peak Formation greenstones; (B) = Hozameen Group greenstones. Numbers refer to Sample Numbers in Appendix 1.

Plate 5. Hozameen Group (Unit PJHc). Ribbon cherts deformed by D_1 folds. 200 metres northeast of the confluence of the Coquihalla River and Sowaqua Creek.

mation that affected these rocks is apparent in thin section; folded calcite twin lamellae and kinked, transposed bedding are commonly observed. Numerous samples of Hozameen limestone, marble and chert from throughout the area were collected for radiolarian dating and conodont identification but attempts to extract microfossils were unsuccessful (M.J. Orchard, personal communications, 1983, 1984).

East and northeast of Hells Gate Mountain the Hozameen Group cherts are interlayered with a heterogeneous rock suite (Unit PJHs) whose origin and protolith are uncertain due to the intense deformation and alteration. This unit, which is believed to include metamorphosed volcaniclastic rocks, aquagene breccias, immature siltstones and possibly thin greenstone volcanic flows, forms bands up to 200 metres thick. Some highly altered outcrops of greenstone and volcaniclastic rock contain angular pods of marble up to 30 centimetres across; these probably represent clasts within gravity slide deposits. Most of the rocks in Unit PJHs are light to dark green, well cleaved, strongly foliated and intensely altered. Remnant bedding and layering are apparent locally and flattened lithic clasts up to 2 centimetres long are seen in some volcaniclastic rocks. In thin section these rocks are seen to comprise mainly chlorite, tremolite-actinolite, strongly altered plagioclase and lesser amounts of quartz. Accessory hornblende, sericite, epidote, carbonate and sphene are also present.

McTaggart and Thompson (1967) identified a 6000-metre stratigraphic sequence in the Hozameen Group southeast of Hope which may be partly correlative with the succession recognized further north in the Boston Bar–Spuzzum area (Figure 16). The southern sequence comprises four stratigraphic units (Figure 16B), the upper three of which, although thicker, may be stratigraphic equivalents of the upper two units distinguished in the Boston Bar–Spuzzum area (Figure 16A). If this correlation is correct, it suggests that in the area southeast of Hope, Unit 1 of McTaggart and Thompson (*op. cit.*) may not represent the lowest member of the Hozameen Group succession, but may instead be a down-faulted slice of Unit 4 (Figure 16B).

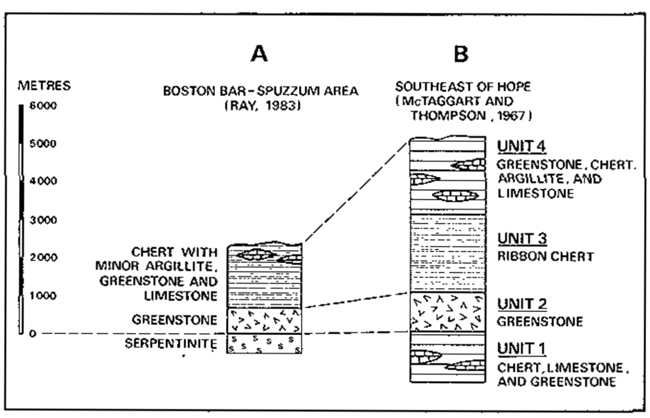


Figure 16. A comparison between the Hozameen Group stratigraphy in the Boston Bar–Spuzzum area (A) and in the area southeast of Hope (B).

Minor Intrusions in the Hozameen Group

Compared to rocks east of the Hozameen fault, minor intrusions are relatively uncommon in the Hozameen Group. They include sills and dykes of feldspar quartz porphyry (Unit F), basic to intermediate rocks (Unit d) and rare quartz veins (Unit Q).

The feldspar quartz porphyries generally form narrow sills and dykes less than 25 metres thick, although one body exposed 800 metres southwest of Spider Peak apparently exceeds 100 metres in outcrop width. They are mostly confined to Hozameen Group rocks between the Coquihalla River and Bijon Lake (approximately 5 kilometres north of Siwash Creek) and are not found east of the East Hozameen fault. Thus, they apparently predate the major transcurrent movement along this structure. Some feldspar quartz porphyry sills have siliceous, equigranular chilled margins, but many bodies have faulted contacts and are strongly fractured and weakly cleaved.

Samples from a quartz porphyry sill outcropping on the old railway line 1.6 kilometres north-northeast of the Coquihalla River–Sowaqua Creek confluence were collected for dating by K-Ar and U-Pb methods. However, the extensively chloritized mica and scarcity of zircons meant that no analyses were possible.

In outcrop, the feldspar quartz porphyries (Unit F) are fine to medium-grained leucocratic rocks that weather to a cream, buff or very pale grey colour. Most are porphyritic and characterized by large phenocrysts of quartz and/or feldspar up to 3 millimetres in diameter. In some cases the phenocrysts are preferentially concentrated toward the centre of the sills. The fine-grained ophitic-textured groundmass comprises interlocking quartz and feldspar crystals less than 0.2 millimetre in length. The large quartz phenocrysts vary from subhedral and hexagonal, to rounded, partially resorbed and heavily embayed crystals surrounded by reaction rims consisting of exceedingly fine grained quartz and feldspar intergrowths. The quartz phenocrysts are generally clear, strained and cracked, and may contain inclusions of fresh, radiating muscovite with some feldspar. The euhedral to subhedral feldspar phenocrysts include cloudy twinned sanidine with abundant coarse perthitic textures and minute inclusions, as well as finely twinned oligoclase (An_{20}) crystals. The groundmass contains both cloudy potassium feldspar and lesser amounts of andesine (An_{34}). Other trace and accessory minerals include biotite, sericite, sphene, zircon, epidote and chlorite; chlorite is largely replacing biotite.

Minor intrusions of gabbroic to dioritic composition are rare in the Hozameen Group; most form thin, sheared sills, but one crosscutting dyke, 8 metres wide with preserved intrusive contacts, outcrops in the Sowaqua Creek valley, approximately 3 kilometres south of the Coquihalla River (Figure 40B). The steeply dipping dyke intrudes an east-striking faulted contact between chert and argillite units. The centre of the dyke is massive and medium grained, and contains rare, anhedral plagioclase phenocrysts up to 0.5 centimetre long. Faint layering is seen subparallel to the locally preserved chilled margins, and the adjacent argillites show evidence of weak thermal alteration. Some margins are weakly sheared. In thin section this late dyke is seen to comprise 60 to 70 per cent interlocking laths of fresh andesine-labradorite (An_{45-60}) up to 0.5 millimetre in length which are intergrown with augite crystals that make up between 20 to 30 per cent of the rock. The augite is weakly altered to, and rimmed by, tremolite-actinotite and chlorite. The larger feldspar phenocrysts are cloudy and partially altered. Accessory and trace minerals include biotite, hornblende, pyrite, magnetite, ilmenite and sphene.

Irregular, thin, quartz-filled tension veins are fairly common in cherts adjacent to the East Hozameen fault, and numerous easterly striking quartz veins crosscut the ribbon cherts approximately 1 kilometre north of Siwash Creek. However, none of the veins contain sulphides and they do not appear to be of economic interest.

One northerly striking quartz vein, 2 metres wide, is exposed in an old rock trench approximately 2.5 kilometres north-northeast of Alexandra Bridge (Figure 41B). The vein cuts sheared, altered greenstone and gabbroic rocks of the Hozameen Group, approximately 200 metres east of the Petch Creek fault and contains veinlets and disseminations of pyrite and minor pyrrhotite; assays of sulphide-rich grab samples show it is barren of gold.

ROCKS WITHIN THE HOZAMEEN FAULT SYSTEM (COQUIHALLA SERPENTINE BELT — Unit U)

The Coquihalla serpentine belt is enclosed by the Hozameen fault system over a 50-kilometre strike length extending from Mount Dewdney northward to the vicinity of Spuzzum (Figure 2). At its northern and southern ends the belt comprises a discontinuous string of narrow serpentinite lenses, generally less than 100 metres wide, within the Hozameen fault zone. Between Spider Peak and the Mount Jarvis, however, the belt forms a continuous, steeply dipping unit that exceeds 2 kilometres in outcrop width in the Coquihalla River area (Figures 2, 3, 24 and 40). Dark, strongly sheared to massive serpentinites (Unit Us), of presumed peridotite and dunite parentage, characterize the belt (Plate 6). However, in its widest section it also contains a substantial proportion of coarse to fine-grained intrusive rocks (Unit Ug; Figure 40) of gabbroic composition (Figure 6C) as well as minor amounts of magnesite-rich, fuchsite-bearing quartz-carbonate (listwanite) rock (Unit Um).

The eastern margin of the Coquihalla serpentine belt is sharply delineated by the East Hozameen fault (Figures 2,

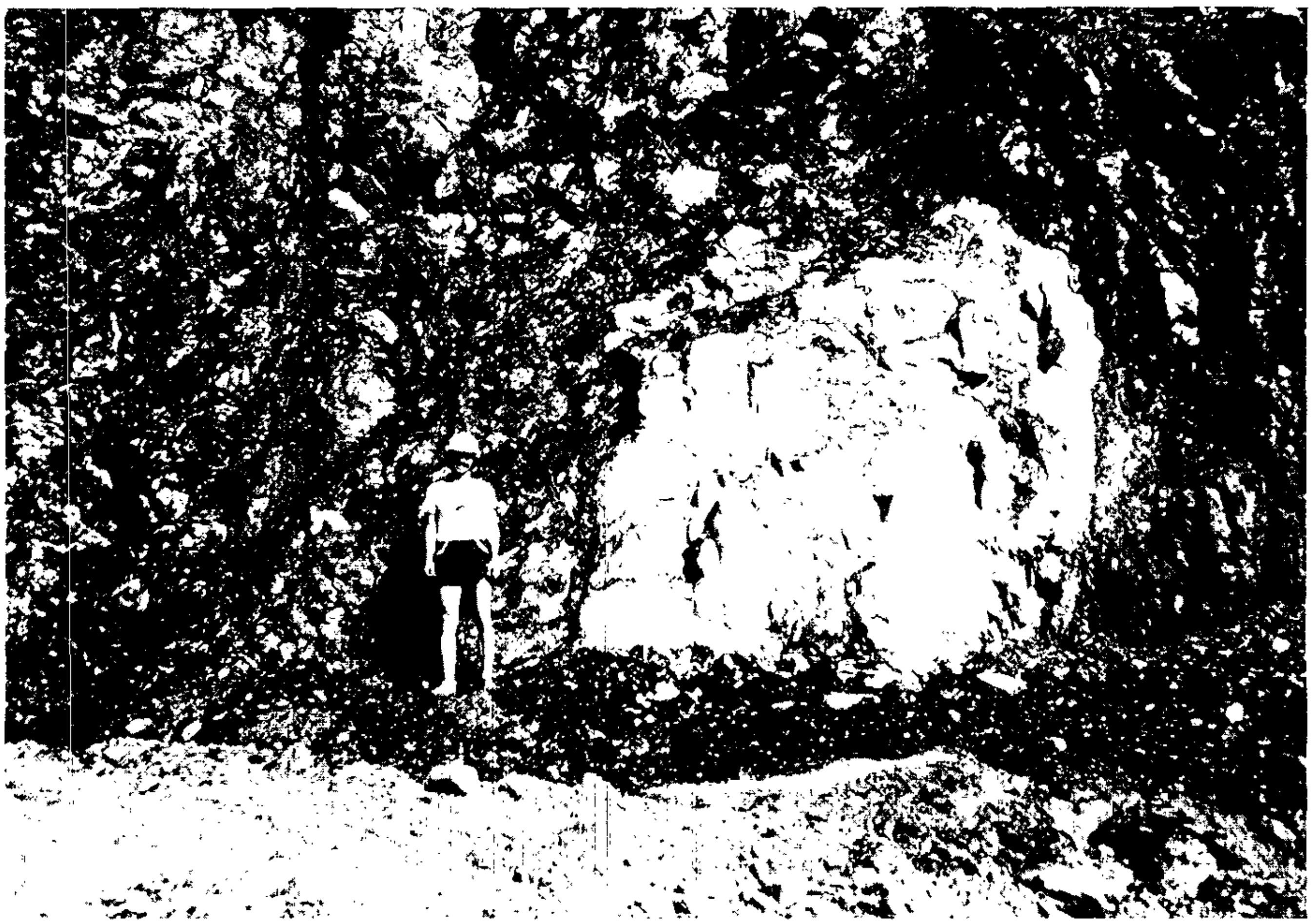


Plate 6. Coquihalla serpentine belt. Dark serpentinite (Unit Us) containing tectonic boudin of light-coloured microgabbro (Unit G). Approximately 800 metres southeast of the Idaho zone, Carolin mine.

24, 40 and 41; Plate 7) which, due to its proximity to many gold occurrences, has been mapped and studied in detail (Cairnes, 1929; Cochrane *et al.*, 1974; Anderson, 1976; Cardinal, 1981; Ray, 1982, 1983, 1984; Wright *et al.*, 1982). The fault is poorly exposed and usually lacks topographic expression. It generally dips steeply eastward, but locally exhibits an undulating character (Cairnes, 1929; Cardinal, 1982) and may reverse attitude to a westward dip. The fault zone comprises several generations of oblique, intersecting fractures which may account for the varying degree of shearing and alteration along the system. Locally, it is sharply defined and unaltered (Plate 7), but elsewhere it is occupied by a band of sheared talc several metres in width (Cairnes, 1929; Cardinal, 1982).

The western margin of the serpentine belt, the West Hozameen fault (Figures 2, 24, 40 and 41), is a major subvertical fracture that has greater regional structural importance than its eastern counterpart. Hozameen Group rocks close to the serpentine belt show signs of increased deformation, slickensiding, silicification and elongate, subhorizontal mullion structures, while serpentinites immediately adjacent to the fault contain thin layers of talc and minor amounts of poor-quality nephrite.

Serpentinite (Unit Us)

These rocks, which were first described in detail by Cairnes (1929), are best developed in the Coquihalla serpentine belt south of Spider Peak (Figures 2 and 3) and are particularly well exposed in the area between the Carolin mine and Serpentine Lake (Figure 40). Fresh rocks vary from light green to black in colour, but weathered surfaces are light grey, yellow or brown. Texturally they vary from massive to intensely schistose and sheared (Plate 6). Some outcrops comprise a densely packed mass of shear polyhedrons (Chidester *et al.*, 1951) comprising irregular, spheroidal, pillow-like masses up to 2 metres in diameter, that are separated from one another by thin layers of intensely sheared serpentinite. The shear polyhedrons have highly polished surfaces that locally show irregular slickensiding.

Most serpentinites in the Coquihalla belt are massive, but locally they contain either wholly altered phenocrystic pseudomorphs after olivine and pyroxene, or are speckled with light-coloured carbonate clots up to 4 millimetres in diameter; textures suggest that most of these rocks were derived from ultramafic cumulates. Thin, irregular veinlets of chrysotile and talc cut some outcrops, particularly toward the more sheared eastern and western margins of the belt.

Plate 7. East Hozameen fault. Exposed easterly dipping faulted contact between serpentinites of Coquihalla serpentine belt (Unit Us) to the right, and Ladner Group wackes and siltstones (Units JLw and JLs) to the left. Approximately 800 metres southeast of the Idaho zone, Carolin mine.

In thin section the serpentinite is seen to consist largely of lamellar antigorite, bastite and massive lizardite with only trace amounts of chrysotile. Antigorite generally comprises between 50 and 95 per cent of the rock, forming pseudomorphs after olivine up to 3 millimetres in length. Many of the pseudomorphs are rimmed with fine trails of magnetite and chromite which produce a reticulate network outlining the original olivine crystals. Some sections contain rounded clots of dark brown, pleochroic carbonate which overgrow the antigorite crystal boundaries. Many bastite pseudomorphs after enstatite contain abundant elongate clusters of opaque minerals arranged parallel to the original pyroxene cleavages. Other trace or accessory minerals include tremolite-actinolite, hornblende, epidote, chlorite, hematite and some skeletal ilmenite. Traces of relict enstatite are seen occasionally, but unaltered olivine remnants are extremely rare.

Major and trace element analyses of serpentinite samples collected from throughout the belt are shown in Appendices 2A and 2B. Although it is not possible to determine the precise origin of a serpentinite from its chemical composition (Pirsson and Knopf, 1966) the relatively high chromium and nickel content in the Coquihalla serpentinites (Appendix 2A), compared to those of metasedimentary origin, indicates they were derived from ultramafic igneous rocks.

In the Carolin mine–Coquihalla River area the serpentinites are locally cut by very pale green to yellow-coloured, strongly altered dykes up to 2 metres wide; these massive and fine-grained dykes are commonly deformed and broken up into pods within the serpentinite. In thin section, remnant ophitic textures are visible, but the original feldspar laths are completely replaced by fine-grained carbonate and minor sericite, and the mafic minerals are altered to carbonate, chlorite, epidote, clinozoisite and minor opaque minerals. An analysis of a single sample of this rock, from a dyke that intrudes the serpentinites near Carolin mine, is shown in Appendix 3. It is not known whether these rare, pale dykes within the serpentinite are related to the gabbroic rocks (Unit Ug) found elsewhere in the Coquihalla serpentine belt.

Gabbro, Microgabbro and Minor Greenstone (Unit Ug)

The Coquihalla serpentine belt between Mount Tulameen and Spider Peak (Figures 2 and 40) contains substantial amounts of mafic intrusive rock of gabbroic composition (Appendix 4; Figure 6C). These rocks form elongate tectonic boudins, sheets, lenses and highly disrupted dykes within the ultramafics, and vary from a few metres (Plate 6) to 250 metres in width and up to 750 metres in strike length. Contacts between the gabbroic and ultramafic rocks are usually faulted, and the serpentinite adjacent to the gabbro sheets is strongly schistose and sheared. However, the local presence of remnant chilled margins suggests the gabbroic rocks intrude the serpentinites. Texturally the gabbroic rocks range from coarse to fine grained, and many of the finer grained varieties are indistinguishable both in appearance and geochemistry from the greenstones of the Spider Peak Formation. Nevertheless, all of these rocks in the Coquihalla serpentine belt are believed to be intrusive rather than extrusive in origin. In outcrop they are massive, dark grey to green-coloured, strongly altered rocks that are locally cut by irregular veins of either carbonate, quartz or cream to buff-coloured feldspar. At one location approximately 2 kilometres south-southeast of Spider Peak, very coarse grained gabbroic rocks are intruded by numerous northerly trending dykes of fine-grained greenstone generally less than 1 metre wide. Contrary to reports by Anderson (1976), no sheeted dykes were seen in the Coquihalla serpentine belt, and neither was igneous layering identified in any of the gabbros.

In thin section the gabbroic rocks are generally seen to comprise between 20 and 60 per cent plagioclase and 20 to 40 per cent amphibole, with variable amounts of chlorite, epidote and carbonate. All show varying degrees of alteration; the finer grained intrusives are often totally altered to a mixture of chlorite, clinozoisite, actinolite, carbonate and epidote. Ophitic textures are recognizable in the coarser grained rocks and the poorly twinned, locally zoned, plagioclase (An_{34-50}) grains reach 2 millimetres in length. They are partially replaced by clusters and intergrowths of epidote, clinozoisite, carbonate and sericite. Generally the pale green hornblende is moderately altered to chlorite, tremolite, actinolite and epidote. In some sections the hornblende-tremolite intergrowths envelope small corroded remnants of strongly altered augite. Other trace to accessory minerals include magnetite, ilmenite, sphene, apatite and quartz. The skeletal ilmenite is rimmed with sphene and leucoxene.

Analytical results for samples collected from the mafic intrusive rocks are presented in Appendix 4. Plots of these data (Figure 6C) demonstrate the gabbroic composition of the rocks, while Figure 9D shows they are enriched in sodium and depleted in potassium as are the greenstones in the Spider Peak Formation (Figure 9C). As the gabbroic rocks in the belt are considered to be the feeders for the Spider Peak greenstones, it suggests that either the volcanism was intrinsically sodic or that the spreading-ridge system that gave rise to the Spider Peak Formation was affected by very deep level spilitization.

Fuchsite-bearing Quartz Carbonate Rocks (Listwanite) (Unit Um)

Although boulder float of this distinctive rock type is widespread in the Spider Peak–McMaster Lake area, it crops out at only a few separate localities throughout the Coquihalla serpentine belt, usually in tectonic slices within or immediately adjacent to the East Hozameen fault. The largest of these slices is situated 700 metres south-southeast of Spider Peak and is approximately 600 metres in strike length and up to 100 metres wide (Figure 40A). The other slices are much smaller; one of them lies on strike and 100 metres southeast from the Murphy gold occurrence where it forms a sliver, 5 to 15 metres wide, within the East Hozameen fault zone. Another thin fuchsite-bearing quartz-carbonate unit lies within the Hozameen fault, about 2 kilometres north of its intersection with Siwash Creek (Figure 40A). In addition to these outcrops, abundant large angular boulders of this rock type, presumably derived from a nearby unexposed source, are seen close to the East Hozameen fault approximately 300 metres southeast of McMaster Pond, and northwest of the McMaster zone gold occurrence (Figure 36).

Fresh surfaces of these massive to weakly foliated, coarse to medium-grained rocks are generally pale grey or green in colour, and are characterized by sparse disseminations and rare, thin veinlets of the bright green chromium mica, fuchsite (Plate 8). Weathered surfaces are soft, rotted and characterized by a distinctive medium to dark yellow-brown hue (Plate 9). Locally, these rocks are cut by a dense, irregular network of thin white quartz veins, some of which appear to be either folded, or occupying sigmoidal tension fractures. Most of these rocks are strongly deformed and sheared, with the shear planes containing abundant talc and minor fuchsite.

Thin sections show the matrix of the rocks comprises 30 to 70 per cent medium to coarse-grained carbonate and up to 50 per cent quartz, 5 per cent plagioclase and lesser amounts of chlorite (1 to 3 per cent), fuchsite (trace to 2 per cent) and opaque minerals. The carbonate is mainly magnesite with only minor amounts of calcite, and mostly forms a mosaic intergrown with the quartz crystals.

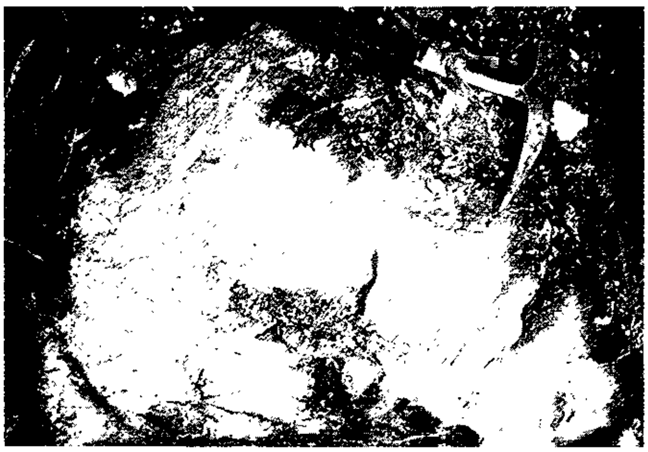


Plate 8. Coquihalla serpentine belt. "Listwanite" (Unit Um). Fuchsite-bearing quartz-magnesite rock crossed by late quartz veins. Boulder float, 150 metres northwest of the McMaster Zone.

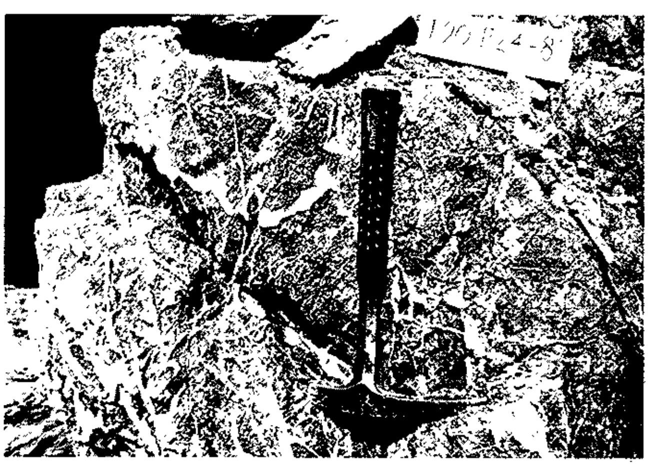


Plate 9. Coquihalla serpentine belt. "Listwanite" (Unit Um). Highly weathered fuchsite-bearing quartz-magnesite rock crossed by deformed quarts veins. Approximately 600 metres south-southwest of Spider Peak.

Both the finer grained quartz crystals in the matrix and the coarser (up to 2 millimetres) crystals in the crosscutting quartz veins show evidence of intense strain, such as undulating extinction, deformation lamellae and tension cracks. The fuchsite forms small, pale green, deformed flakes that are partially altered to chlorite. Fuchsite occurs either as thin irregular veinlets, as flakes surrounding the opaque minerals, or as radiating clusters within the quartz-magnesite groundmass. The opaque minerals include ilmenite and magnetite. Two analyses of rocks collected from the small fault slice located 2 kilometres north of Siwash Creek are shown in Appendices 5A and 5B. The relatively high magnesium and carbon dioxide values reflect the abundance of magnesite. The elevated arsenic values (Appendix 5B) suggest the presence of arsenopyrite, although it has not been identified in the field.

ROCKS EAST OF THE HOZAMEEN FAULT SYSTEM

SPIDER PEAK FORMATION (UNIT TV)

The Spider Peak Formation was first described and formally named by Ray (1986b) after the prominent hill approximately 5 kilometres northwest of Carolin mine (Figure 40A). The formation, which mainly comprises greenstone, is traceable for more than 15 kilometres along the eastern side of the East Hozameen fault. It generally forms a narrow discontinuous belt separating the Ladner Group from the Coquihalla serpentine belt (Figure 24) and is best developed around Spider Peak where it has an estimated maximum stratigraphic thickness of 500 metres; elsewhere, however, it is generally less than 300 metres thick. Its contact with the Coquihalla serpentine belt is invariably faulted, while an unconformable relationship exists between the formation and the stratigraphically overlying Ladner Group. In the Carolin mine area (Figure 42) the Ladner Group contains two elongate, fault bound units of Spider Peak Formation that are interpreted to represent thrust slices.

The type section, exposed 6 kilometres south-southeast of Emancipation mine and 1.5 kilometres east-northeast of Serpentine Lake, is approximately 250 metres thick (Figure 3, section S-S′). At this locality the formation dips steeply east and its stratigraphic base to the west is faulted against serpentinites and gabbros of the Coquihalla serpentine belt. The bottom of the formation consists of approximately 50 metres of massive, medium to coarse-grained gabbro (Unit TVg). This is overlain by 200 metres of both massive (Unit TVm) and pillowed greenstone (Unit TVp), the latter containing deformed pillows between 0.3 and 1.3 metres in diameter. Near the top of the section, areas between individual pillows contain volcaniclastic sedimentary material and sporadic angular chert fragments. Some thin beds of aquagene breccia (Unit TVb) and immature volcanic sandstone (Unit TVs) are also present. The stratigraphic and structural top of the section is marked by the basal conglomerate of the Ladner Group; at this locality the conglomerate is between 1 and 5 metres thick and contains deformed, elongate clasts of greenstone and black to grey-banded chert up to 20 centimetres in length.

The Spider Peak Formation is inverted and structurally overlies the Ladner Group in the Carolin mine area (Figure 42), but north and south of the mine tectonic inversion becomes less common. North of Spider Peak, the greenstones are exposed beneath rocks of the Ladner Group within a northerly plunging anticlinal inlier, while immediately south of the peak, the formation forms a large folded and faulted mass that apparently structurally overlies the Coquihalla serpentine belt (Figures 24 and 40A). Here the formation comprises a tectonically thickened sequence approximately 650 metres wide; to the east, a major dislocation along the upper reaches of Siwash Creek marks the stratigraphic base of the formation which is faulted against rocks of the Coquihalla serpentine belt farther east. The stratigraphic section in this area (Figure 24, section TT′) comprises a 250-metre-thick lower unit of massive greenstone and coarse-grained gabbro to the east, overlain successively westward by 100 metres of schistose greenstone, which passes stratigraphically upward into 300 metres of both massive and brecciated greenstone with rare thin beds of aquagene breccia and volcanic sandstone; no pillow basalts are seen in this area. The contact between the formation and the Ladner Group is not exposed, but farther west a faulted slice of westerly facing Ladner siltstones and argillites, 75 metres thick, separates the Spider Peak Formation from rocks of the Coquihalla serpentine belt (Figures 22, 24 and 40A).

The Spider Peak Formation is largely made up of strongly altered, fine to medium-grained volcanic greenstones in which the original pyroxene is sporadically preserved. Most of the volcanic rocks are massive, but both tectonic and aquagene breccia textures are locally present; some greenstones close to the Ladner Group unconformity display amygdules, faint layering and pillows (Plate 10) with rare interpillow chert breccias. Many outcrops are cut by veins of carbonate and epidote, while some are locally characterized by randomly orientated crystals of late-stage stilpnomelane up to 1.5 centimetres long (Plate 11).

The degree of alteration of the original feldspars and pyroxenes in these rocks is highly variable throughout the area. In the Spider Peak–Carolin mine area, remnant augite is relatively uncommon and the feldspars are almost wholly altered and of indeterminate composition. Farther south, east of Serpentine Lake, remnant augite is far more abundant (Plate 12) and the feldspars are of oligoclase-andesine composition (An_{10-35}). Irrespective of the amount of alteration, good ophitic textures are visible in all of the Spider Peak volcanic rocks.

The greenstones comprise mainly plagioclase (40 to 65 per cent), amphibole (5 to 25 per cent), chlorite (5 to 25 per cent) and augite (0 to 15 per cent). Lesser but variable amounts of carbonate and epidote are also present as veins and disseminations, particularly in the pillowed greenstones. Remnant augite is present in both the massive and pillowed volcanic rocks; it generally forms small (0.2 millimetre)

Plate 11. Spider Peak Formation. Photomicrograph (PPL) of pillowed, brecciated basaltic greenstone (Unit TVp) containing late, randomly orientated crystals of stilpnomelane. Sample from outcrop on the Coquihalla River 200 metres northeast of confluence with Dewdney Creek.

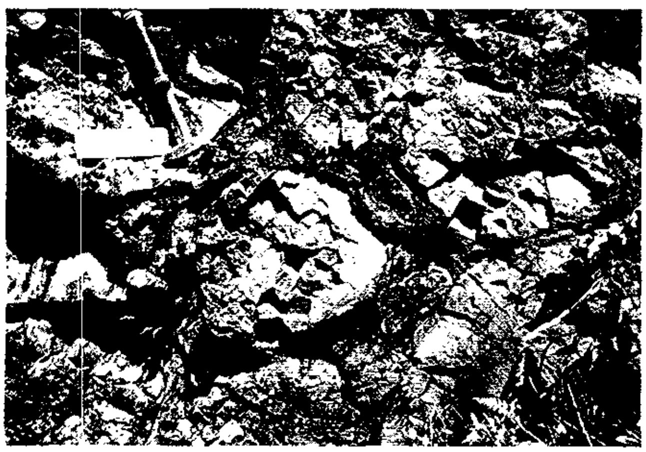


Plate 10. Spider Peak Formation. Structurally overturned pillowed basaltic greenstones (Unit TVp); stratigraphic tops to lower right. Outcrop on ridge between Dewdney and Sowaqua creeks, 1.9 kilometres east-northeast of Serpentine Lake.

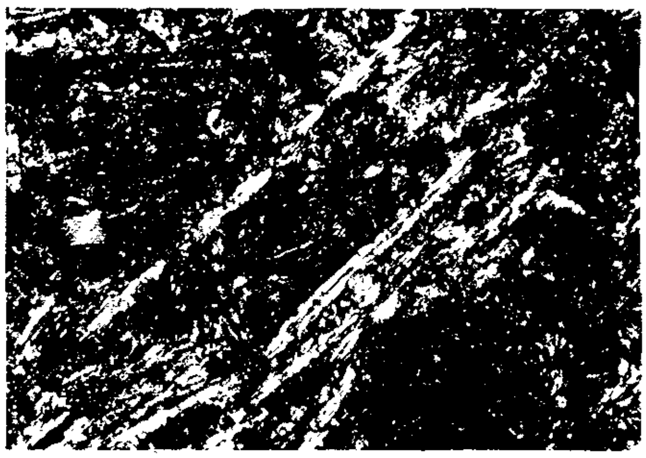


Plate 12. Spider Peak Formation. Photomicrograph (X Nicols) of pillowed basaltic greenstones (Unit TVp) with remnant augite, long, acicular, quench-textured plagioclase crystals and abundant chlorite. Sample from outcrop on ridge between Dewdney and Sowaqua creeks, 1.9 kilometres east-northeast of Serpentine Lake.

rounded, altered cores that are surrounded by hornblende, tremolite-actinolite, chlorite and opaque minerals. East of Serpentine Lake, however, fairly fresh, subhedral augite crystals up to 1 millimetre in length are common. The weakly to intensely altered, locally zoned plagioclase laths are generally 1 to 2 millimetres long. Some of the pillow lavas contain exceedingly thin, acicular plagioclase crystals (Plate 12) up to 3 millimetres long, that are curved and branched. Many of these acicular feldspars contain thin cores filled with divitrified glass and opaque minerals. The groundmass in the pillowed greenstones consists largely of fine-grained feldspar, amphibole, augite and devitrified glass. The acicular, branching feldspars and devitrified glass are interpreted to be the result of rapid quenching. The amygdules in the amygdaloidal lavas are rounded to elongate, up to 4 millimetres in length, and are generally filled with either quartz, calcite, sericite or chlorite. Trace and accessory minerals in the greenstones include potassium feldspar, sericite, clinozoisite, quartz, sphene, apatite, skeletal ilmenite, leucoxene and late-stage, crosscutting, randomly orientated laths of stilpnomelane (Plate 11). X-ray diffraction studies suggest the presence of pumpellyite (Y.J. Kwong, written personal communication, 1982).

Some whole-rock and trace element analyses of the Spider Peak volcanic rocks are shown in Appendix 6. Various plots of these data (Figures 6 to 15) indicate that the greenstones represent sodium-rich, low-potassium, oceanic ridge subalkaline basalts; the high sodium content (Figure 9A and 9C) is probably due to spilitization.

At the base of the formation the volcanic rocks pass gradationally into coarse-grained gabbros (Figure 5B), while elsewhere, and higher in the sequence, they are interlayered with very rare, thin beds of ash and lapilli tuff, argillite, volcanic sandstone, siltstone and wacke. Approximately 900 metres northeast of Spider Peak, the formation includes a thin bed of coarse tuffaceous conglomerate (Unit TVc). This contains both rounded and sharply angular clasts of varied lithologies, up to 10 centimetres in length, set in a poorly sorted matrix of coarse volcanic sandstone, tuff and siltstone. Clasts are mostly fresh augite-porphyritic apatite-bearing basalts and andesites, together with fragments of euhedral augite crystals, rounded quartz grains and altered feldspar fragments. Rare pebbles of well-layered basalt and recrystallized devitrified acid volcanic rocks are also present.

The age of the Spider Peak Formation is uncertain because the interpillow chert breccias were sampled for microfossils without success. However, at one locality close to the type section, approximately 6 kilometres south-southeast of Emancipation mine (Figure 40B), angular clasts within a chert-conglomerate horizon marking the unconformity between the Spider Peak Formation and the Ladner Group yielded conodonts of probable Early Triassic age (Geological Survey of Canada Location No. C-102363; M.J. Orchard, personal communication, 1983). The angular chert clasts may have come from a distant, unknown source, or from the interpillow chert breccias within the immediately adjacent Spider Peak Formation. If the latter interpretation is correct, the Spider Peak volcanic rocks are of probable Early Triassic age, and a considerable time interval exists between them and the overlying Ladner Group.

Ladner Group (Unit JL)

East of the Hozameen fault system are turbidite and successor basin deposits of the Methow-Pasayten trough which range from Early Jurassic to Middle Eocene in age (Coates, 1974; Greig, 1989) and have an estimated maximum thickness of 9000 to 12 000 metres (Figure 5B). The Ladner Group was formerly considered to be Early to Middle Jurassic on fossil evidence (Coates, 1974; O'Brien, 1986b) but fossil discoveries at Pipestem mine (Ray, 1986b) suggest the group extends into the Upper Jurassic. It is the oldest sedimentary sequence in the Methow-Pasayten trough and, between Mount Tulameen and Boston Bar (Figure 2), it represents a marine succession with an estimated maximum thickness of 2000 metres (Figure 5B). It mostly comprises a sequence of fine-grained, poor to well-bedded, slaty argillites (Unit JLa) and siltstones (Unit JLs) with minor amounts of wacke (Unit JLw), lithic or tuffaceous wacke (Unit JLwl) and conglomerate (Unit JLc). Apart from minor tuffs, no conclusive evidence of widespread volcanism is seen in the Ladner Group in the Coquihalla River–Spider Peak area, but in the Manning Park area farther south Coates

Plate 13. Ladner Group. Thinly bedded wacke (Unit JLw) with minor siltstone. Graded bedding and sedimentary scouring indicate the rocks young easterly (to the right) and are overturned. Outcrop on Carolin mine road 1150 metres north of Dewdney Creek—Coquihalla River junction.

(1974) and O'Brien (1986b) described some volcanic rocks in the group. Most outcrops show evidence of low-grade metamorphism and the imposition of a slaty cleavage. The sedimentary rocks were subjected to at least three periods of regional folding; nevertheless, a wide variety of sedimentary structures are clearly preserved and these rocks are less intensely deformed than the Hozameen Group. Graded bedding is widespread in the siltstones and coarse clastic units (Plate 13). Other less common features include crossbedding, ripple marks, scours, flame structures, load casts, ball-and-pillow structures, chaotic slumping and rip-up clasts. Graded bedding and scour structures indicate that some sections of the Ladner Group adjacent to the Coquihalla serpentine belt, including those hosting gold mineralization at Carolin mine (Ray, 1982), are structurally inverted (Figure 42; Plate 13).

The Ladner Group in the Manning Park area contains Early to Middle Jurassic fossils (Coates, 1974). Farther north, between Boston Bar and Mount Tulameen (Figure 2), it is generally unfossiliferous and the only locality where megafossils are recognized is near the abandoned Pipestem mine, approximately 1.8 kilometres east-southeast of Spider Peak (Figures 40A and 43). Thin tuffaceous wacke beds within the predominantly argillite succession contain Late Jurassic fossils — *Buchia (Anaucella)* ex. gr. *Concentrica* (Sowerby) *sensu lato* (Geological Survey of Canada Locality Nos. C-101209 and C-101210; H.W. Tipper and J.A. Jeletzky, written personal communication, 1983). These fossiliferous beds lie only 500 to 650 metres above the base of the Ladner Group, although widespread faulting has probably removed some of the succession. Nevertheless, the fossils suggest that the Ladner sedimentation continued into the Late Jurassic, and was in part time-equivalent to the Late Jurassic Dewdney Creek Group rocks of Cairnes 1924, 1944) and the Thunder Lake sequence of O'Brien (1986b).

The contact between the Ladner Group and the Spider Peak Formation is commonly marked by shearing and quartz veining. However, the unconformity is recognizable at a number of widely separated localities and a basal conglomerate is sporadically preserved. This is generally less than 10 metres thick but can rarely reach 70 metres in thickness; it contains angular to well-rounded clasts up to 20 centimetres in diameter. Most clasts were derived from the underlying Spider Peak Formation, but grey to black chert pebbles predominate locally. Other less common clast lithologies include granite, granodiorite, diorite, gabbro, acid volcanic rock and, rarely, limestone.

The Ladner Group rocks immediately overlying the basal unconformity are locally distinct in containing either very finely bedded, tuffaceous siltstones, or rare thin beds of impure limestone. The limestone beds outcrop at four widely separated localities in the district. Several 1-metre-thick beds of impure limestone are exposed close to the Ladner Group basal conglomerate on the Carolin-Pipestem mine road, approximately 900 metres east-southeast of Spider Peak. On a drill road about 200 metres north of Emancipation mine, the basal Ladner Group includes a 3-metre bed of impure, coarse clastic limestone (Figure 25), while thin limy horizons and limestone breccias are exposed at two locations close to the contact with the Spider Peak Formation approximately 1100 metres and 2.6 kilometres southeast of the confluence of the Coquihalla River and Dewdney Creek (Figure 40B). At these four localities the limestone beds contain dark, angular to rounded carbonate clasts. Thin sections show the limestones comprise 70 to 95 per cent carbonate and are characterized by very thin, strongly deformed bedding. The fragmental limestones contain abundant angular to rounded clasts of both massive black carbonate and bedded limestone up to 3 centimetres in diameter. Rarer fragments of chert, quartz, fresh plagioclase, strongly altered basalt and devitrified acid volcanic rock were also noted, as well as a single small clast of altered granite. Accessory minerals include epidote, clinozoisite, chlorite and detrital zircon.

Numerous samples of the limestones in the basal part of the Ladner Group were collected for microfossils, generally without success. The limestone breccia bed exposed 1100 metres southeast of the Coquihalla River–Dewdney Creek confluence yielded two undiagnostic fish teeth, while limestone samples collected 200 metres north of the Emancipation mine (Figure 25) contained one conodont fragment which is probably of Early to Middle Triassic age (M.J. Orchard, oral personal communication, 1983). This may indicate that the basal part of the Ladner Group is Triassic. An alternative and more likely interpretation is that the conodont specimen represents a fragment derived through the pre-Ladner weathering of the immediately underlying Spider Peak Formation.

A broad upward-fining stratigraphic sequence is recognized in the Ladner Group in the Spider Peak–Coquihalla River area. It consists of a locally developed lower unit characterized by a heterogeneous assemblage of coarse clastic sedimentary rocks, a middle unit of largely well-bedded siltstone, and a thick upper unit dominated by poorly bedded, carbonaceous, pyritiferous and slaty argillite (Figures 5B and 42). The upper argillite unit contains the fossiliferous tuff and wacke beds of Late Jurassic age at Pipestem mine. The lower coarse clastic unit is economically important because these rocks host many of the mineral occurrences in the Coquihalla gold belt (Ray, 1982, 1983), including the Carolin orebody (Shearer and Niels, 1983). The unit is best developed near Carolin mine where it exceeds 200 metres in thickness (Figures 28 and 42); to the north and south it thins and pinches out. Overturned flame structures in wackes at Carolin mine and near the McMaster gold showing suggest an easterly derivation for the lower unit of the Ladner Group. It is marked by rapid lateral facies changes and includes discontinuous wedges of interbedded greywacke, lithic or tuffaceous wacke, breccia, interformational conglomerate (Plate 14), and possible reworked tuff, together with intercalated sequences of argillite and volcaniclastic siltstone.

The interformational, polymicitic conglomerate layers (Unit JLc) within the lower unit seldom exceed 30 metres in thickness. They vary from densely packed, clast-supported sedimentary breccias (Unit JLcb) with angular lithic fragments and some rip-up clasts, to conglomeratic mudstones (Unit JLcm) containing isolated, well-rounded clasts generally up to 30 centimetres in diameter (Plate 14), set in a mudstone matrix; some conglomerates exhibit reverse grading. The pebbles, cobbles and boulders are predominantly volcanic greenstone with lesser amounts of chert, gabbro,

Plate 14. Ladner Group — lower unit. Conglomerate (Unit JLc) containing pebbles and cobbles of basaltic greenstone. McMaster Zone gold occurrence.

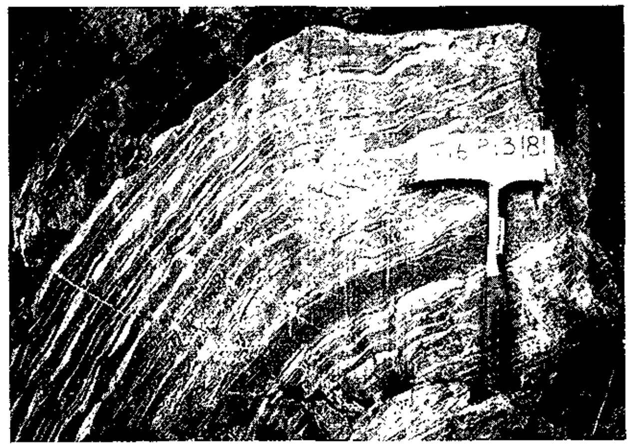


Plate 15. Ladner Group — middle unit. Siltstone (Unit JLs) with thin turbidite wacke interbeds deformed by D_2 folding. Drill-road outcrop 290 metres east-northeast of the old Idaho adit, Carolin mine.

diorite, granite, granodiorite, porphyritic andesite, limestone and devitrified, flow-banded dacite. The mudstone matrix often displays evidence of soft-sediment disruption and chaotic slumping. One conglomeratic mudstone horizon at Carolin mine is traceable for more than 1.5 kilometres along strike. Another polymictic conglomeratic mudstone, cropping out approximately 4 kilometres southeast of the confluence of the Coquihalla River and Dewdney Creek, lies close to the basal Ladner Group unconformity; it exceeds 70 metres in thickness and contains angular limestone blocks up to 2.5 metres in diameter.

In thin section the wacke beds (Unit JLw) in the lower unit of the Ladner Group are seen to comprise largely clastic grains of plagioclase (An_{25-45}) and quartz, generally between 0.2 to 0.4 millimetre in diameter. These are set in an altered, fine-grained matrix of chlorite with lesser amounts of quartz, plagioclase and sericite. The twinned plagioclase grains are weakly to moderately altered to carbonate, chlorite and epidote. The lithic and tuffaceous wackes (Unit JLwl) contain variable amounts of angular, poorly sorted, matrix-supported clasts; these average 1 to 2 millimetres in diameter although rare clasts up to 6 centimetres across are locally present. Generally, over 80 per cent of the clasts in the lithic wackes in the lower part of the Ladner Group are strongly chloritized basic volcanic rock. Rarer fragments of quartz, plagioclase, carbonate, chert, hornblende, epidote and thin-bedded sedimentary rock are also present. Trace to accessory minerals include potassium feldspar, detrital zircon and opaque minerals.

The thin beds of Late Jurassic, fossiliferous and tuffaceous wacke higher in the succession at Pipestem mine (Figures 5B and 43) have a different groundmass mineralogy and overall clast lithology from their counterparts in the lower unit of the Ladner Group. Locally, the groundmass in these younger rocks is carbonate rich, and in some cases over 90 per cent of the elongate deformed clasts comprise massive fine-grained calcite, as well as single carbonate crystals, broken bivalve shells and some belemnites. Elsewhere in the Pipestem mine area, the wackes are tuffaceous and contain abundant angular fragments of altered feldspar-porphyritic acid volcanic rock, broken feldspar and quartz crystals and variable amounts of

Plate 16. Ladner Group — upper unit. Argillite (Unit JLa). Photomicrograph (X Nicols) of cubic pyrite crystals enveloped by chlorite-filled pressure shadows.

basalt, andesite and chert. A high proportion of the groundmass comprises epidote, chlorite and minor carbonate. Some of the Late Jurassic wackes near Pipestem mine are also distinct in containing large, euhedral cubes of pyrite up to 1 centimetre across.

The middle siltstone unit of the Ladner Group (Unit JLs) is approximately 200 metres thick at Carolin mine (Figures 5B and 28). It consists mainly of grey to black, generally well-bedded siltstones (Plate 15) with good grading and beds varying from a few millimetres to 10 centimetres in thickness. Many of the individual graded beds have coarser grained, light-coloured silty bases, which pass gradationally upwards into fine-grained, dark argillaceous tops. In thin section the siltstones are seen to contain abundant fragments of quartz and altered plagioclase, up to 0.2 millimetre in diameter, set in a finer grained matrix of quartz, chlorite, epidote and plagioclase.

The slaty argillites (Unit JLa) in the uppermost part of the Ladner Group succession exceed 1000 metres in thickness (Figures 5B and 28) and are black to grey, generally unbedded sedimentary rocks that are locally pyrite and organic rich. In thin section they are seen to be composed mainly of very fine grained quartz, altered plagioclase, and chlorite with variable amounts of sericite, carbonate, pyrite and exceedingly fine grained opaque organic material. Cleavage in both the argillites and siltstones is defined by the subparallel alignment of chlorite and the elongate growth of quartz, feldspar and pyrite crystals. Some black argillites contain late, second generation pyrite cubes, up to 2 millimetres across, that postdate both the slaty cleavage and the elongate pyrite crystals. Complex multistage rims of quartz and chlorite crystals have grown locally within areas of pressure shadow immediately adjacent to the pyrite cubes (Plate 16).

DEPOSITIONAL ENVIRONMENT OF THE LADNER GROUP

The discontinuous wedges of highly variable, poorly sorted coarse material interbedded with lesser amounts of

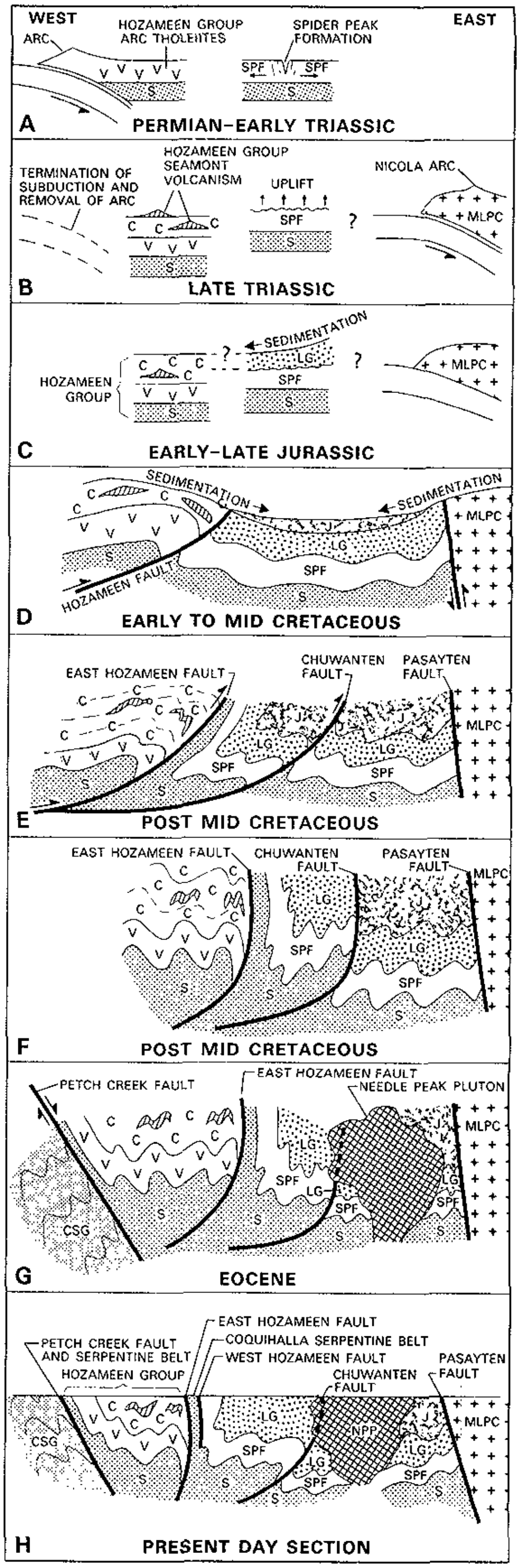


Figure 17. Postulated history of the Hope–Boston Bar area. (A) Permian to Early Triassic: Development of a multi-rifted, marginal back-arc basin. Permian (Haugerud, 1985) eruption of the Hozameen Group arc tholeiites (V) adjacent to an oceanic arc. Back-arc spreading farther east resulting in the Early Triassic(?) eruption of Spider Peak Formation basalts (SPF). S = serpentinite. (B) Late Triassic: Termination of subduction in the west. Deposition of cherts (C) and ocean island–seamount volcanic rocks in the Hozameen Group; uplift and erosion of the Spider Peak Formation (SPF). Easterly subduction beneath the Mount Lytton–Eagle plutonic complex (MLPC) and formation of the Nicola arc. The relationship between the Mount Lytton–Eagle plutonic complex and rocks farther west is uncertain. (C) Early to Late Jurassic: Unconformable deposition of the Ladner Group (LG) as an easterly derived turbidite prism on the eroded Spider Peak Formation. Coeval(?) deposition of the predominantly chert sequence (C) in the upper part of the Hozameen Group within a distal, oceanic environment. The relationship between the Ladner Group and the Mount Lytton–Eagle plutonic complex farther east is uncertain. (D) Early to mid-Cretaceous: Juxtaposing and uplift of Mount Lytton–Eagle plutonic complex (MLPC) against Methow-Pasayten trough sediments along Pasayten fault. Development of west-dipping precursor thrust for the Hozameen fault. Oblique (dextral?) and east-directed uplift of Hozameen Group over Ladner Group. Sedimentation from west and east sources leading to deposition of Jackass Mountain and Pasayten Groups (J). (E) Continuing east-directed thrusting and imbricate stacking along precursor for Hozameen fault, and development of Chuwanten fault. Sedimentation in trough continues into the Eocene (Greig, 1989). Upthrust ultramafic material (S) from beneath the Methow-Pasayten trough to produce Coquihalla serpentine belt. Local tectonic inversion of the Spider Peak Formation and Ladner Group. (F) Continuing compression with folding in Hozameen Group and Methow-Pasayten trough sediments. Hozameen and Chuwanten faults steepened into subvertical attitude. (G) Eocene: Extensional movement along Petch Creek fault juxtaposes Custer-Skagit gneiss (CSG) against Hozameen Group, with development of Petch Creek serpentine belt. Intrusion of Needle Peak pluton into Methow-Pasayten trough, followed by dextral transcurrent movement along Hozameen fault. (H) Present day east-west section.

fine sediments in the lower unit of the Ladner Group (Figure 5B) imply alternating periods of low and high-energy deposition, the latter involving high-density turbidity currents, chaotic slumping and mass gravity transport. The sedimentary breccias and mudstone conglomerates are interpreted to be gravity-slide olistostrome deposits. The variable character and thickness of the lower unit suggest that rapid lateral facies changes initially occurred as the Ladner Group was being deposited on the irregular basement topography underlain by the Spider Peak Formation. The finely bedded siltstones and argillites comprising the middle and upper units of the succession (Figure 5B) are predominantly DE-sequence turbidites (Bouma, 1962), that were probably deposited in a deeper water, lower energy environment.

Overturned flame structures in the vicinity of Carolin mine suggest that the lower part of the Ladner Group was deposited by westerly moving paleocurrents. This agrees with conclusions reached by Coates (1974) in his study farther south. The Ladner Group is consequently interpreted to represent an easterly derived turbidite prism that was deposited on an irregular, westerly inclined paleoslope (Figure 17C). The locally developed lower coarse clastic unit is believed to represent a deep-water, channel-slope or turbidite-fan deposit laid down near the base of the continental rise, and the coarse, limestone-boulder-bearing gravity slide mudstone-conglomerate horizons in the basal part of the Ladner Group suggest the presence of steep submarine gradients during the initiation of the basin.

Dewdney Creek and Jackass Mountain Groups (Units JKJ and JD)

Rocks of the Dewdney Creek Group, as defined by Cairnes (1924, 1944), underlie the Mount Dewdney–Mount Tulameen area (Figure 2) where they form a sequence of tuffaceous sedimentary rocks 3300 metres thick that was deposited in a marine environment. Undiagnostic fossils indicated Early Jurassic to Early Cretaceous age limits, although a Late Jurassic age was preferred (Cairnes, 1924).

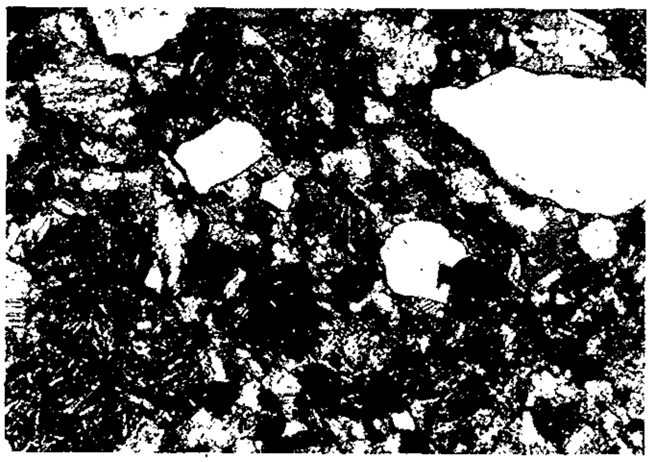


Plate 17. Dewdney Creek Group (Unit JDl). Photomicrograph (X Nicols) of bedded lapilli tuff. Rounded clasts of andesitic volcanic rocks together with subangular fragments of quartz, plagioclase and carbonate in a chloritic-carbonate matrix. Sample taken 1.2 kilometres southwest of Mount Snider.

Farther south, in the Manning Park area, Coates (1970, 1974) used fossil control to restrict the Dewdney Creek Group to a thin, Late Jurassic sedimentary sequence of sandstones, fossiliferous sandy argillites and conglomerates that totalled less than 300 metres in thickness.

During this project, a small area believed to be underlain by the Dewdney Creek Group was mapped on the southwest-facing slopes of Sowaqua Creek, approximately 1.5 kilometres southwest of Mount Snider (Figure 40B). The rocks (Unit JD) include a very immature sequence of massive to poorly bedded, cream to pale green, waterlain crystal-lithic and lapilli tuffs, with some wackes and lithic wackes that locally exhibit sedimentary slump structures. In thin section they are seen to be highly chloritized, poorly sorted rocks containing angular to subangular lithic and crystal fragments, generally between 0.2 and 0.5 millimetre in diameter. A few fragments up to 5 millimetres are also present and clasts of altered basic volcanic lavas and broken feldspar crystals predominate (Plate 17). Fragments of carbonate, quartz, chlorite and extremely fresh diopside are also locally abundant and the matrix is usually chloritic and kaolin-rich.

An interfolded sequence of tuffaceous wacke, lithic wacke, bedded ash and lapilli tuffs and minor siltstone (Unit JD), that outcrops immediately southwest of the East Anderson River (Figure 41A), may represent a northern extension of the Dewdney Creek Group. These tuffaceous sedimentary rocks vary from massive to well bedded and display sedimentary slump structures. The lithic wackes and bedded lapilli tuffs contain basic volcanic clasts up to 2.5 centimetres in diameter, with lesser amounts of carbonate, quartz and plagioclase fragments, set in a carbonate-quartz-chlorite matrix.

North of the East Anderson River (Figure 41A) is a folded, steeply dipping succession of green ash tuffs, lapilli tuffs, wackes and boulder and cobble conglomerates (Unit JKJ) that are interbedded with lesser amounts of siltstone, volcanic sandstone and argillite. This sequence, which is believed to largely represent the Lower Cretaceous Jackass Mountain Group, is separated from the Ladner Group farther west by the northerly trending Anderson River fault (Figure 41A) which follows the Anderson River valley. The coarse conglomerates contain boulders of various sedimentary, volcanic and gneissic rocks, as well as chert and granite. The bedded tuffs, wackes and siltstones exhibit slump structures and some grading indicating that they mostly young westward (Section C-D, Figure 41). The green tuffs, wackes and conglomerates probably belong to the Lower Cretaceous Jackass Mountain Group (Selwyn 1872; Cairnes 1924, 1944), however, bivalves of Late Jurassic age have been found in some fine-grained sedimentary rocks in this area (J.A. O'Brien, oral personal communication, 1985). Thus, the Jackass Mountain Group sequence east of the Anderson River fault apparently contains interfolded or interfaulted units of possible Dewdney Creek Group or Thunder Lake sequence rocks.

Needle Peak Pluton (Unit NP)

The Needle Peak pluton was named by Monger (1970) but was first described by Cairnes (1924). It is of Middle Eocene age (Greig, 1989) and outcrops over an area of 200 square kilometres, intruding and crosscutting the sedimentary rocks of the Methow-Pasayten trough east of Carolin mine (Figure 2). Much of its southeastern contact coincides with a fault along the Coquihalla valley, while a portion of its northwestern margin is possibly offset by 1 to 2 kilometres of dextral transcurrent movement along the Anderson River fault (Figure 2). Cairnes (1924) describes the pluton as a massive, coarse-grained granite and granodiorite that contains biotite and hornblende.

During this study parts of the western margin of the main pluton were mapped (Figures 40A and 41B). This contact is characterized by swarms of various minor felsic and basic intrusives and a wide thermal metamorphic aureole that overprints the Ladner Group country rocks. The Needle Peak pluton comprises massive, grey to very pale pink, medium to coarse-grained rocks of granitic, quartz monzonitic and granodioritic composition. They include both equigranular and porphyritic varieties that generally contain from 1 to 4 per cent biotite, 15 to 25 per cent quartz, and variable amounts of potassium feldspar and andesine-oligoclase plagioclase. In thin section they are seen to be moderately fresh rocks with some biotite laths being weakly chloritized, while the feldspars are clouded and partially altered. Phenocrysts may exceed 1 centimetre in diameter and include both plagioclase and potassium feldspar that are complexly zoned and contain small randomly orientated flakes of muscovite. Trace to accessory minerals include microcline, chlorite, muscovite, zircon, tremolite, sporadic hornblende and pyrite.

Southeast of Hidden Creek (Figure 41B) the pluton is locally strongly altered and contains quartz veins and small, open cavities lined with euhedral quartz crystals. The altered granodiorite is characterized by a general absence of biotite, but contains variable amounts of muscovite, carbonate and disseminated pyrite. The muscovite forms fresh, coarse flakes and the carbonate occurs as both interstitial crystals in the groundmass and coarser aggregates up to 0.5 millimetre in diameter. The pyrite forms scattered euhedral cubes, and some disseminated skeletal ilmenite is also present.

The thermal metamorphic aureole that overprints the Ladner Group along the western margin of the pluton is generally 0.75 kilometre wide, but may exceed a width of 1.4 kilometres. The hornfelsed slaty argillites and siltstones are distinguished by a siliceous, black appearance and the presence of fine-grained biotite with variable amounts of disseminated pyrite. Some hornfelsed outcrops closer to the pluton are spotted with porphyroblasts of biotite, andalusite and cordierite (Plate 18).

In thin section the hornfelses contain abundant very fine carbonaceous and other opaque material which is responsible for the black colour of these rocks. The groundmass largely comprises fine-grained biotite, quartz and plagioclase which have a pronounced subparallel alignment and have grown along the original S_1 slaty cleavage (Plate 18). Larger, dark red biotite porphyroblasts up to 2 millimetres in length are also present mimetically overgrowing the original chloritic foliation. Locally the hornfelses are cut by thin quartz-feldspar veins containing fresh, coarse biotite crystals and sporadic sericite; the biotite in the veins, in contrast to the porphyroblasts overgrowing the hornfelsic groundmass, does not generally contain opaque inclusions (Plate 19).

Plate 18. Ladner Group argillite (Unit JLa) thermally metamorphosed by the Needle Peak pluton. Photomicrograph (X Nicols) showing euhedral andalusite crystal (upper right) and anhedral cordierite crystal containing abundant inclusions (lower left). The groundmass includes biotite (after chlorite), quartz and fine carbonaceous material.

Plate 19. Ladner Group siltstone (Unit JLs) thermally metamorphosed by the Needle Peak pluton. Photomicrograph (PPL) of siltstone containing fine carbonaceous material and biotite cut by a vein containing quartz and coarse biotite.

The spotted hornfelsic slates generally contain numerous euhedral to subhedral rectangular crystals of chiastolitic andalusite up to 0.4 millimetre in diameter which have overgrown the biotite foliation without disturbance (Plate 18). Less commonly, the spotted slates also contain rounded, diffuse, anhedral cordierite porphyroblasts up to 5 millimetres wide. These crystals are generally packed with opaque inclusions and occasionally exhibit lamellar and sector twinning, as well as some yellow-coloured pinite alteration. Accessory minerals in the hornfelsed metasedimentary rocks include pyrite, pyrrhotite, sericite and chlorite.

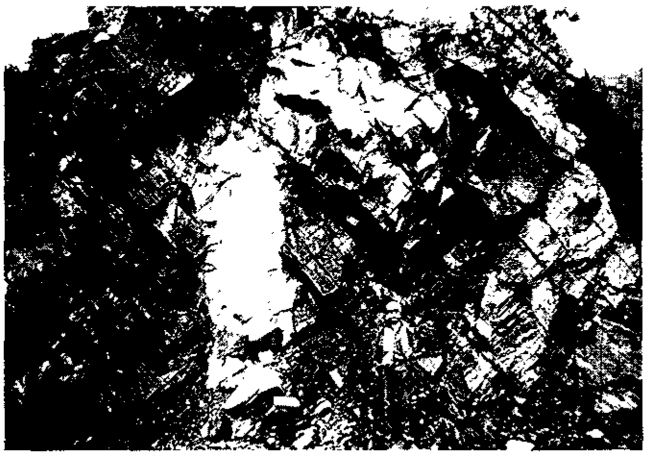


Plate 20. Faulted felsic dyke (Unit f) intruding Ladner Group siltstones (Unit JLs) that are thermally hornfelsed by the Needle Peak pluton; approximately 500 metres west of the Needle Peak pluton margin, 4.5 kilometres east of Stout.

MINOR INTRUSIONS INTO ROCKS OF THE PASAYTEN TROUGH

In contrast to the Hozameen Group, the sedimentary rocks east of the Hozameen fault system contain abundant minor intrusions of uncertain age and highly variable composition. These range from narrow dykes and sills which locally form swarms, to less common but larger bodies up to 300 metres wide. Compositionally the minor intrusions are separable into felsic and basic bodies.

MINOR FELSIC INTRUSIONS

Felsic sills and dykes (Units f, fm and p) are common within the sedimentary rocks of the Methow-Pasayten trough, particularly the Ladner Group, but are apparently absent in both the Spider Peak Formation and the Coquihalla serpentine belt. They vary considerably in texture, mineralogy and appearance, and probably include several different generations of unrelated intrusive material. Some of these rocks are of economic interest as one suite is associated with several gold occurrences, including mineralization at the Ward mine. Some bodies reach up to 30 metres in width, but most are less than 5 metres wide (Plate 20). They vary from single, isolated bodies to dense swarms of sills and dykes that are mostly developed close to the western margin of the Needle Peak pluton. The ages of the felsic intrusions are unknown, although some of the swarms are probably related to the adjacent Middle Eocene pluton. These rocks range from grey to buff to dark brown in colour and are generally leucocratic and strongly altered. They vary from equigranular to coarsely porphyritic and from quartz-rich to quartz-deficient. They are mostly massive but some narrow bodies are weakly foliated, particularly close to their margins. Many bodies are strongly fractured and have faulted contacts, but good crosscutting intrusive contacts are also commonly seen (Plate 20). Narrow, bleached wallrock-alteration envelopes, seldom more than 15 centimetres wide, are present adjacent to some of the thicker felsic bodies, but no thermal metamorphic biotite, cordierite or garnet were identified in them.

The felsic sills are generally alkalic and range from monzonite to granodiorite in composition; many are highly feldspathic, sodium-rich (Appendix 7A) and are characterized by abundant albitic plagioclase (An_{6-12}) both in the groundmass and as large phenocrysts. In thin section the feldspar porphyry sills (Unit p) are seen to contain subhedral to partially resorbed, rounded stubby crystals of twinned albite-oligoclase that are generally 1 to 4 millimetres in diameter, but which may reach 3 centimetres in length. These phenocrysts are moderately altered, generally zoned and are randomly orientated; they vary from isolated matrix-supported crystals, to densely packed masses of coarse phenocrysts. The groundmass mostly comprises an interlocking mosaic of altered albite-oligoclase plagioclase crystals up to 0.2 millimetre in diameter, intergrown with variable amounts of quartz (0 to 15 per cent). Other groundmass minerals include chlorite (up to 15 per cent), sericite (up to 3 per cent) and carbonate (up to 3 per cent) with traces of epidote, clinozoisite, zircon, pyrite and magnetite. Many of the porphyritic sills contain up to 90 per cent feldspar, and mafic minerals are generally rare. However, chloritic pseudomorphs after original hornblende crystals, up to 1 millimetre in length, are locally recognizable. In the Gilt Creek area, southeast of Alexandra Bridge (Figure 41B), some of the predominantly feldspathic, feldspar porphyry sills contain and grade into equigranular hornblende-rich dioritic phases. These mafic rocks are fresh to moderately altered and contain up to 60 per cent hornblende that forms interlocking, pale green crystals up to 3 millimetres in length. They also contain up to 5 per cent quartz, up to 35 per cent plagioclase of An_{30-40} composition, and variable amounts of clinozoisite, epidote, carbonate, sphene, ilmenite and magnetite.

The quartz porphyry sills and dykes in the Ladner Group (Unit p) closely resemble the more widely developed feldspathic varieties in appearance and texture, except they contain rare, partially resorbed and rounded, highly strained quartz phenocrysts up to 2 millimetres in diameter. They also contain abundant albitic plagioclase phenocrysts as well as minor amounts of potassium feldspar megacrysts. The plagioclase phenocrysts are up to 4 millimetres in diameter, strongly altered to sericite, and have clouded cores and clear margins. Most of the quartz porphyry sills are highly leucocratic, but some contain up to 1 per cent biotite as poikiloblastic laths up to 1 millimetre in length. Accessory minerals include chlorite, zircon, carbonate, sericite, epidote, carbonate, pyrite, magnetite and ilmenite.

The swarm of felsic dykes and sills cropping out near the Needle Peak pluton, approximately 4.5 kilometres east of Stout (Figure 41B), includes at least three suites. These are: (1) coarse feldspar porphyries which are common and widespread, (2) less common quartz-feldspar porphyries with rounded quartz phenocrysts, and (3) rare, equigranular, siliceous dacitic sills and dykes containing biotite and variable amounts of pyrite. The latter are associated with pervasive pyritization in the wallrocks and are apparently related to a pyrite-chalcopyrite-molybdenite showing situated at UTM 620100E; 5498500N (Figure 41B).

Some analyses of albite-rich felsic sills within the Ladner Group near the Pipestem and Emancipation mines and from east of Carolin mine are shown in Appendices 7A and 7B.

These rocks are characterized by low iron and potassium and high alumina and sodium contents which reflect their feldspathic and albitic composition. One felsic sill at the Pipestem mine contains late paragonite while others commonly contain traces of a radiating, acicular, translucent mineral that x-ray diffraction studies suggest is probably the hydrated manganese oxide todorokite (Y.J. Kwong, personal communication, 1982).

Two additional distinct and rare types of felsic intrusion warrant mention. One of these is seen in a single biotite-garnet-bearing granitic sill, 0.6 metre thick, that intrudes the hornfelsic Ladner Group argillites close to the Needle Peak pluton between Boston Bar and Ladner creeks at UTM 629100E; 5484000N, (Figure 40B). This rock comprises early, deformed phenocrysts of altered potassium feldspar up to 2 millimetres in diameter, set within a clear, unaltered granoblastic mosaic of small (<0.2 millimetre) quartz, plagioclase and potassium feldspar crystals. The fresh biotite, which makes up to 5 per cent of the rock, forms a pronounced foliation oriented subparallel to the sill margins. Individual biotite laths reach 0.5 millimetre long, but clusters exceed 3 millimetres in length. The biotite is cut by large secondary muscovite flakes, and the rock contains small (0.2 to 1 millimetre) euhedral, pale pink and clear garnet crystals. Accessory minerals include epidote, pyrite, magnetite and ilmenite.

The other distinctive felsic intrusive suite is represented by several narrow (0.6 to 2 metres) dykes that intrude the Ladner Group just south of the Ladner Creek–Coquihalla River confluence (UTM 627440E; 5483080N). These medium-grained, grey-coloured and ophitic-textured rocks largely comprise andesine-labradorite laths up to 1.5 millimetres in length; some plagioclase crystals are bent. Large rounded clots of carbonate, up to 2 millimetres in diameter and rimmed by chlorite, occur within the groundmass plagioclase; these may represent amygdules. The dykes also contain traces of biotite rimming the opaque minerals, as well as some sphene and apatite.

MINOR BASIC INTRUSIONS (UNIT h)

Minor basic intrusions within the Methow-Pasayten trough range from quartz diorite to diorite to gabbro in composition, from light to dark, and from fine to very coarse grained. It is believed that several generations of basic intrusion are present. Generally they occur as single, thin, isolated sills and dykes. However, swarms of basic sills are developed locally and some larger bodies reach 300 metres in thickness.

The largest basic body within the Ladner Group, which is here formally named the Sowaqua Creek stock, outcrops at an elevation of 1160 metres (3800 feet) on the southwest-facing slope of the Sowaqua Creek valley, approximately 2 kilometres southwest of Mount Snider (Figure 40B). It is an oval-shaped, coarse-grained, equigranular and massive body up to 300 metres wide and 700 metres long that ranges in composition from quartz diorite through diorite to gabbro. Its mafic content varies considerably. The margins are grey coloured, leucocratic and highly feldspathic; they are monzonitic to quartz dioritic in composition and locally contain less than 5 per cent mafic minerals. Most of the body

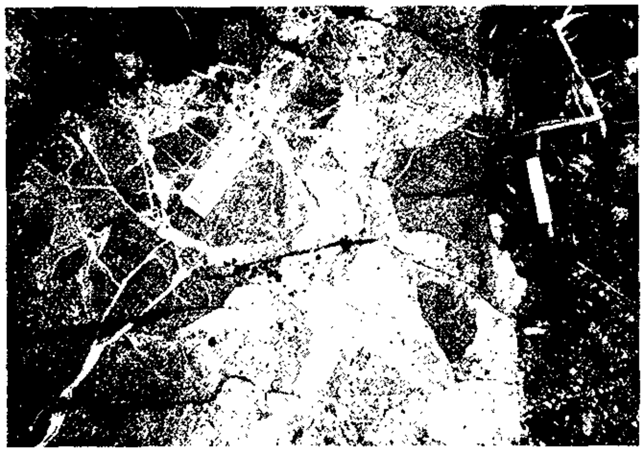


Plate 21. Sowaqua Creek stock (Unit h). Mafic gabbro-diorite containing xenoliths of ultramafic hornblendite (left of hammer) both of which are crosscut by late veinlets of leucodiorite. Outcrop 1.9 kilometres southwest of Mount Snider.

is dark coloured, containing between 20 and 55 per cent mafic minerals, but in parts it comprises highly mafic hornblendite that contains more than 95 per cent coarse amphibole. There is field evidence that the ultramafic hornblendite suite is older than the mafic diorite and the leucodiorite (Plate 21). Angular xenoliths of hornblendite, together with xenoliths of hornfelsed Ladner argillite, are widespread, particularly close to the leucocratic margins of the stock. In some outcrops there are agmatitic, intrusive breccia textures with both the ultramafic xenoliths and mafic diorite being injected by a dense network of leucocratic veins (Plate 21). The adjacent Ladner sedimentary rocks are hornfelsed and contain minor amounts of biotite and cordierite.

Thin section studies show the equigranular marginal phase to be composed mainly (up to 80 per cent) of plagioclase (An_{30-40}) with minor amounts of potassium feldspar. The pale brown, zoned plagioclase crystals exhibit good twinning and ophitic textures; they are weakly altered to epidote and sericite. Augite comprises up to 10 per cent of the rock and forms weakly altered, colourless prismatic crystals up to 4 millimetres in length. The quartz crystals are euhedral and weakly strained, and form up to 5 per cent of the rock by volume. Accessory minerals include chlorite, tremolite, clinozoisite, epidote and ilmenite. Within the more mafic dioritic phases, quartz is absent, pyroxene is less common, but hornblende may exceed 50 per cent by volume. It is commonly strongly altered and may be totally replaced by chlorite, epidote, tremolite-actinolite and clinozoisite. The darker hornblendite comprises up to 95 per cent large, prismatic, interlocking hornblende crystals that are colourless to pale green. The amphibole crystals may exceed 5 millimetres in length and are generally fresh. Augite occurs in trace amounts as small, remnant, corroded cores surrounded by chlorite. Some large chloritic pseudomorphs after euhedral augite are also present. Plagioclase is generally present in only trace amounts as small rounded inclusions of andesine within the hornblende crystals. Other trace minerals include ilmenite, leucoxene and hematite.

Several dioritic sills and dykes, one of which is 70 metres wide and nearly 1 kilometre in length, outcrop between 0.5 and 1.5 kilometres southwest of the Sowaqua Creek stock. These minor intrusions are believed to be coeval and related to the larger body. Some of them have faulted contacts, and are enveloped by narrow thermal metamorphic aureoles that contain quartz and carbonate veining and minor pyrite. The diorites are strongly altered; most of the original pyroxene and hornblende is replaced by actinolite and chlorite, although some small remnant cores of augite are preserved. The andesitic plagioclase, which forms up to 60 per cent of these rocks, is clouded, zoned and weakly altered, and contains small needle-like crystals of tremolite-actinolite. Occasional phenocrysts of altered plagioclase up to 5 millimetres in length are present.

Farther north, east of Ladner Creek, and within or close to the thermal aureole of the Needle Peak pluton, is a northerly trending swarm of mafic sills and dykes of dioritic and gabbroic composition. They are mostly less than 20 metres thick and are probably coeval and related to the Sowaqua Creek stock. However, one oval-shaped basic intrusion outcropping just north of the Coquihalla River (UTM 628850E; 5483700N) is 150 metres wide. This body is similar to the larger Sowaqua Creek stock. It includes a central core of coarse-grained hornblendite which grades outwards to diorite and quartz diorite; toward the margins, the body becomes more leucocratic and feldspathic and the fine-grained chilled margins are siliceous and of granodioritic composition. The intrusion sharply crosscuts bedding in the Ladner Group and the contacts are steeply dipping. The body is weakly cleaved in places; this cleavage is subparallel to the slaty cleavage in the surrounding Ladner Group, which suggests this suite of mafic intrusions was affected by the regional D_2 episode of deformation (*see* Table 3). The adjacent argillites are black, hornfelsed and spotted; they contain an abundance of exceedingly fine grained disseminated carbonaceous material, as well as both well-aligned and randomly orientated red-brown biotite laths up to 0.5 millimetre in length, and some euhedral, inclusion-filled cordierite crystals.

In thin section the hornblendite core of this body is seen to comprise over 90 per cent hornblende forming interlocking, mostly fresh, pale green to pale brown crystals up to 1.5 centimetres in length. There is minor alteration to sericite and chlorite, and the rock contains traces of plagioclase, carbonate, epidote, sphene and pyrite. The dioritic phases are also coarse grained but altered. They contain up to 25 per cent hornblende, forming crystals exceeding 1 centimetre in length, that are rimmed by chlorite. The amphibole crystals contain abundant small opaque inclusions, as well as flakes of randomly orientated biotite. The altered, twinned plagioclase crystals form up to 75 per cent of the rock; they also contain radiating needles of tremolite and minute biotite flakes. Other trace minerals include apatite, zircon, magnetite and ilmenite. The biotite alteration in the amphibole crystals may be due to thermal overprinting by the nearby Needle Peak pluton. The quartz diorite phases of the body contain between 5 and 8 per cent quartz, but the fine-grained chilled margins contain up to 50 per cent quartz. This forms a granoblastic mosaic of minute crystals less than 0.2 millimetre in size, intergrown with clouded, altered plagioclase. This contact phase also contains clusters of muscovite up to 1 millimetre in diameter, traces of biotite, and small, clear, euhedral pink garnet crystals.

The swarms of basic sills and dykes of this suite exposed between Ladner Creek and the Needle Peak pluton contain between 35 and 45 per cent hornblende and 40 to 65 per cent fresh andesine-labradorite plagioclase, as well as accessory chlorite, apatite, carbonate, sphene, ilmenite and magnetite. These sills and dykes, like the larger differentiated body north of the Coquihalla River, have narrow thermal metamorphic aureoles containing biotite and cordierite.

Other minor gabbroic and andesitic intrusives, apparently unrelated to the previously described suite, are found throughout the Ladner Group. For example, a single east-northeasterly trending dyke of porphyritic diorite (Unit h), 2 metres wide, crops out 3 kilometres northeast of Serpentine Lake (UTM 5479600E; 629500E) at an elevation of 1065 metres (3500 feet). It contains euhedral, clouded and zoned phenocrysts of plagioclase up to 2 centimetres in length, set in a groundmass of andesitic plagioclase (60 to 75 per cent) and chloritized hornblende (up to 20 per cent). Accessory minerals include tremolite-actinolite, quartz and sulphides. Several minor dioritic and gabbroic bodies cut the Ladner Group north of Siwash Creek, and possible Dewdney Creek wackes and tuffs (Unit JD) southwest of the East Anderson River. These rocks contain up to 70 per cent pale brown hornblende as stubby, weakly chloritized crystals, and 25 to 50 per cent altered andesine-labradorite plagioclase.

STRUCTURAL GEOLOGY

GEOLOGICAL HISTORY OF THE HOPE–BOSTON BAR AREA

A history of the geological events believed to have occurred west and east of the Hozameen fault is outlined respectively in Tables 2 and 3.

The Hozameen, Petch Creek and Pasayten faults separate four contrasting crustal units whose relationships to one another are still poorly understood; from west to east these units are the Custer-Skagit gneiss, the Hozameen Group, the Methow-Pasayten trough and the Mount Lytton–Eagle plutonic complex. The sedimentary rocks in the trough are mainly turbidite and successor basin deposits ranging in age from Early Jurassic to Middle Eocene. The oldest sedimentary sequence, the Ladner Group, has been interpreted to represent either fore-arc sediments (Anderson, 1976) or a turbidite prism laid down along the margin of an oceanic or back-arc basin (Ray, 1986b); they were unconformably deposited on a westerly inclined paleoslope underlain by the Spider Peak Formation. The Spider Peak Formation, on the basis of tenuous microfossil evidence, may be Early Triassic in age; it is characterized by sodic, ocean-floor subalkaline basalts that probably formed in a spreading-ridge environment.

The Hozameen Group includes basaltic greenstones, ultramafic rocks and thick sequences of chert, and is interpreted to be an ophiolite suite. Its volcanic rocks include both island arc tholeiites and ocean island–seamount assemblages, but mid-oceanic ridge basalts (MORB) are absent. Dewey (1974) suggested that many ophiolites formed within marginal back-arc basins; some, such as the classical Troodos ophiolites on the island of Cyprus, show evidence of crustal extension such as sheeted dyke complexes (Gass, 1967; Moores and Vine, 1971), but possess island arc geochemical characteristics (Miyashiro, 1973; Schmincke *et al.*, 1983). Robinson *et al.* (1983) concluded that the island arc at Troodos was immature and formed over relatively thin oceanic crust. A similar environment is inferred for the Hozameen Group arc volcanism; the scarcity of pyroclastics may reflect both its immaturity and its initial development in deep water, although there are indications that the upper parts of the succession were deposited in a more shallow marine environment.

The Hozameen Group in the Maselpanik area of southwestern British Columbia (Figure 2) and Jack Mountain area of Washington State ranges in age from Permian to Middle Jurassic (Haugerud, 1985). Thus, the upper portion of the Hozameen Group is time equivalent to the lower part of the Ladner Group. Haugerud (1985) recognized two basaltic eruptive episodes in the Hozameen Group which produced a Permian tholeiitic suite and an Upper Triassic ocean island–seamount suite. These may be stratigraphically equivalent to the two volcanic suites recognized in the Hope–Boston Bar area, although the lack of fossil control makes this correlation tenuous. The geochemical evidence (Potter, 1983; Haugerud, 1985; this study) suggests that these two volcanic suites are regionally developed throughout the Hozameen Group and Bridge River complex and thus represent a fundamental feature of the basin volcanism.

Due to sparse data, the relationships between the Hozameen Group and Methow-Pasayten trough are still controversial and two divergent views have been suggested. O'Brien (1987) argued that contrasting volcanic geochemical signatures for the Hozameen Group and Spider Peak Formation indicate they were not closely associated prior to Jurassic time. Alternatively Ray (1986b) considered the rocks on either side of the Hozameen fault to be related, rather than independently developed elements juxtaposed by later plate movement; it was argued that the rocks of the Hozameen Group, Spider Peak Formation and Methow-Pasayten trough were deposited in a single, long-lived oceanic or marginal basin.

The early history of this basin involved development of a Permo-Triassic subduction-related volcanic arc and eruption of the Hozameen Group arc tholeiites (Figure 17A). Continuing subduction was accompanied farther east by back-arc spreading and development of a marginal basin; sea-floor rifting in this basin resulted in Early Triassic volcanism responsible for the Spider Peak Formation (Figure 17A). Throughout the Triassic, deposition was mainly characterized by deep-water cherts; however, the presence of both arc tholeiite and ocean island–seamount volcanic rocks in the Hozameen Group suggests that they may have been deposited in a multi-rifted back-arc basin. Proposed models for such complexly rifted marginal basins indicate that they involve oblique spreading and subduction movements and form above shallow-dipping subduction zones (Dewey, 1980; Tamaki, 1985). The apparent absence of a mature volcanic arc in the Hozameen Group may reflect its removal from the region either by oblique sea-floor spreading or later transcurrent faulting (Figure 17B).

During Middle to Late Triassic time the subduction zone apparently migrated eastward (Figure 17B) and the easterly subduction of oceanic lithosphere then took place beneath rocks of the Mount Lytton–Eagle plutonic complex to produce the Nicola arc (Monger *et al.*, 1972; Godwin, 1975; Monger, 1975, 1977; Anderson, 1976; Preto, 1979). However, the relationship between the plutonic complex to the east and rocks of the Methow-Pasayten trough and Hozameen Group to the west is uncertain (Figures 17B and 17C) because the timing and amount of transcurrent movement along the Pasayten fault is unknown. Despite its easterly derivation, the lack of tuffaceous material in most of the Ladner Group (apart from the lowermost units), and the preponderance of argillites laid down in a low-energy environment, argue against deposition in an active fore-arc basin. There are indications, however, that the Late Jurassic Thunder Lake sequence of O'Brien (1987) and the Cretaceous and younger sediments in the trough were deposited in a fore-arc environment. No convincing evidence exists that the eroded rocks of the Mount Lytton–Eagle plutonic complex contributed to the Methow-Pasayten trough until Cretaceous time, and the sedimentation in both the Ladner

TABLE 2.
HISTORY OF EVENTS WEST OF THE HOZAMEEN FAULT

Age	Event
	Late faulting — A southeast to south-southeast-trending set followed by a northeast to north-northeast-striking set.
16–35 Ma (Oligocene to Early Miocene)	Intrusion of the Chilliwack batholith.
	Major dextral transcurrent displacement along the Petch Creek and Hozameen faults; this was possibly related to the right-lateral movements along the Fraser fault system.
40–44 Ma (Late Eocene)	Intrustion of the Hells Gate pluton into the Custer-Skagit gneiss (Wanless, *et al.*, 1973).
?	Local kink folding and development of a strain-slip cleavage.
Post Mid-Cretaceous	D_2 — open, upright folding with southeast-striking axial planes and subhorizontal axes.
Post Mid-Cretaceous	D_1 — asymmetric, open to tight, similar folding with southeast-trending axial planes and subhorizontal axes, associated with the development of the regional S_1 slaty cleavage. Possibly related to the easterly overriding of the Hozameen Group onto the Pasayten trough rocks along a precursor structure to the Hozameen fault.
Permian to Jurassic	Hozameen Group volcanism and sedimentation, possibly in a multirifted marginal back-arc basin environment.

TABLE 3.
HISTORY OF EVENTS EAST OF THE HOZAMEEN FAULT

Age	Event
	Late faulting — A southeasterly trending set followed by a northeast to east-northeasterly striking set.
21 Ma (Early Miocene)	Deposition and emplacement of the Coquihalla volcanic complex.
	Regional dextral strike-slip movement along the Hozameen fault and minor transcurrent displacement along the Chuwanten fault; possibly related to right-lateral movement along the Fraser fault system.
46 Ma (Late Eocene)	Intrusion of the Needle Peak pluton and related felsic dyke swarm into the Pasayten trough rocks.
?	Local kink folding and development of a strain-slip cleavage with axial planes striking east-southeast and south.
Post Mid-Cretaceous	D_3 — asymmetric folding in the Ladner Creek area, but no associated metamorphic axial planer fabric was developed.
Post Mid-Cretaceous	D_2 — major concentric to similar-type, open to tight, upright to asymmetric folding in the Ladner Group with southeasterly striking axial planes and subhorizontal axes; development of the regional S_1 axial planer slaty cleavage occurred with extensive late D_2 flattening and formation of the L_1 lineation.
Post Mid-Cretaceous	D_1 — oblique, easterly directed thrusting along the precursors to the Hozameen and Chuwanten faults, causing local structural inversion of the Ladner Group and Spider Peak Formation.
Early Cretaceous to Middle Eocene	Closure of the Pasayten trough.
Early Jurassic to Early Cretaceous	Deposition of the Pasayten trough sedimentary rocks.
~~ Erosional Unconformity ~~~~~~~~~~~~	
? Early Triassic	Spider Peak Formation volcanism occurred, possibly within a spreading back-arc ridge environment.

Group and the upper parts of the Hozameen Group was probably unrelated to, and unaffected by, subduction that occurred farther east toward the Nicola arc (Figure 17C). The Ladner Group was apparently deposited along the eastern margin of an extensive oceanic or back-arc basin; it may represent a proximal facies equivalent to the more distal, Early to Middle Jurassic oceanic sequence (Haugerud, 1985) in the upper part of the Hozameen Group (Figure 17C). During Late Jurassic time, the basin began to close, and by Early Cretaceous time a western margin to the Methow-Pasayten trough had developed (Figure 17D); this was marked by sedimentation from both western and eastern sources (Coates, 1974; Kleinspehn, 1985; Trexler and Bourgeois, 1985). Davis *et al.* (1978) and Trexler and Bourgeois (1985) believed that the trough was generated by dextral wrench faulting during mid-Cretaceous time and that the basin had an active, high-relief western margin with extensive westerly derived fan deltas, and a low, stable eastern margin. However, recent workers (Mohrig and Bourgeois, 1986; McGroder, 1988) argue that the basin was deforming during mid-Cretaceous overthrusting and believe there is little supportive evidence for syndepositional strike-slip activity. McGroder and Miller (1989) present two alternative models for the Oxfordian to Cenomanian evolution of the Methow-Pasayten trough in northern Washington. Their "piggyback model" involved the trough forming and residing in a structurally high position during early and middle Albian time, while in the "foreland model" there was easterly overthrusting of the Hozameen Group, and the trough resided in a structurally low, foreland position. Structural and stratigraphic data from this study support the foreland model with easterly overthrusting of the Hozameen Group along a low-angle, westerly inclined thrust that was a precursor to the Hozameen fault (Figure 17D). Steady narrowing of the trough, accompanied by uplift of the Hozameen Group and Mount Lytton–Eagle plutonic complex during the Early to mid-Cretaceous led to sedimentation from western and eastern sources, and deposition of the Jackass Mountain and Pasayten groups (Figure 17D); episodic sedimentation in the trough continued into the Middle Eocene (Greig, 1989).

During the final closure of the trough, easterly directed movements continued, causing further easterly directed movement along the Hozameen fault and development of the Chuwanten fault (Figure 17E). These faults are now subvertical but structural inversion of the Spider Peak Formation and Ladner Group in the Carolin mine area suggests that the Hozameen fault represents an upturned, easterly directed thrust zone that originally dipped west (Figure 17D and E). The same original orientation is surmised for the Chuwanten fault. The original inclination of the Pasayten fault is unknown although mid-Cretaceous fabrics dip steeply eastward (Greig, 1989). The thrust movement along the Hozameen fault was responsible for the emplacement and development of the Coquihalla serpentine belt. The belt marks a major crustal boundary, a feature that is noted in many other ultramafic belts throughout the world (Shackleton, 1976). Many of these belts represent oceanic crust or upper mantle material emplaced as allochthonous slices during horizontal plate movement (Moores, 1970; Coleman, 1971). This mechanism is believed responsible for thrusting of incompetent oceanic ultramafic basement material along the Hozameen fault to produce the Coquihalla serpentine belt (Figure 17E); the belt represents ultramafic cumulate material derived from oceanic basement beneath the Spider Peak Formation. The spatial association between the Spider Peak Formation and Coquihalla serpentine belt along the Hozameen fault, together with the geochemical similarity of the Coquihalla belt gabbros and Spider Peak greenstones (Figures 9C and 9D), is supportive evidence for the two units being genetically and stratigraphically related. Consequently, the Spider Peak Formation and the Coquihalla serpentine belt are considered to represent oceanic layers 2 and 3 respectively (Cann, 1974); this suggests that the east-directed thrusting took place mainly along the West Hozameen fault, and that the East Hozameen fault is a relatively minor structure.

Following emplacement of the Coquihalla serpentine belt, and local structural inversion of the Ladner Group and Spider Peak Formation, further compression was accommodated by several periods of tight to open folding in rocks of the Methow-Pasayten trough, which were overprinted by a regional slaty cleavage. The histories of the structural deformation west and east of the Hozameen fault are outlined in Tables 2 and 3. This later deformation reoriented the Hozameen fault and Coquihalla serpentine belt into their present subvertical position (Figures 17F, G and H).

The relationship between the Custer-Skagit gneiss and the Hozameen Group is uncertain, as are the ages and timing of movements along the Petch Creek fault. The latter is a major, easterly inclined normal fault that is downthrown to the east. However, the lineations and structural styles identified in the fault suggest it has undergone both ductile and brittle deformations involving early transcurrent and later vertical movements. Ray (1986b) originally suggested that the Petch Creek fault, like the Hozameen fault, developed as a westerly inclined, Cretaceous thrust above which the Custer-Skagit gneiss was moved eastwards over the Hozameen group. Subsequent studies on the Ross Lake fault farther south (Tabor *et al.*, 1989; Miller *et al.*, 1989; Haugerud, personal communcation, 1989) indicate that this hypothesis is unlikely. Instead, the recognition of Middle Eocene ductile extensional deformation in the Custer-Skagit gneiss (Haugerud *et al.*, in preparation) may have coincided with the vertical juxtaposing of deeper level gneisses against Hozameen Group. This suggests that late, normal movement along the Petch Creek fault was related to Tertiary crustal extension. These extensional movements resulted in the emplacement of the Petch Creek serpentine belt which represents a basal part of the Hozameen Group succession (Figure 17G). During the Eocene, the Needle Peak pluton and its possibly related swarm of felsic sills and dykes were intruded into rocks of the Methow-Pasayten trough (Figure 17G). This was preceded and followed by large-scale dextral transcurrent displacement along the Petch Creek and Hozameen faults, similar to that described for other strike-slip faults in the Canadian Cordillera (Roddick, 1964; Tipper, 1969; Monger, 1977; Tempelman-Kluit, 1977). This movement resulted in the regional offset of the felsic dyke swarms (Units p and f) which are common in the Ladner Group, but absent west of the Hozameen fault. If these dykes are related to the 46 Ma Needle Peak pluton, it suggests that the strike-slip offset of the swarm was a post Middle Eocene event. This seemingly contradicts evidence from Washington State where the Hozameen fault is apparently cut and intruded by the 50 Ma Golden Horn batholith (McGroder, 1987). Some transcurrent movement along the Hozameen fault may have been related to dextral motion along the Fraser faults; Vance (1985) suggested that the principal movements along the older Ross Lake fault and younger Fraser faults took place during the Early to Middle Eocene. The major transcurrent faulting in the lower Fraser Canyon ended prior to the intrusion of the 16 to 35 Ma Chilliwack and Mount Barr batholiths (Richards and White, 1970; Richards and McTaggart, 1976; Vance, 1985), which cut across southern extensions of the Fraser and Petch Creek–Ross Lake faults (Figure 2). Consequently, intrusion of the Needle Peak pluton and Chilliwack batholith set maximum and minimum ages for regional transcurrent faulting in the Hope–Boston Bar area.

Faulting in the District

The sequence of faulting in the Coquihalla district is not clearly understood because of the complex, long-lived history of fracturing and lack of age constraints. The two most important fractures, the Petch Creek and Hozameen faults, mark major crustal boundaries, are associated with ultramafic belts, and have undergone both vertical and transcurrent movements. The northerly trending Petch Creek fault is believed to be a northern extension of the Ross Lake fault; it dips steeply to moderately east, and the locally developed subhorizontal mylonitic and rodding fabrics indicate it underwent ductile, possibly dextral transcurrent movement. Overall it represents a normal fault that was downthrown to the east (Figure 17G). The Hozameen fault is mostly a steep east-dipping structure. It underwent an early, easterly directed episode of oblique thrust displacement that resulted in the upthrown Hozameen Group being moved eastwards over the less deformed and less metamorphosed Ladner Group (Figures 17D and E). This overthrusting caused local tectonic inversion of the Spider Peak Formation and Ladner Group, and thrust thin, fault-bounded slices of the formation into the Ladner Group succession; two thrust slices of Spider Peak Formation within the Ladner Group are seen at Carolin mine (Figure 42).

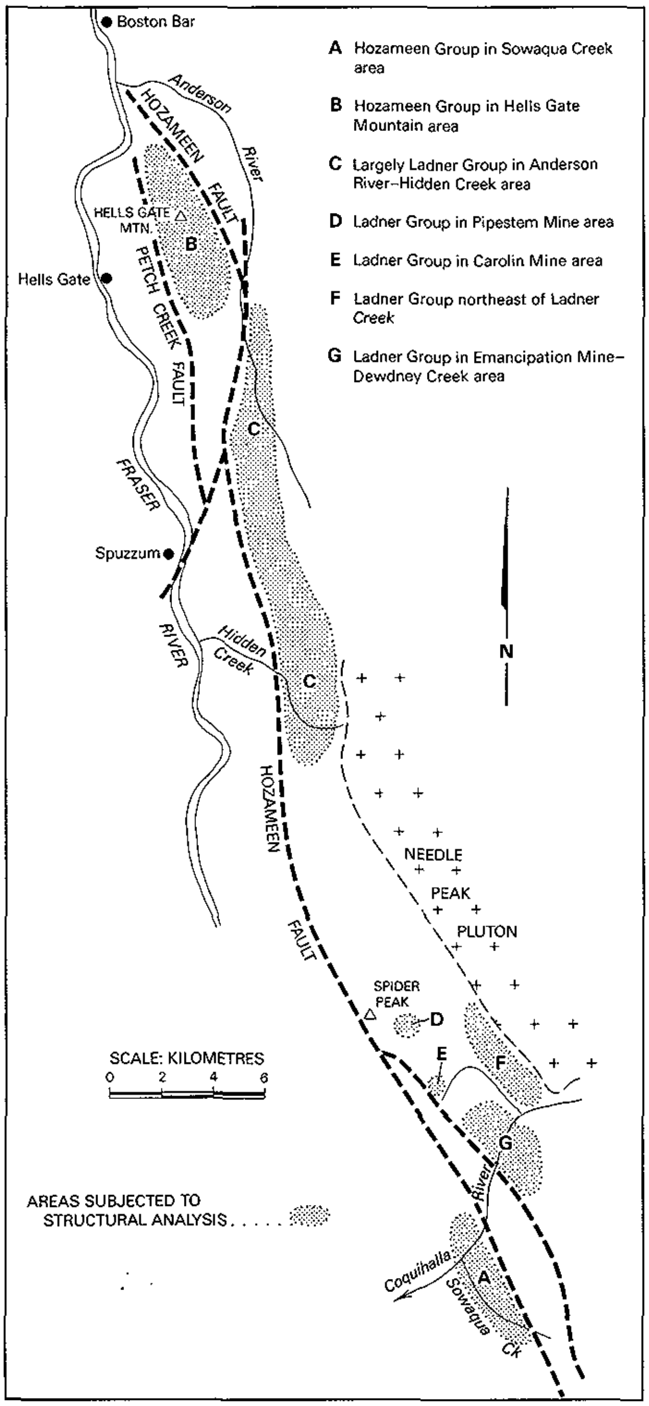


Figure 18. Areas adjacent to the Hozameen fault that were subjected to structural analysis (see Figures 19 and 20).

Where the Hozameen fault is spatially associated with the Coquihalla serpentine belt, it is separable into two fractures that bound the belt, the East and West Hozameen faults. The East Hozameen fault is a brittle, normal structure that generally separates the serpentine belt from either the Spider Peak Formation or the Ladner Group. Since the serpentinite and Spider Peak Formation are believed to be stratigraphically related, it suggests that the East Hozameen fault has undergone relatively minor displacement (Figure 17H). By contrast, the West Hozameen fault is believed to have been the main locus of both early overthrusting of the Hozameen Group, and later transcurrent, dextral displacement. Intense, subhorizontal linear structures are more prevalent in the Hozameen Group immediately adjacent to the West Hozameen Fault, and the main transcurent movement is believed to have been a post Needle Peak pluton (46 Ma) event.

The Anderson River fault, which follows the Anderson River valley and trends subparallel to the Hozameen fault system, is not exposed. It is believed to be a steeply dipping structure that was downthrown to the east, and it separates younger sediments of the Jackass Mounain Group from Ladner Group rocks farther west. There is an increased development of a phyllitic foliation in argillites close to the fault, which are locally deformed by kink or strain-slip fold structures.

The Petch Creek, Hozameen and Anderson River faults are crosscut and displaced by a set of north-northeast to northeast-striking fractures. Movement along these younger faults is typically right lateral; this is best seen north of Spuzzum, where the Hozameen fault is displaced 7 to 8 kilometres. To the north these younger faults appear to merge into the north-striking Anderson River fault (Figure 41A and 41B). Another group of northeast to north-northeast-striking faults is seen southeast of Serpentine Lake (Figure 40B), where they cut the Coquihalla serpentine belt and Hozameen fault with right-lateral offset. They represent a southwestern extension of the Coquihalla fault (Monger, 1989).

STRUCTURAL ANALYSIS OF THE DISTRICT

Structural data collected during detailed geological mapping in seven different areas throughout the district were subjected to statistical analysis; the location of these areas is shown on Figure 18 and various computer-generated contoured stereoplots of the data are presented on Figures 19 and 20. Two of the study areas are underlain by Hozameen rocks

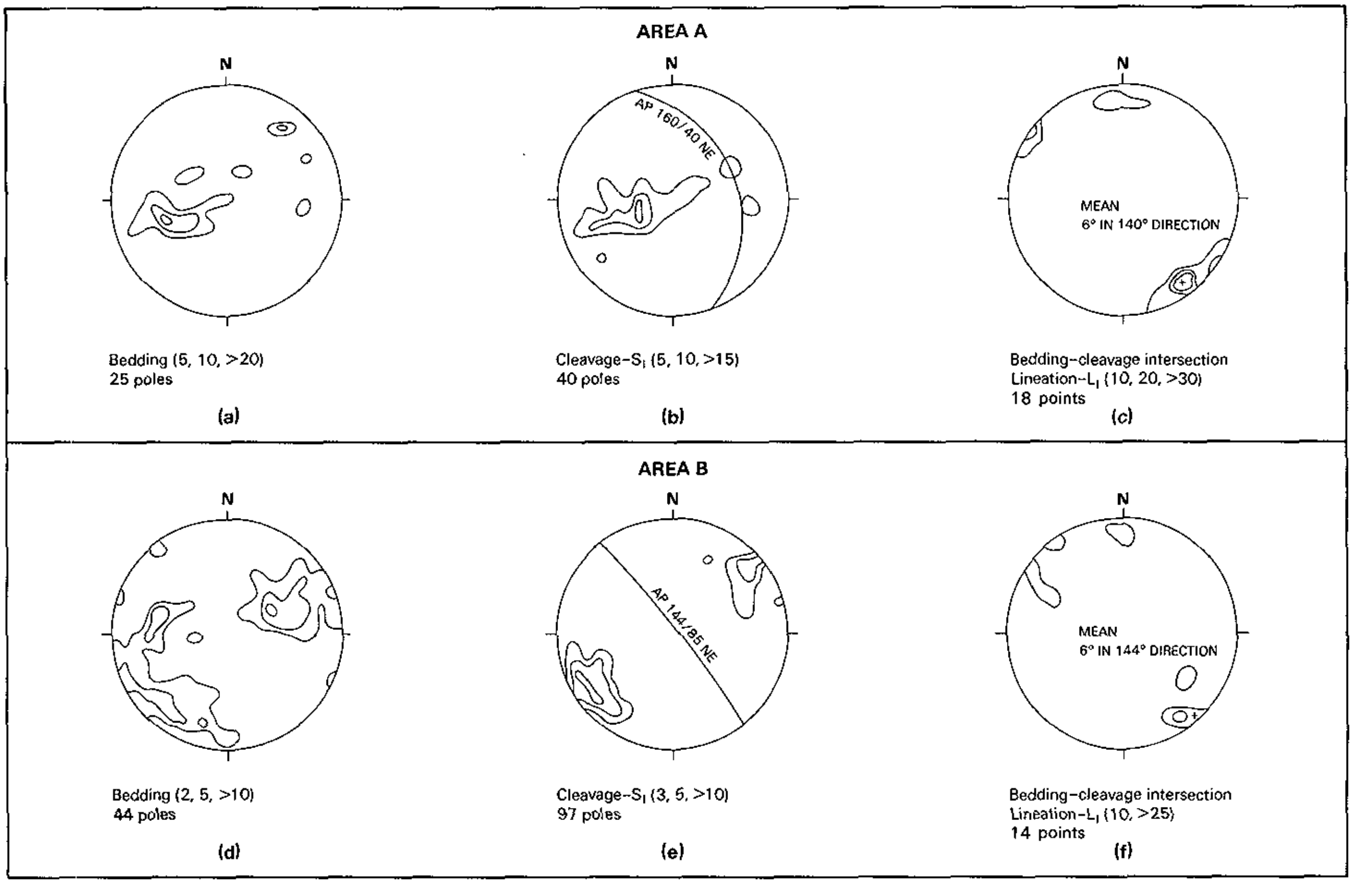


Figure 19. Structures in the Hozameen Group within the Sowaqua Creek (Area A) and Hells Gate Mountain (Area B) areas. Lower equal-area projections. (a) and (d) = poles to bedding; (b) and (e) = S_1 cleavage; (c) and (f) = L_1 lineation. Numbers in brackets are computer-generated contour intervals in per cent. AP = axial plane.

(Figure 18) while the five remaining cover the Ladner Group and include areas surrounding the Pipestem, Carolin and Emancipation mines. The structural history and fold styles seen in the Hozameen and Ladner groups show some similarities. For example, in both groups the most conspicuous episode of regional minor folding was concentric to similar in style and was associated with the formation of the regional axial planar slaty cleavage (Tables 2 and 3). However, it is uncertain whether these two fold episodes that occurred either side of the Hozameen fault system were coeval, correlatable events.

Structures in the Hozameen Group

Two major episodes of folding are recognized in the Hozameen Group (Table 2). Following the easterly overthrusting along the precursor to the Hozameen fault (Figures 17D and E), the rocks were deformed by major and minor D_1 structures. These are best seen in the ribbon cherts where the bedding is deformed by minor asymmetric open to tight similar folds (Figure 19a and d) that have subhorizontal to gently southeast-plunging axes (Figure 19c and f) and southeast striking axial planes (Figure 19b and e). Most of these folds are upright, but in some areas, particularly close to the East Hozameen fault, they may have moderately dipping axial planes (Figure 19b) or even be recumbent. The D_1 folding is associated with the formation of a regional slaty cleavage (S_1); an L_1 lineation resulting from the intersection of this cleavage with bedding is widely developed subparallel to the D_1 fold axes (Figure 19c and f). Adjacent to the East Hozameen fault the Hozameen Group is characterized by gently plunging rodding and mullion structures that overprint the rocks with an intense, linear fabric. This rodding plunges subparallel to the L_1 lineations, but it developed during later strike-slip movement along the East Hozameen fault.

Locally the S_1 slaty cleavage in the Hozameen Group is deformed by a second generation of open, concentric, upright folds (D_2) with southeasterly striking axial planes and subhorizontal axes. It is possible that this second deformation is related to an episode of kink folding that produced a strain-slip cleavage in the more slaty, argillaceous rocks (Table 2).

The precise ages of the D_1 and D_2 structural events are unknown, but they are believed to be post-mid-Cretaceous to pre-Late Eocene in age.

Structures in the Ladner Group

At least three major phases of deformation are recognized in the Ladner Group (Table 3). The first (D_1) is believed to be related to major easterly directed thrust movements along the precursor structure of the Hozameen fault, which resulted in the easterly overriding of the Hozameen Group onto rocks of the Methow-Pasayten trough (Figure 17D and E). This caused local tectonic inversion in both the Ladner Group and

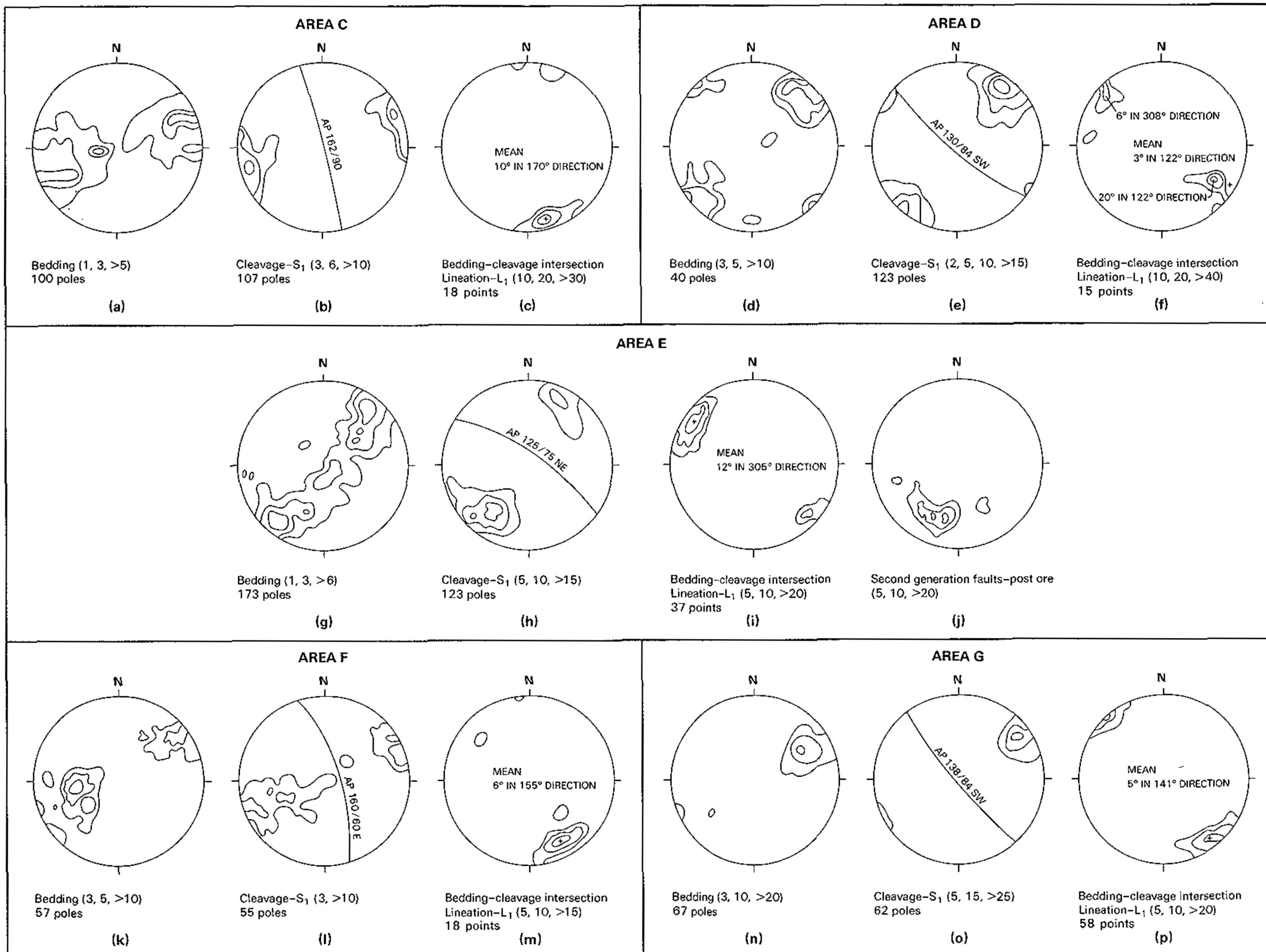


Figure 20. Structures in the Pasayten trough sedimentary rocks in the Anderson River–Hidden Creek (Area C), Pipestem mine (Area D), Carolin mine (Area E), northeast of Ladner Creek (Area F) and Emancipation mine–Dewdney Creek (Area G). Lower equal-area projections — poles to bedding, S_1 cleavage and L_1 lineations. Numbers in brackets are computer-generated contour intervals in per cent.

Spider Peak Formation close to the fault. The inversion is documented in the Carolin mine area (Figure 42) although no D_1-related folds or structural and/or metamorphic planar fabrics are positively identified. However, abrupt changes of sedimentary facing direction in some fault-bounded sections of the Ladner Group (Figure 42) may be due to unrecognized isoclinal D_1 folding and very rare, rootless isoclinal minor folds present in the Ladner Group at Carolin mine may be D_1 structures.

The second deformation (D_2) is the most important and widely recognized structural event affecting the rocks in the Methow-Pasayten trough. D_2 folds are particularly well developed in the Carolin mine area (Figure 42, Plate 22) and are economically important because the hinge zone of a major D_2 antiform is an ore control (Figure 29). The D_2 event folded the bedding into upright and overturned minor and major folds. Near Carolin mine it folded and overprinted the previously inverted Ladner Group rocks and produced folds having wavelengths of 60 to 110 metres and amplitudes of 25 to 50 metres (Figure 42). The D_2 folds vary from concentric to similar in style and some of the tighter folds have disrupted, faulted hinges and limbs, along which quartz veins are locally injected (Plate 22). The folding was accompanied by regional development of the prominent axial planar slaty cleavage (S_1) that overprints the Ladner argillites and siltstones (Figure 20b, e, h, l and o). The bedding-cleavage intersection lineations (L_1) are oriented subparallel to the D_2 fold axes, but both the slaty cleavage and intersection lineations are generally absent in the Ladner Group wacke units. Stereoplots of the bedding and (S_1) cleavage data from throughout the district (Figure 20) show that the D_2 folds have southeast to south-southeasterly striking axial planes that vary from steeply northeast to southwest-dipping. Bedding-cleavage intersection lineation (L_1) measurements indicate that the D_2 fold axes are remarkably uniform throughout the district, plunging either gently northwest or southeast (Figure 20c, f, i, m and p).

Plate 22. Ladner Group siltstones (Unit JLs) deformed by D_2 folds. Note quartz veins injected along disrupted hinge zones. Drill-road outcrop 290 metres east-northeast of old Idaho adit, Carolin mine.

The third phase of folding (D_3) to affect the Ladner Group resulted in the local warping of the S_1 cleavage; it produced gentle to open, upright to asymmetric minor folds with subhorizontal axes and southeasterly striking axial planes, but has no associated cleavage (Table 3). A major fold of this age is believed responsible for the change in attitude of the S_1 cleavage across the Ladner Creek valley northeast of Emancipation mine. Minor kink folds that are locally developed in the Ladner siltstones and argillites may be related to the D_3 episode. These kink folds are associated with a conjugate set of strain-slip cleavages.

Subsequent to the D_1 overthrusting event along the Hozameen fault, at least three episodes of faulting affected the Ladner Group in the Carolin mine area. The first resulted in northwest-trending dislocation zones along some of the F_2 fold hinges and either preceded or accompanied the gold mineralization. The second generation postdates the mineralization and produced both high-angle reverse and normal faults that strike northwest and cut the Carolin orebodies (Figure 29A). A contoured stereoplot of second generation fault attitudes measured at Carolin mine is shown in Figure 20j. These faults follow the S_1 slaty cleavage rather than the sedimentary bedding, and tend to be preferentially concentrated along the hinges and limbs of D_2 folds. The third and youngest fault set strikes east to northeast and includes the northerly dipping Richardson normal fault (Figure 42) which truncates the Carolin deposit. This fault set is also well developed near Spider Peak and apparently offsets the Hozameen fault system.

The Hozameen fault is a complex fracture system that has undergone repeated normal, reverse and transcurrent movement. Near Emancipation mine, the East Hozameen fault has undergone at least two episodes of movement; an early northerly trending fracture set is displaced left laterally by a later southeasterly trending set (Figure 25). In the Spider Peak area the fault system records a complex, poorly understood history of movement; two alternative models are presented to explain the faulting in this area (Figure 21). In the first model an early phase of dextral transcurrent motion along the Hozameen fault was followed by sinistral displacement on the Siwash Creek fault and finally by dextral displacement on the McMaster Pond fault. Alternatively, in the second, more favoured model, the early dextral transcurrent movements along the Hozameen fault were followed by a single episode of high-angle fracturing along the composite Siwash Creek–McMaster Pond faults. This later high-angle fracturing may represent either normal faults downthrown to the east or easterly directed thrusts that originally dipped to the west and were subsequently overturned (Figure 22).

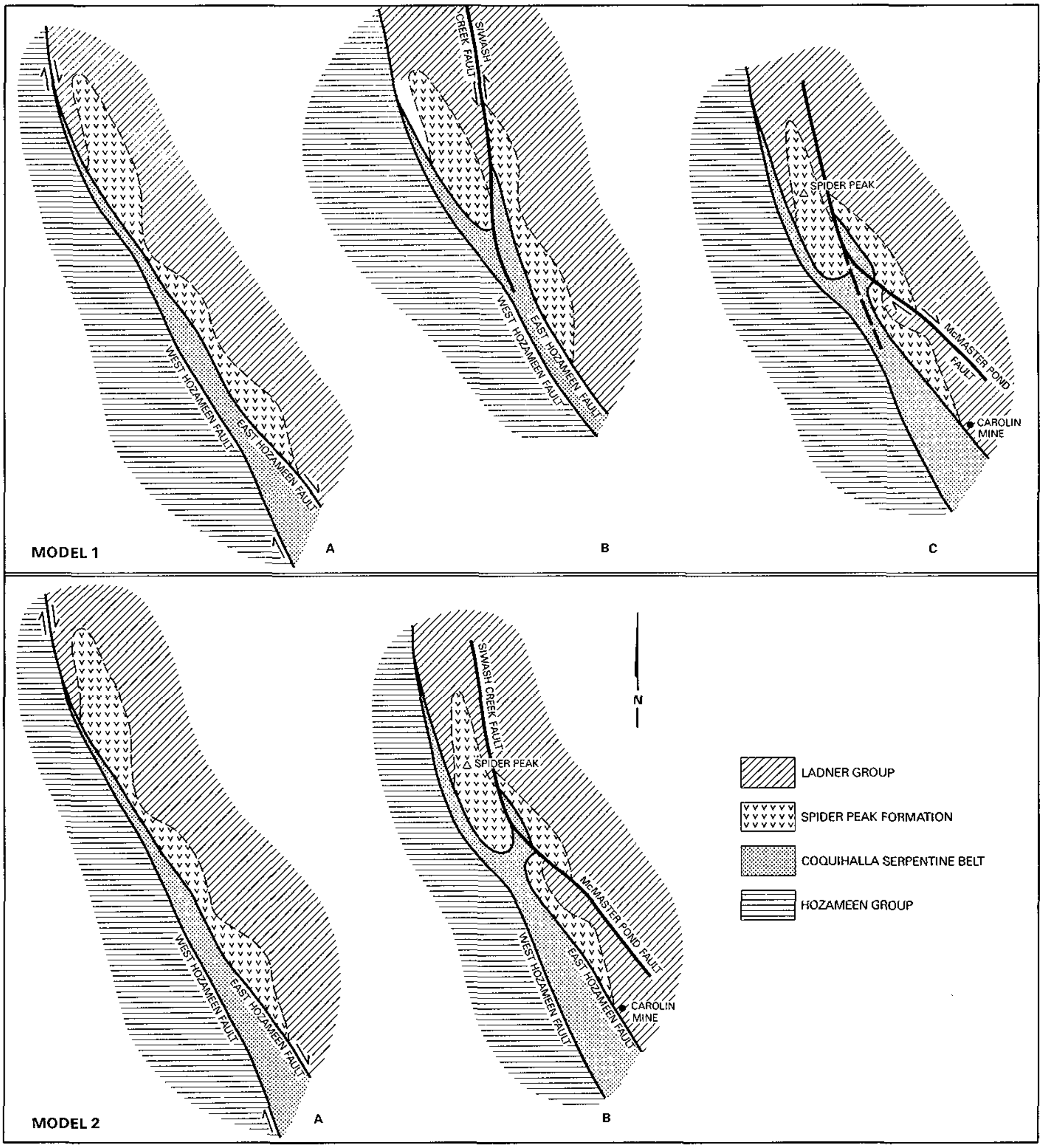


Figure 21. Two alternative models to explain the history of faulting in the Spider Peak area. (Model 1): Dextral transcurrent movement along the Hozameen fault system (A) followed by sinistral faulting along the Siwash Creek fault (B) with subsequent dextral faulting along the McMaster Pond fault. (Model 2): Dextral transcurrent motion along the Hozameen fault system (A) followed by movement along the composite Siwash Creek–McMaster Pond fault, which may represent either a normal fault or an overturned thrust.

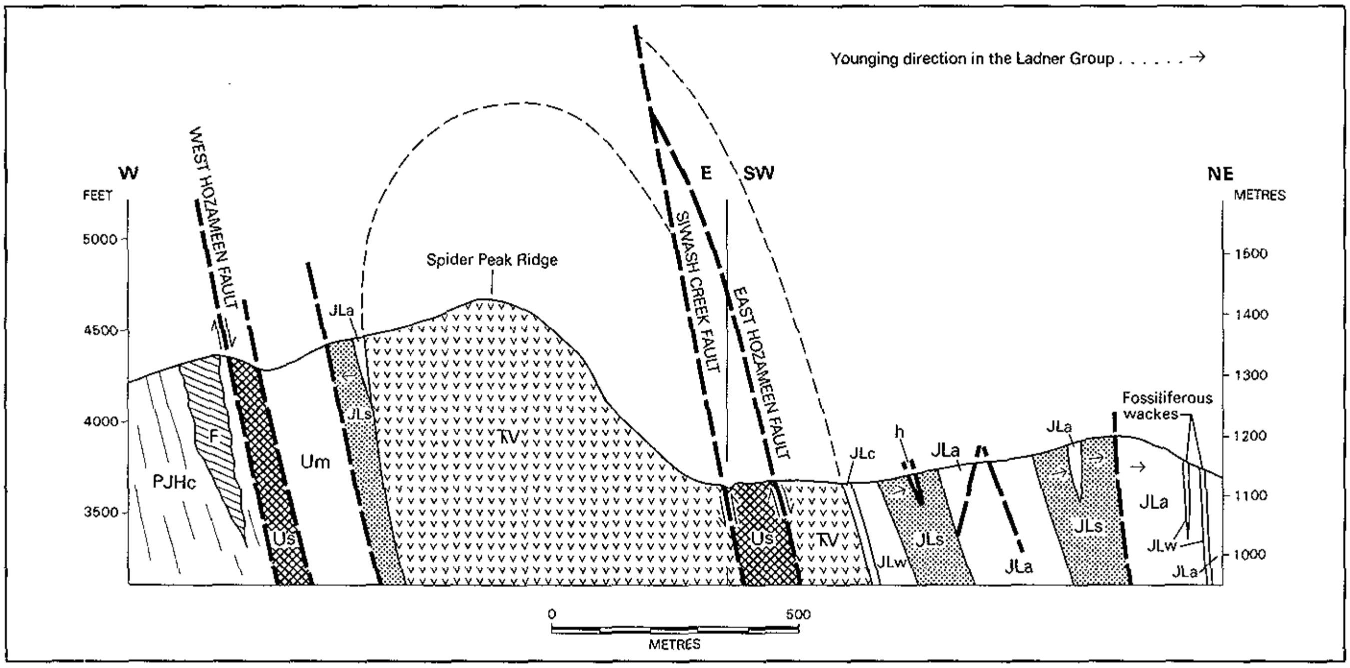


Figure 22. Longitudinal east-west and northeast-southwest section through the Spider Peak area.

ECONOMIC GEOLOGY

The Coquihalla gold belt comprises five past-producing mines (Carolin, Emancipation, Aurum, Pipestem and Ward), and at least 25 minor gold occurrences whose locations are plotted on Figures 23. However, it should be noted that the precise location and the geology of some occurrences reported long ago are uncertain. Nearly all the occurrences and deposits in the belt lie east of, but generally close to, the East Hozameen fault (Figure 23).

PAST PRODUCERS IN THE COQUIHALLA GOLD BELT

Total production from the five mines in the Coquihalla gold belt was 1473 kilograms of gold from just over 800 000 tonnes of ore mined[4] (Table 4). Over 90 per cent of the gold came from one deposit (Carolin mine), and information on the early producers such as the Ward, Aurum and the Pipestem mines is poorly documented and unreliable.

Until the closure of the Emancipation mine in 1941, only 119.0 kilograms of gold had been won from the belt, mostly (90.1 kilograms) from Emancipation mine. During its first year of operation in 1982, Carolin mine produced approximately 253 kilograms of gold which is more than twice the amount won from the entire belt during its previous 80-year history.

EMANCIPATION MINE (MINFILE 092HSW034) (PAST PRODUCER NO. 1, FIGURE 23)

The abandoned Emancipation gold mine is situated approximately 2.5 kilometres southeast of Carolin mine (Figure 24), close to Tangent Creek, a small tributary of the Coquihalla River; it is the most southerly past producer in the belt (Figure 23). Previous literature relevant to the mine includes that by Cairnes (1920, 1924, 1929), Bullis (1971), Cardinal (1981, 1982) and Ray (1984). The mine was originally developed by at least five adits (Adit Nos. 1 to 4 and Adit A) that were surveyed and geologically mapped by Cairnes (1929). These workings were concentrated along a series of gold-bearing quartz ± carbonate veins that cut the Spider Peak Formation; these veins provided the principal ore of the deposit. However, the lower two workings (Adit Nos. 3 and 4; Cairnes, 1929) investigated a wide talc-bearing zone within the East Hozameen fault which separates the Spider Peak greenstones from the Coquihalla serpentine belt. This fault zone, which trends along Tangent Creek, was explored because its lithology and structural setting resemble the very rich gold-bearing talcose shear at the Aurum property (Cairnes, 1929) located approximately 2.5 kilometres to the northwest. However, the talcose zone at the Emancipation mine was apparently barren.

Ore from the quartz ± carbonate veins was transported from the adits by an overhead bucket and cable system to a mill located just above the abandoned Canadian Pacific Kettle Valley railway line. The mill was powered by petroleum-fueled engine and treated approximately 5 tonnes of ore per shift (Cairnes, 1929). The mill foundations are still discernible, but the bucket and cable system has collapsed and no trace of it remains.

The reported annual production from Emancipation mine between 1916 and 1941 is shown in Table 5. A total of approximately 90.1 kilograms of gold and 18.8 kilograms of silver was won from 578 tonnes of ore milled, making it the second largest gold producer in the belt after Carolin mine. The extremely high gold grades determined from the data in Table 5 suggest some sorting of the ore by hand cobbing, particularly during the early period of mining.

[4] These figures do not include the reported, but uncertain, minor production from the Georgia 2 claim (MINFILE 92HNW008) of uncertain location.

TABLE 4.
PRODUCTION FROM THE COQUIHALLA GOLD BELT

Number on Figure 23	Property	Year(s) of Production	Reported ore milled (tonnes)	Reported total production (kg)** Au	Ag	Reference
1	Emancipation	1916-1941	578	90.1	18.8	1
2	Aurum	1930-1942	494	16.5	3.0	1
3	Carolin	1982-1984	799 199*	1354.0	Not reported	2
4	Pipestem	1935-1937	1 498	8.5	1.1	1
5	Ward	1905 and 1911	Not reported	4.2	Not reported	1, 3
Totals			801 689	1473.2	22.9	

References

1. B.C. Ministry of Energy, Mines and Petroleum Resources, Mineral Inventory File.
2. P.W. Richardson, Carolin Mines Ltd., personal communication, 1986.
3. B.C. Ministry of Energy, Mines and Petroleum Resources, Annual Report, 1917.

* Reported tonnes milled at Carolin mine (P.W. Richardson, personal communication, 1986).
** Recalculations of production quoted in troy ounces to grams using conversion factor of 31.103.

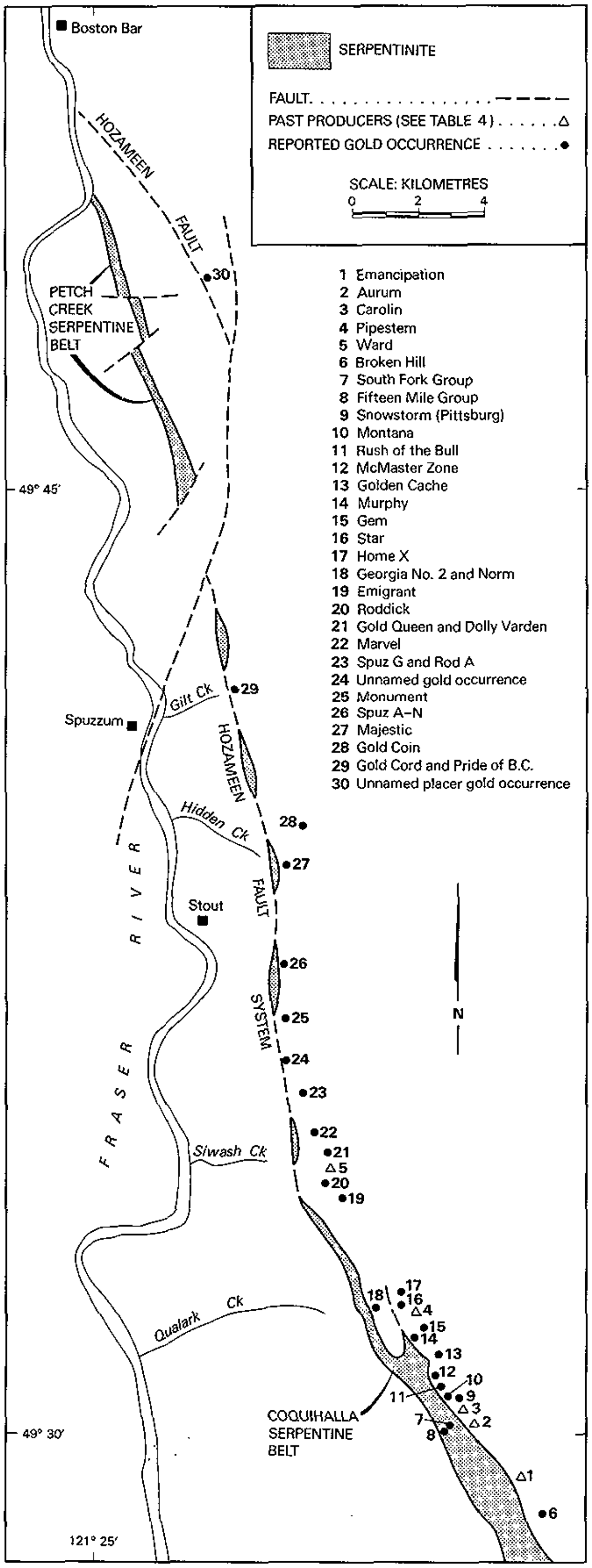


Figure 23. Location of the past-producing mines and minor occurrences comprising the Coquihalla gold belt.

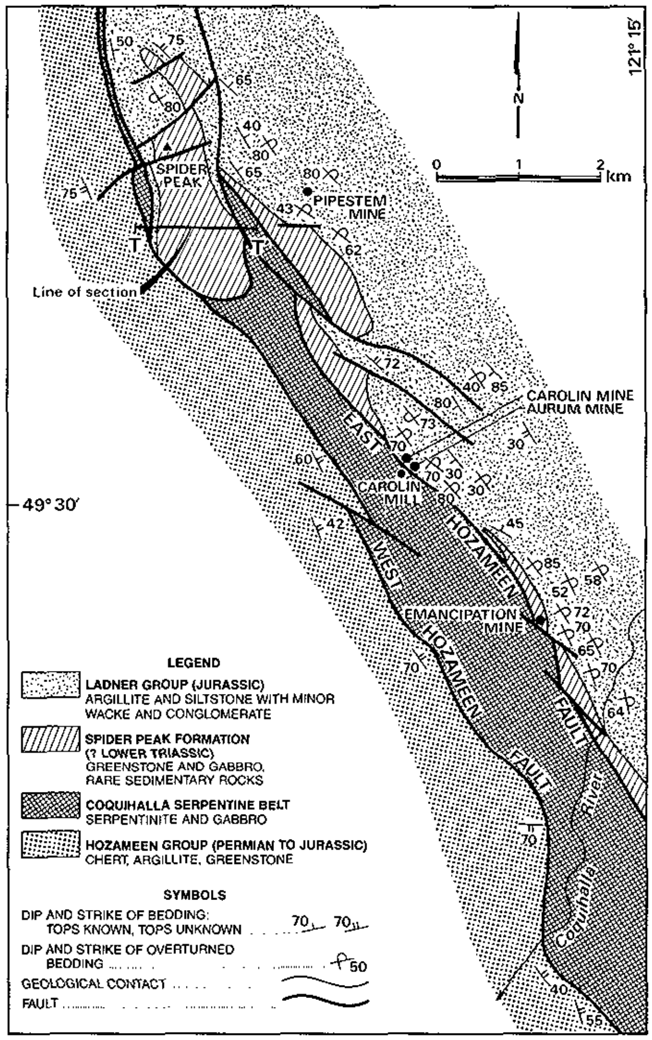


Figure 24. Geology of the area between Spider Peak and the Coquihalla River showing locations of the Emancipation, Aurum, Carolin and Pipestem mines.

For several decades following World War II the mine area was ignored, but during the early 1980s Aquarius Resources Ltd. carried out an exploration and diamond-drilling program (Cardinal, 1981, 1982). The No. 2 adit, which is approximately 180 metres long, contains several crosscuts and provides access to several stopes, was reopened and sampled (Cardinal, 1981). The underground workings accessible from the No. 2 adit were also examined and sampled by the author during this survey.

GEOLOGY AND MINERALIZATION

The geology of the mine area and a diagrammatic geological section through the deposit are shown on Figures 25 and 26. The Ladner Group sedimentary rocks are separated from the Coquihalla serpentine belt to the west by a fractured, elongate slice of Spider Peak greenstone 100 to 180 metres wide. The Ladner rocks are generally overturned, being west dipping and east facing; the unconformity between them and the Spider Peak Formation is poorly exposed and has been faulted and sheared. There is no evidence of a basal con-

TABLE 5.
REPORTED ANNUAL PRODUCTION FROM THE EMANCIPATION MINE*

Year	Tonnes milled	Gold production (g)	Silver production (g)
1916	3	93	0
1917	55	34 098	6 625
1918	17	14 245	2 488
1919	10	5 256	902
1920	1	560	93
1922	21	4 821	1 058
1924	1	280	62
1926	290	1 835	529
1930	9	404	871
1931	27	3 888	653
1932	127	10 295	24
1933	9	404	840
1934	Not reported	2 115	218
1938	8	591	218
1940	Not reported	2 084	Not reported
1941	Not reported	9 144	1 804
Totals	578	90 104	18 818

* (Data from MINFILE, 092HSW034)

glomerate in the mine area and the lowermost sediments generally comprise a very thin unit of immature volcanogenic wacke, lithic wacke and siltstone. Approximately 200 metres north of the mine the basal section of the Ladner Group also includes a unit of impure, clastic limestone, 3 metres thick, that yielded one conodont fragment of probable Early to Middle Triassic age (Figure 25).

The East Hozameen fault system in the mine area dips steeply east and apparently involves two generations of fracturing. The oldest set strikes northerly and is offset 250 metres left laterally by a younger, northwest-striking fault along Tangent Creek. The gold-bearing veins are hosted by a wedge-shaped, fault-bounded slice of altered Spider Peak greenstones that are mostly massive, but which locally contain elongate, sheared clasts and may represent aquagene breccias. Immediately to the west, along Tangent Creek, the greenstones are in fault contact with serpentinites of the Coquihalla serpentine belt. Outcrops of massive to highly sheared talc are seen in Tangent Creek, and both drilling and the underground workings indicate the talc-bearing fault zone is locally several metres wide (D. Cardinal, personal communication, 1985).

Close to the No. 2 adit the contact between the Spider Peak Formation and the Ladner Group is a high-angle reverse fault (Figure 26). In this locality the Ladner Group youngs eastward and mostly comprises slaty argillites and siltstones. Immediately adjacent to the faulted greenstones there is a 1 to 2-metre-wide unit of lithic wacke and siltstone containing small chert and volcanic clasts. This is interpreted as a faulted remnant of the coarse clastic lower unit of the Ladner Group succession which, farther north, around Carolin mine, reaches 200 metres in thickness.

There are essentially three sets of quartz ± carbonate veins at the mine, all of which were probably controlled by a fracture system that developed during reverse movements along the East Hozameen fault system (Figure 26). The three sets are the footwall "Boulder vein" (Plate 23), and the hangingwall "Dyke vein" (Plate 24), separated by a set of irregular, reverse-dipping "flat veins" (Plate 25; Cairnes, 1929). Both the Dyke and Boulder veins usually follow reverse fractures while the flat veins apparently occupy second order, sigmoidal tension fractures formed during northeasterly directed thrust movements along the footwall and hangingwall faults. The Boulder and Dyke veins vary markedly in their attitude and character both along strike and with depth.

On surface, close to the No. 2 adit, the Boulder vein strikes northerly and follows the faulted contact between the Spider Peak Formation and the Ladner Group. Farther north, surface mapping by Cardinal (1981) and examination of the crosscuts on the No. 2 level underground workings show that the vein system splays, swings to a northeasterly strike and is locally hosted entirely by Ladner Group rocks. It is the widest vein on the property, varying between 0.5 and 4.6 metres in width, and dipping from 50 to 65° west. It contains mainly milky to clear massive quartz and minor amounts of calcite; some small quartz-lined vuggy cavities are present locally. The vein also carries sporadic traces of disseminated pyrite, arsenopyrite and chalcopyrite, but little or no gold (Cairnes, 1929; Appendix 9).

Near the No. 2 adit portal the Boulder vein is a discrete vein, between 1.5 and 2 metres wide, that has sharp, weakly sheared contacts with the hostrocks which are themselves cut by rare, subparallel, thin veins of quartz and calcite. Farther north, in the underground crosscuts, this single vein passes into a quartz stringer zone, 3 to 4.6 metres wide, consisting of a series of parallel, white quartz veins between 0.5 centimetre and 1 metre in width that are separated by horses of silicified Ladner Group hostrock (Plate 23). Most of these stringer veins follow the slaty cleavage but crosscut bedding in the Ladner Group. Locally the margins of the Boulder vein grade outwards into brecciated zones up to 3 metres wide. These comprise angular, silicified, disorientated fragments of fractured Ladner country rock containing disseminated sulphides, set in a vein-quartz matrix. The breccia matrix also contains minor to trace amounts of albite, calcite, dolomite, siderite, gypsum, pyrrhotite and marcasite.

Locally, particularly close to the No. 2 adit, the greenstones in the hangingwall of the Boulder vein are intensely silicified over widths of 1 to 4 metres and contain disseminated carbonate, pyrite, pyrrhotite, arsenopyrite and chalcopyrite, but no gold (Cardinal, 1981). Drilling by

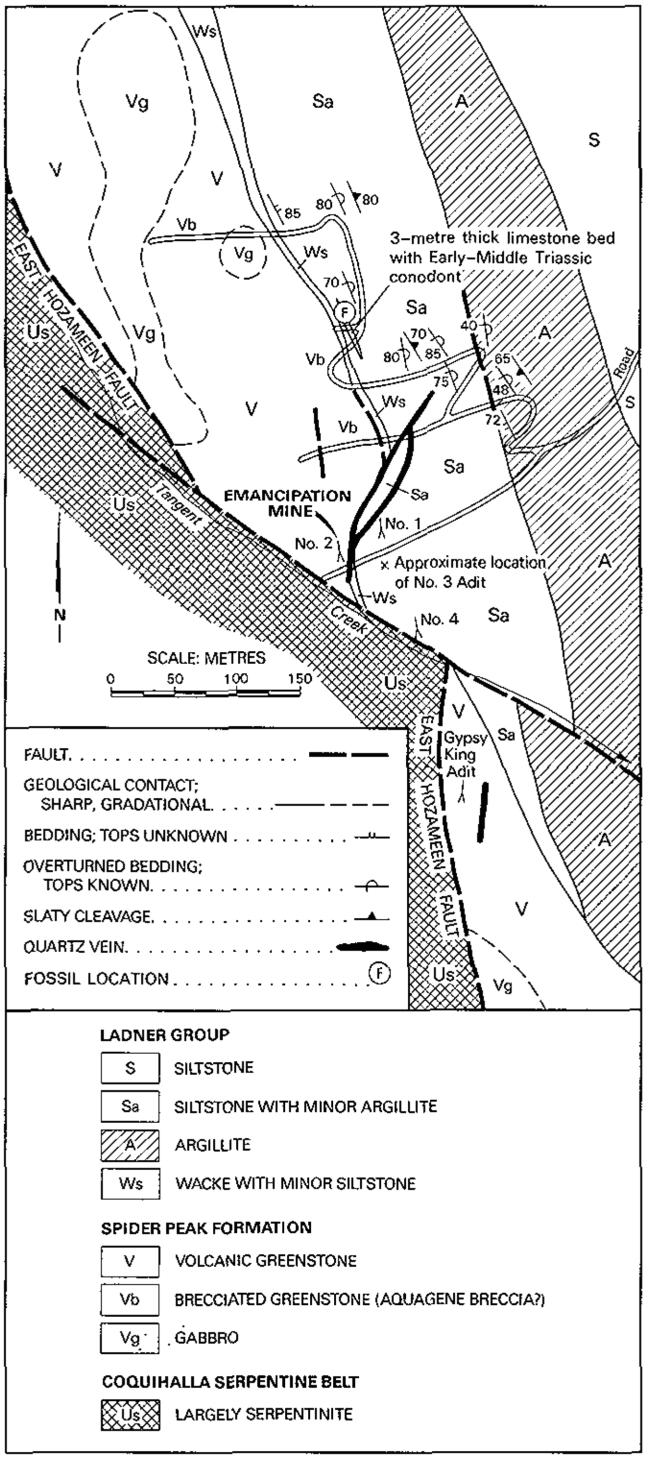


Figure 25. Geology of the Emancipation mine area.

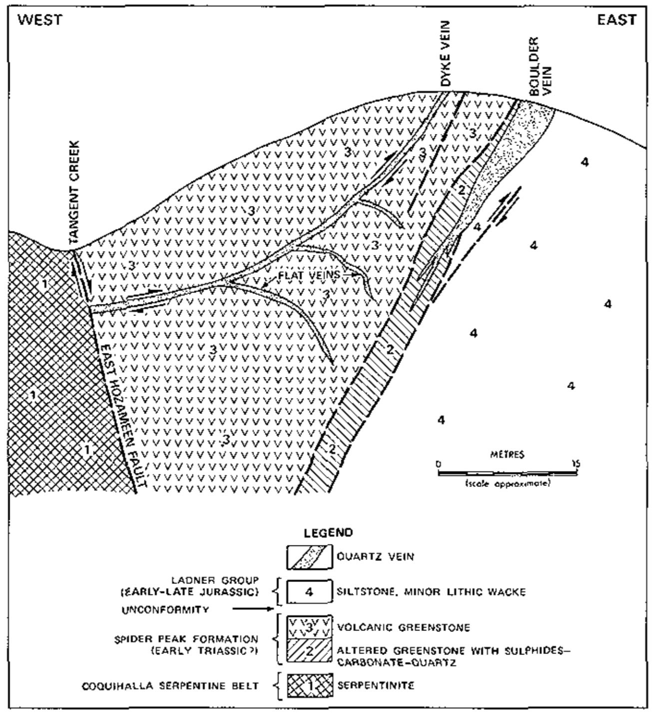


Figure 26. Diagramatic vertical cross-section through the Emancipation gold mine (adapted after Cardinal, 1981).

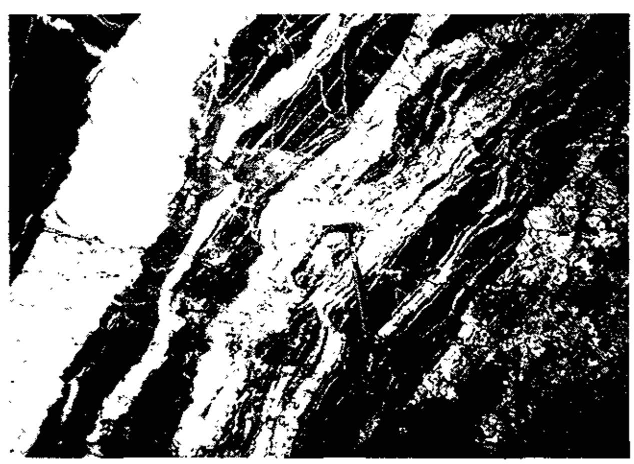


Plate 23. Emancipation mine — Boulder vein. Westerly dipping quartz stringer zone (centre and left) and quartz breccia (lower right). Crosscut on No. 2 level, Emancipation mine.

Plate 24. Emancipation mine — Dyke vein. Westerly dipping, bifurcating quartz and quartz-carbonate veins along shear zone within basaltic greenstones of the Spider Peak Formation. No. 2 level, Emancipation mine.

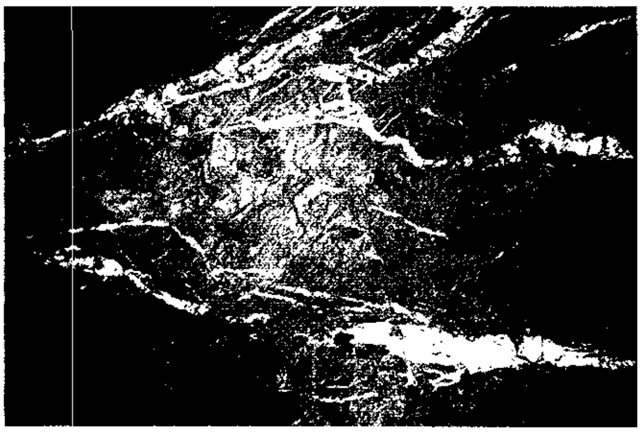


Plate 25. Emancipation mine — flat veins and Dyke vein. Easterly dipping flat veins (bottom and right) splaying out from the westerly dipping Dyke vein (upper left), both of which cut altered Spider Peak Formation greenstones. Note — angular xenoliths of host greenstone within the lower flat vein. Lower stope on 3rd level, Emancipation mine. (Width of lower flat vein is approximately 15 centimetres.)

Aquarius Resources Ltd. indicates that this hangingwall alteration zone persists at depth, but the Boulder vein quickly pinches out down dip (Figure 26).

The hangingwall Dyke vein (Plate 24) was probably the most important source of ore as it was stoped for 85 metres along strike and over 40 metres down dip (Cairnes, 1929; Bullis, 1971). Like the Boulder vein, it too strikes north but differs in that it is narrower (generally between 1 centimetre and 60 centimetres wide) and its dip varies with depth. In the upper mine workings the Dyke vein dips 45° west, but with increasing depth the dip flattens progressively until the vein eventually forms a gently undulating, subhorizontal structure. The Dyke vein system also varies in character along strike and down dip. On the upper levels it is represented by a single vein, up to 20 centimetres wide, within a strongly sheared, chloritic fault zone. At depth it comprises several irregular subparallel veins and veinlets of quartz and/or calcite, 2 to 5 centimetres wide, that follow a chloritic shear 0.3 to 1 metre wide (Plate 24). These veins have sharp contacts; they dilate and split (Plate 24) and eventually pinch out entirely with increasing depth. They include both quartz-rich and calcite-rich types, both of which sporadically carry gold (Appendix 9). The quartz-rich veins contain both turbid, ribbon-textured quartz and some clearer vuggy quartz; small specks of visible gold were observed in the latter during this survey. The Dyke vein system also contains pink albite nodules (Cairnes, 1929) and gypsum. Disseminated pyrite and pyrrhotite are present in both the quartz veins and the sheared wallrocks, but the calcite veins are sulphide poor. The principal sulphides in the quartz veins, in decreasing order of abundance, are pyrrhotite, arsenopyrite, pyrite, chalcopyrite and marcasite. Cairnes (1929) concluded that the pyrite and probably the pyrrhotite were the earliest sulphides and that they were succeeded by the gold and arsenopyrite; the chalcopyrite may also have been contemporaneous with the latter minerals. Cairnes also noted the local presence of enargite (Cu_3AsS_4) and spectacular amounts of free gold in the Dyke vein. The gold-silver ratio was reportedly 6:1; recent assays on grab samples indicate gold-silver ratios varying from 2:1 to 9:1 (Appendix 9). The quartz, sulphide and gold contents decrease both down dip and along strike to the north.

The flat veins (Plate 25) comprise numerous thin quartz $\pm$ calcite veinlets, irregular lenses and stringer networks together with at least three more prominent quartz veins. They strike north to northwest, are from 0.5 to 20 centimetres wide and dip 20 to 45° easterly. They are splays from the overlying, gently inclined Dyke vein, but quickly pinch out with depth. Some of the veinlets exhibit tension gash and pinch-and-swell features, while the larger quartz veins carry angular fragments of altered greenstone wallrock. The flat veins consist of white quartz with variable amounts of calcite, plagioclase, gypsum and sulphides, together with some free gold. Both the quartz-rich and calcite-rich veins contain gold (Appendix 9) and carry some of the highest gold values encountered in the mine, particularly close to where they intersect the Dyke vein (Cairnes, 1929; Bullis, 1971).

GEOCHEMISTRY OF THE MINERALIZATION

A number of grab samples were collected from the three vein sets at Emancipation mine, and from the altered wallrocks associated with the Boulder vein both on surface and underground. These were analysed for major and trace elements and the results are presented in Appendices 8 and 9.

Samples collected from the Boulder vein and from its alteration envelope were not auriferous while both the quartz-rich and calcite-rich veins in the Dyke and flat vein systems are locally gold and silver bearing.

Both the flat and Dyke vein sets are sporadically enriched in arsenic and antimony, while anomalous tungsten values are recorded in all three vein sets (Appendix 9). However, an ultraviolet light survey of the underground workings revealed no evidence of scheelite in the veins. It is noteworthy that one sample of altered wallrock adjacent to the Boulder vein (sample GR 100) contains anomalous amounts of tellurium

(820 ppb) suggesting the possible presence of tellurides in the Emancipation hydrothermal system. Furthermore, the quartz-carbonate-sulphide alteration adjacent to the Boulder vein is enriched in sodium (up to 7.2 per cent Na_2O; Appendix 8) similar to the quartz-albite gold mineralization at the Carolin mine and the McMaster zone.

CONCLUSIONS ON EMANCIPATION MINE

The mineralization at the Emancipation mine includes two types that are probably genetically and temporally related. One of these is gold-sulphide-bearing quartz ± carbonate veins in a reverse fault and complimentary tension fractures cutting Spider Peak greenstones. The second is a barren, siliceous carbonate-sulphide replacement of wallrock adjacent to the margins of the generally barren Boulder vein. The gold is associated with erratic enrichment in arsenic, antimony, tungsten and possibly tellurium, but not with mercury. The zone of wallrock alteration is also depleted in potassium and enriched in sodium which suggests a possible link with the albite-rich replacement gold mineralization at Carolin mine and the McMaster zone.

It is possible that the quartz veins near the Gypsy King adit (Figure 25), which were not sampled during this survey, represent an offset southern extension of the Emancipation vein system. Consequently, the area between the Gypsy King adit and Tangent Creek warrants more detailed prospecting.

AURUM MINE (MINFILE 92HNW003) (PAST PRODUCER NO. 2, FIGURE 23)

The old Aurum mine workings are situated on the north side of the Ladner Creek valley, approximately 300 to 350 metres south of the outcrop of the Carolin orebody (Figures 24 and 42). The deposit was discovered in 1927 when several shoots containing spectacular free gold were located within a talcose shear along the East Hozameen fault. Several adits were driven and sporadic production between 1930 and 1942 reportedly totalled 16.5 kilograms of gold from 494 tonnes of ore (Table 6); the gold-silver ratio was 5:1. Detailed studies of the deposit were not undertaken during this project, although the area around the workings was mapped (Figure 42) and some lithogeochemical samples were collected. Most of the following details are taken from Cairnes (1929), who mapped the underground workings and described the geology and mineralization in some detail.

Near the Aurum mine, the East Hozameen fault separates the Coquihalla serpentine belt to the west from either Ladner wackes or thin slices of Spider Peak greenstones to the east. In the mine area, this fault is a talcose shear that varies from "less than a foot to several feet" in thickness (Cairnes, 1929). The shear is the principal host for the gold mineralization; the talc zone and its controlling fracture, the East Hozameen fault, have an undulating character dipping from northeasterly to southwesterly. Some narrow quartz veining is locally present within it.

Gold at the Aurum property is mostly free and is locally associated with sulphides; in decreasing abundance, these are pyrrhotite, pyrite and arsenopyrite, with traces of chalcopyrite and possible millerite. In places the sulphides are strongly oxidized to hematite and limonite, but early reports that the ore contained native mercury and cinnabar were not substantiated (Cairnes, 1929). The gold is not evenly distributed throughout the talc zone, but is concentrated in pockets and veinlets, often where arsenopyrite is abundant and conspicuous amounts of quartz, carbonate and albite are present. Locally the gold and sulphides occur as polished films on slickensided surfaces of serpentinite and talc, indicating the mineralizing event was followed by fault movements. The free gold forms "plates, thin wedges, or irregular prongs", as well as "small, roughly corrugated beads" (Cairnes, 1929, page 154A). In some very rich ore the free gold is associated with thin arsenopyrite-rich bands interlayered with partings of calcite, quartz and foliated talc. Some gold also occurs as minute blebs distributed within the arsenopyrite crystals, concentrated along the contacts between pyrrhotite and arsenopyrite, or between pyrrhotite and the gangue minerals. Cairnes concluded that the gold mineralization in the talcose shears is related to nearby gold-sulphide-bearing quartz veins. Lithogeochemical sampling during this project revealed that zones of pronounced potassium depletion and sodium enrichment are present on the Aurum property, similar to those overlying the Carolin deposit (Idaho zone) 300 metres farther north (Figure 33). Thus, introduction of the gold at the Aurum mine, like the Carolin mineralization, was probably accompanied by some albitization. This, together with the identical sulphides at both

TABLE 6.
REPORTED ANNUAL PRODUCTION FROM THE AURUM MINE*

Year	Tonnes milled	Gold production (g)	Silver production (g)
1930	59	11 975	2 737
1931	20	1 120	156
1932	7	404	124
1939	227	2 799	Not reported
1942	181	280	Not reported
Totals	494	16 578	3 017

* (Data taken from MINFILE, 092HNW003.)

properties (abundant pyrrhotite and pyrite, sporadic arsenopyrite and trace chalcopyrite), suggests the mineralization at the Aurum and Carolin mines is genetically and temporally related.

Carolin Mine (Minfile 92HNW003 and 007) (Past Producer No. 3, Figure 23)

The Carolin gold mine is located about 20 kilometres northeast of Hope (Figure 2) on the northwest side of Ladner Creek at an approximate elevation of 1070 metres (3500 feet) above sea level. The deposit represents mesothermal epigenetic mineralization that is characterized by the introduction of gold with abundant sulphides, albite, quartz and carbonate. It is hosted by metasedimentary rocks of the Ladner Group, close to both their unconformable contact with greenstones of the Spider Peak Formation and their faulted contact with ultramafic rocks of the Coquihalla serpentine belt (Figures 24 and 42).

The property (originally called the Idaho claims) was first staked in 1915. The surface showings of the Idaho zone, the gold deposit which later supported the Carolin mine operation, were originally described by Cairnes (1929). In 1945 and 1946, eight shallow diamond-drill holes were put down in the Idaho zone; they intersected mineralization grading 5.8 grams gold per tonne over an average width of 5.4 metres. In 1966, trenching by Summit Mining Ltd. extended the surface showings for a strike length of 75 metres. In 1973, the Ladner Creek property was purchased by Carolin Mines Ltd. which conducted a major exploration and drilling program, and by the end of 1974 the mining potential of the Idaho zone was realized. Underground diamond drilling and bulk sampling of the Idaho zone were carried out from an exploration decline in 1977 and 1978, and the mill, with a design capacity of 1360 tonnes per day, was completed in 1981 (Plate 1). Milling began in December 1981, and the first doré bar was poured in February 1982. Mining was by open-stope blast-hole methods taking vertical slices from longhole rings placed 1.5 metres apart. Further details on the initial mining methods and milling procedures are given by Samuels (1981). At the time of initial development, reserves in the Carolin deposit were estimated at 1.5 million tonnes grading 4.4 grams per tonne gold (at a cut-off grade of 2.7 grams per tonne). However, production data (Appendix 10) indicate less than 800 000 tonnes grading 3.2 grams per tonne were mined. During its three years of operation, Carolin mine produced a total of 1354 kilograms of gold from 799 119 tonnes of ore; the annual mining and gold production statistics are given in Appendix 10 and Figure 27. During the life of the mining operation there were several periods of shutdown resulting from environmental concerns and poor gold recoveries. Gold recoveries for 1982, 1983 and 1984 averaged only 33, 60 and 61 per cent respectively and these and other difficulties resulted in the the closure of the mine at the end of 1984.

GEOLOGY OF THE CAROLIN MINE AREA

The surface geology around Carolin mine is shown on Figure 42. To the east are metasedimentary rocks of the

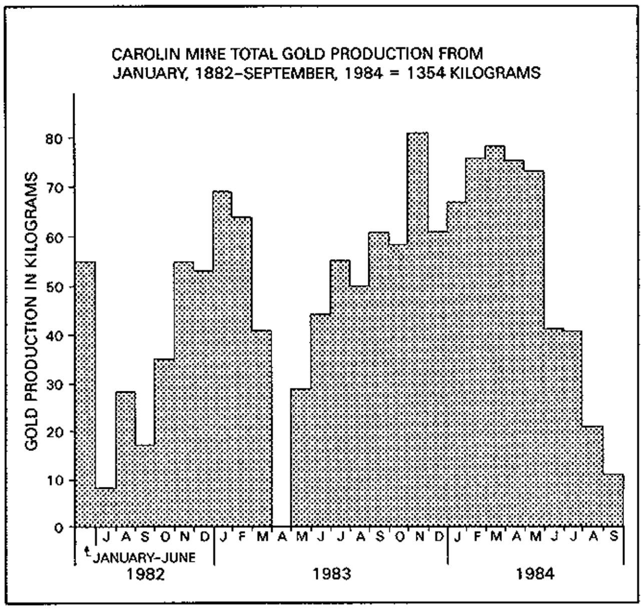


Figure 27. Histogram showing monthly gold production from Carolin mine between January 1982 and September 1984.

Ladner Group and massive to pillowed volcanic greenstones of the Spider Peak Formation. These are separated from serpentinites of the Coquihalla serpentine belt farther west by the East Hozameen fault. The gold-bearing Idaho zone, which forms the Carolin deposit, outcrops approximately 150 metres east of this structure. The contact between the older Spider Peak Formation and the Ladner Group is not exposed in the immediate mine area. Consequently the existence of a basal conglomerate in the Ladner Group at the mine is unproven, although it is exposed elsewhere in the district. The Ladner Group succession at Carolin mine consists of a heterogeneous, coarsely clastic lower unit, 200 metres thick, which is overlain in turn by a middle unit of siltstone, approximately 200 metres thick, and an upper slaty argillite unit more than 1000 metres thick (Figure 28). Graded bedding is widespread in the siltstones and wackes; other less common features include crossbedding, flame structures, chaotic slumping and rip-up clasts.

Gold mineralization is hosted in the lower heterogeneous coarse clastic unit of the Ladner Group succession, approximately 150 to 200 metres stratigraphically above the unconformable contact with the Spider Peak Formation (Figure 28). The lower unit includes discontinuous wedges of interbedded greywacke, lithic wacke, sedimentary breccia and conglomerate, together with intercalated sequences of siltstone and minor argillite. The lithic wackes contain variable amounts of angular rock and mineral fragments averaging 1 centimetre in diameter. Basic and intermediate volcanic clasts predominate although some quartz, carbonate and feldspar fragments, and rare clasts of altered acid volcanic rock, are also present. Sedimentary breccias and polymictic conglomerates, generally up to 30 metres thick, are present in the lower unit. They vary from densely packed, clast-supported sedimentary breccias with angular lithic fragments, to conglomeratic mudstones containing isolated, well-rounded pebbles, cob-

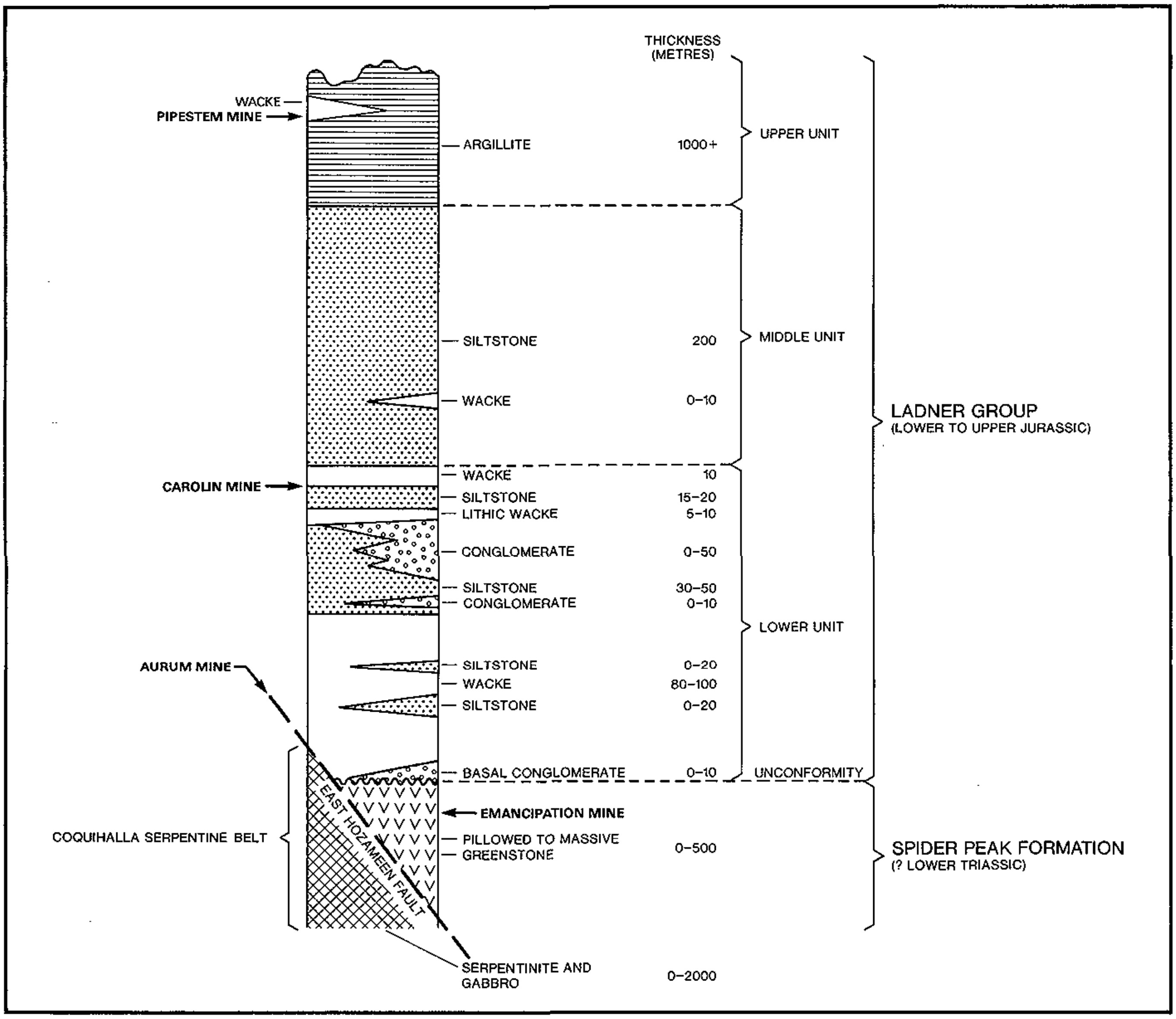


Figure 28. Stratigraphy in the Carolin mine–Spider Peak area showing relative stratigraphic position of the Emancipation, Aurum, Carolin and Pipestem gold deposits.

bles and boulders up to 30 centimetres in diameter. The clasts are set in a mudstone or siltstone matrix which often displays soft-sediment disruption and chaotic slumping. One conglomeratic unit in the mine district reaches 50 metres in thickness and is traceable for 1.5 kilometres along strike. It exhibits an overall reverse grading; its lower section consists of a densely packed, green-coloured breccia which passes stratigraphically upwards into a conglomeratic mudstone containing rounded cobbles and boulders. The clasts in the mudstone are predominantly altered basalt with lesser amounts of chert, gabbro, diorite, granite, granodiorite, porphyritic andesite, flow-banded dacite and limestone. Conodont microfossils of Middle to Late Triassic age were extracted from one limestone boulder within a conglomeratic mudstone outcropping approximately 250 metres north of the Idaho zone (M.J. Orchard, written communication, 1986; Geological Survey of Canada Location No. C-103719).

The middle sedimentary unit of the Ladner Group consists mainly of grey to black, generally well-bedded siltstone (Figure 28). Beds vary from 1 to 10 centimetres in thickness (Plate 15) and are commonly graded.

The slaty argillites in the uppermost unit are black to grey, generally unbedded rocks that are locally pyrite and organic rich; they are composed mainly of very fine grained quartz, altered plagioclase and chlorite with variable amounts of sericite, carbonate and exceedingly fine grained, opaque organic material. Cleavage is defined by the subparallel alignment of chlorite and sericite, and elongate growth of the quartz and pyrite crystals.

Two elongate, fault-bounded slices of gabbro and massive to brecciated greenstone outcrop north and south of the surface exposure of the Idaho zone (Figure 42). These rocks vary from fine grained and equigranular to coarsely porphyritic. During the mapping program it was uncertain whether they represented intrusions or thrust slices of Spider Peak Formation; the latter interpretation is now accepted. The porphyritic gabbros in these slices contain randomly orientated euhedral to subhedral phenocrysts of andesine plagioclase (An_{30-35}) set in a chlorite-plagioclase (An_{30-55}) matrix. The phenocrysts are zoned, corroded and strongly altered, and exhibit good albite-carlsbad twinning. The groundmass comprises strongly altered plagioclase (up to 30 per cent), together with abundant chlorite (up to 40 per cent) which occurs in disseminations, clots and veins. The groundmass also contains up to 10 per cent tremolite-actinolite, as well as variable amounts of epidote, clinozoisite, carbonate, sericite and minor albite. Some greenstones in these slices contain clots of carbonate and chlorite that replace primary vesicles. Late, randomly orientated flakes of stilpnomelane are also present locally; this mineral is usually found in chloritic alteration zones adjacent to microfractures. Locally, the rocks in these thrust slices are mineralized, being overprinted with albitic and sulphide alteration, crosscut by quartz veins, and sporadically auriferous (Appendix 7D). Like the Spider Peak Formation adjacent to the Coquihalla serpentine belt elsewhere, the fault-bounded slices of volcanics and gabbros at Carolin mine are enriched in sodium (Appendix 7C).

The East Hozameen fault dips steeply northeast and sharply crosscuts the Ladner Group stratigraphy in the mine area (Section 1-2, Figure 42). Graded bedding in the Ladner Group reveals that most of the stratigraphic sequence, including that hosting the Idaho zone, is structurally overturned. Consequently, the Spider Peak Formation which lies adjacent to the East Hozameen fault now tectonically overlies the stratigraphically younger Ladner Group (Figure 42).

Most of the post-ore faults strike northwest (Figure 42), subparallel to the East Hozameen fault and the regional slaty cleavage. However, a younger set of east-northeast-striking normal faults is also present; this includes the northerly dipping Richardson fault which truncates the Idaho zone.

GEOLOGY AND MINERALOGY OF THE CAROLIN DEPOSIT

The surface expression of the Carolin deposit is a strongly faulted and altered zone up to 40 metres in outcrop width. It is characterized by secondary manganese and iron oxides, intense albitic alteration, disseminated sulphides, and a dense network of irregular, variably deformed quartz-carbonate veins (Plates 26, 27 and 29). The sulphide-albite-quartz-carbonate mineralization is preferentially hosted by the more permeable, competent rocks such as wackes, lithic wackes, conglomerates and siltstones while the thin units of slaty argillite in the mine sequence are generally unmineralized.

During the first year of mining, the geological controls of the gold mineralization were poorly understood. Surface geological mapping over the deposit (Ray, 1982) revealed the presence of numerous upright and asymmetric, large and small-scale D_2 folds (Plate 22) and it was speculated that the

Plate 26. Carolin mine. Weathered boulder of gold-sulphide-albite-carbonate-bearing ore from the Idaho zone with quartz veining enveloped by disseminated carbonate alteration. Outside Idaho adit.

Plate 27. Carolin mine. Multistage deformed quartz and albite veining associated with Idaho zone mineralization. Underground, 900 slot crosscut.

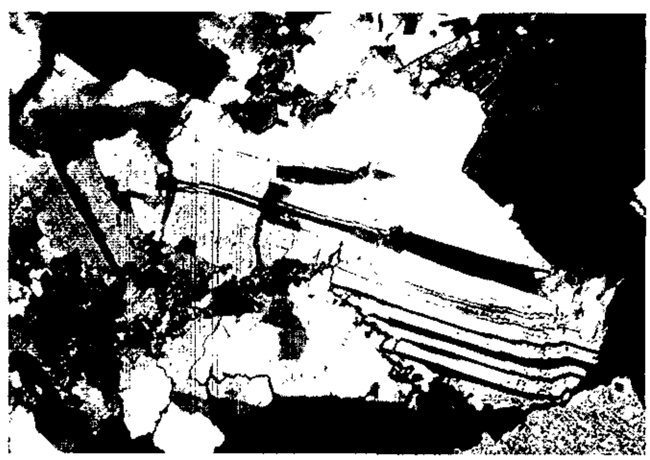


Plate 28. Carolin mine. Photomicrograph (X Nicols) of coarse-grained, third generation albite with deformed twin planes and some late carbonate. Underground, 900 slot crosscut.

geometry of the deposit was influenced by these structures. Subsequent underground mapping demonstrated that the mineralization is both lithologically and structurally controlled (Shearer and Niels, 1983); mineralization is preferentially concentrated in the more permeable, competent sedimentary beds within the hinge of a complex D_2 antiformal fold (Figures 29A and 29B). A boulder and pebble conglomerate marker horizon within the Ladner Group was recognized underground (Figure 29A) which may correlate with the distinctive green breccia and conglomeratic mudstone unit mapped on surface (Figure 42).

A geological cross-section across the Carolin deposit is shown on Figure 29A. The deposit plunges gently northwest, subparallel to the plunge of the D_2 fold axes in the area. The ore amenable to longhole open stoping is located in the thickened region of the fold hinge, while mineralization on the fold limbs tends to be too narrow for profitable mining. At least three saddle-shaped orebodies have been outlined to date, an upper No. 2, a middle No. 1 and a lower No. 3 orebody (Figures 29A and 29B). Deep drilling has shown several additional auriferous zones are present below the No. 3 orebody.

There are significant mineralogical and geochemical differences between the No. 1 and No. 2 orebodies, and the deposit as a whole exhibits a vertical mineralogical zoning. Shearer (1982b) concluded that the upper No. 2 orebody is pyrite-rich, while the lower No. 1 orebody is pyrrhotite-dominant. This vertical pyrite to pyrrhotite zoning is similar to that described in other gold deposits such as the Mount

Plate 29. Carolin mine. Photomicrograph (PPL) of fine-grained Idaho zone sulphide-albite-quartz-gold-bearing wacke cut by late, deformed quartz veins. Underground, 900 slot crosscut. Carolin mine.

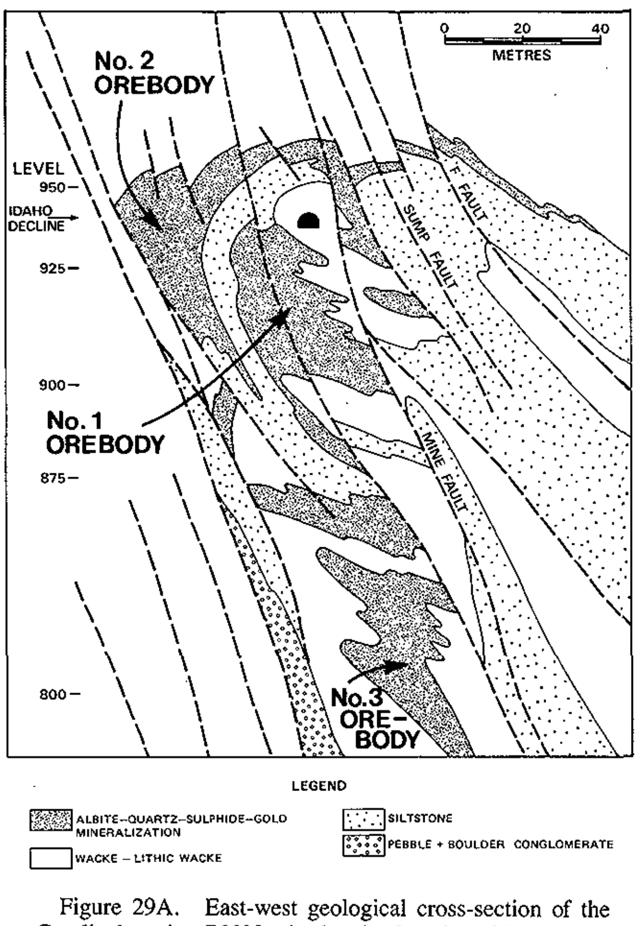


Figure 29A. East-west geological cross-section of the Carolin deposit at 766 North, showing location of the No. 1, 2 and 3 orebodies (adapted after Shearer and Niels, 1983).

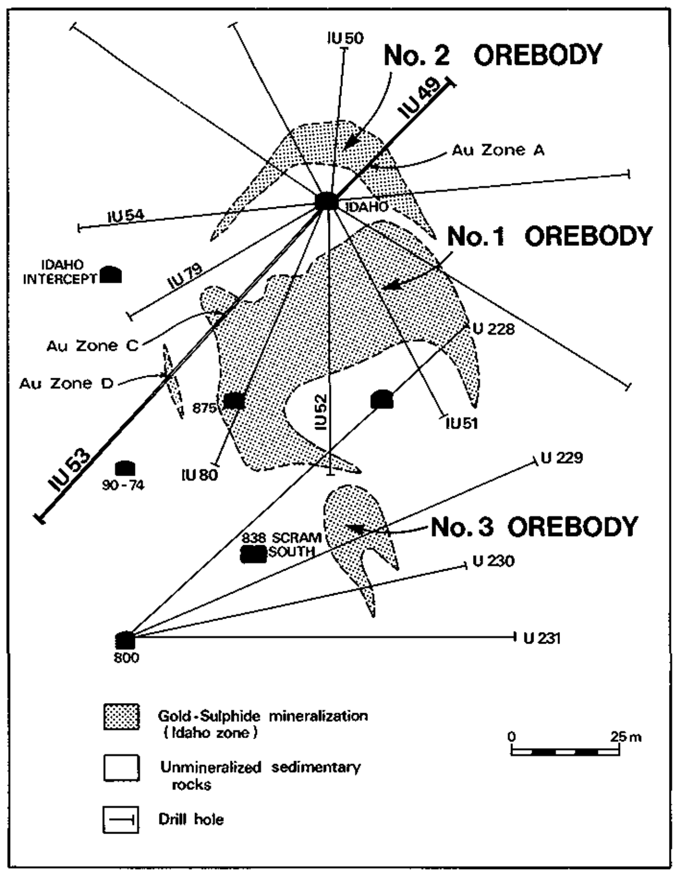


Figure 29B. East-west cross-section through the Carolin deposit at 837 North showing locations of drill holes IU49 and IU53, and auriferous zones A, C and D (after Ray *et al.*, 1986).

Charlotte in Western Australia (Phillips *et al.*, 1983) and the McIntyre mine in Ontario (Langford, 1938). The No. 1 orebody at Carolin mine is hosted mainly by greywacke and has extremely uniform gold grades while the No. 2 orebody has a siltstone host and is characterized by erratic gold values. This probably reflects differences in the original permeability of the hostrocks. Little is known about the deep No. 3 orebody except that it resembles the overlying No. 1 orebody in its mineralogy and hostrock lithology. The gold-silver ratio in the deposit as a whole averages 1:10, but varies from 1:1 to 1:22.

The Carolin deposit is cut by numerous northerly striking faults (Figure 29A), some of which contain carbonaceous material. The deposit is also truncated on the north by the younger, easterly striking and northerly dipping "hanging-wall shear". No mining has taken place north of the shear, and the location of the postulated down-plunge extensions of the orebodies across it is unknown. The shear may be the downward continuation of the Richardson fault mapped on surface (Figure 42); the latter is probably a normal fault which suggests that the northerly extension of the deposit is downthrown to the north.

Lithologies favourable for gold-sulphide-albite-quartz-carbonate mineralization include wackes, pebble conglomerates and siltstones. Coarse-grained, pervasive albitization is present throughout both the ore zones and the adjacent wallrocks. However, the exceedingly fine grained chloritic and sericitic alteration related to the mineralizing event is generally well developed in the surrounding wallrocks, but not so abundant in the ore. The ore consists largely of quartz and albite (An_{3-5}), with variable amounts of carbonate, chlorite, very fine sericite and opaque minerals; it is cut by numerous irregular veins of albite, quartz and carbonate. The opaques range from 1 to 15 per cent by volume and average 6 to 8 per cent; they are mainly pyrrhotite, arsenopyrite, pyrite and magnetite. Less common opaques, in decreasing abundance, include sporadic traces of chalcopyrite, bornite, gold and sphalerite (Kayira, 1975). Pyrite and arsenopyrite generally form coarse euhedral to subhedral crystals (Figure 30), while pyrrhotite and magnetite occur as finer grained disseminations and clusters. Kayira concluded that the paragenesis of the opaque minerals was (1) magnetite, (2) arsenopyrite, (3) pyrite, (4) gold, (5) pyrrhotite, (6) sphalerite and (7) chalcopyrite; a partial overlap in the deposition of arsenopyrite, pyrite and pyrrhotite was noted. However, Shearer (1982b) in his study of both the pyrite-rich and pyrrhotite-rich zones presented the following paragenesis: (1) magnetite, (2) arsenopyrite and some gold, (3) contemporaneous deposition of pyrite, pyrrhotite and some gold, (4) minor magnetite and finally (5) traces of chalcopyrite and gold.

The majority of the magnetite in the ore represents early, first generation material; it forms small, disseminated, rectangular grains and is probably unrelated to gold mineralization as it shows no spatial association with either gold or sulphides. Arsenopyrite is the earliest sulphide associated with gold. Some arsenopyrite crystals are partly rimmed with small blebs of pyrite and pyrrhotite, while the euhedral pyrite crystals locally include small grains of pyrrhotite. The pyrrhotite is magnetic and often contains exsolution rods of pyrite. Shearer notes the presence of minor, second generation magnetite related to gold mineralization and associated with pyrrhotite and arsenopyrite. Gold generally forms very small grains up to 0.02 millimetre in size, commonly as inclusions within the pyrite and arsenopyrite or rims on the pyrite, pyrrhotite and chalcopyrite (Figure 30). Some gold and chalcopyrite rim pyrrhotite. Minute grains of gold also occur within or along grain boundaries of some quartz, carbonate or albite crystals. Although visible gold is uncommon throughout the Idaho zone, it is present as thin plates and smears on some fault surfaces. Rarer forms of visible gold include leaf-like masses, small scales and rods.

Rocks in the Idaho zone are commonly pale coloured, largely due to weak silicification and intense pervasive albitic

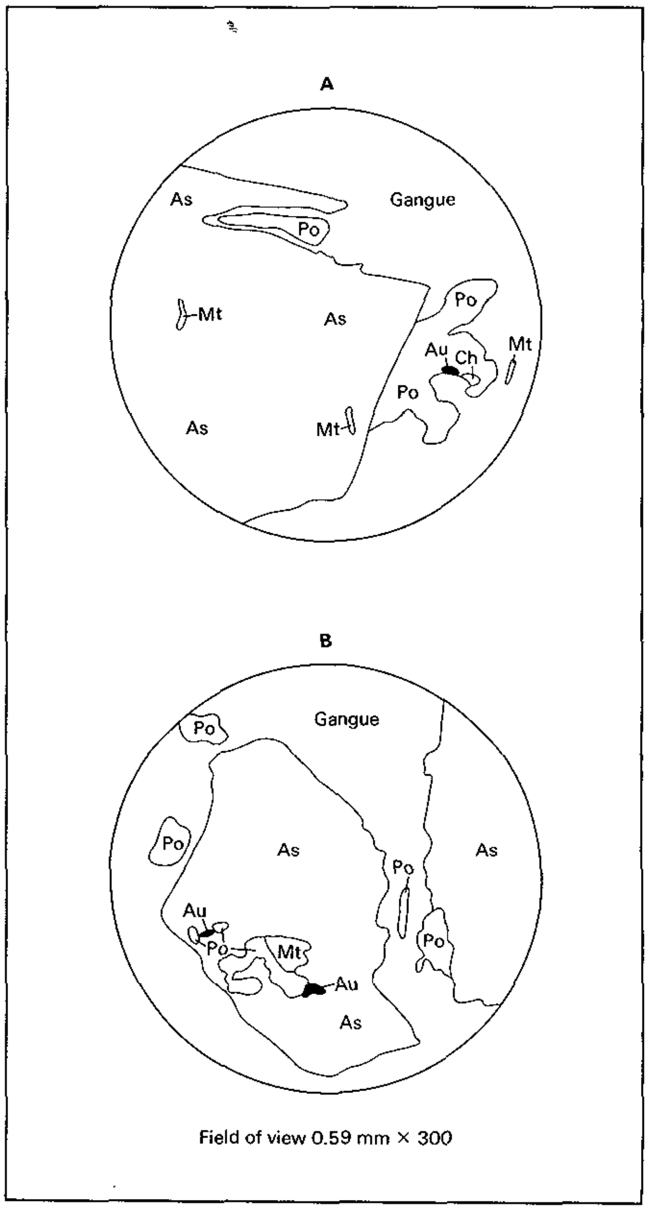


Figure 30. Drawings of polished ore sections taken from the 925 Level, south slot crosscut, Carolin mine (from Shearer, 1982b). As = arsenopyrite; Po = pyrrhotite; Mt = magnetite; Ch = chalcopyrite; Au = native gold.

and carbonate alteration. The auriferous zones are generally associated with albite and quartz veining (Plates 26, 27, 28 and 29) and disseminated sulphides, although not all areas containing these features are necessarily enriched in gold. Widespread albitization produces a sodium-rich envelope that extends hundreds of metres from the deposit. There are at least three generations of albitization. The earliest is fine grained and was probably coeval with sulphide-gold-quartz mineralization; this early albite is weakly altered and disseminated throughout the ore, being intimately intergrown with sulphides and fine quartz crystals. It is cut by numerous thin, deformed veins of poorly twinned, second generation albite. The youngest albite forms veinlets, disseminations and irregular masses throughout the ore zone, comprising coarse, fresh, well-twinned crystals (An_{3-5}) up to 8 millimetres in length with locally deformed twin planes (Plate 28). In places, small angular fragments of sulphide-rich ore are brecciated and entirely engulfed by third generation albitic material.

The deposit is also cut by numerous white quartz-carbonate veins, generally less than 15 centimetres wide, which form a complex, irregular network (Plates 26 and 27). Sigmoidal gash fracturing, and the variation in vein deformation, suggest that multistage quartz injection occurred during recurrent structural deformation, and at least three phases of quartz vein injection are recognized. Many of the early veins are folded (Plates 27 and 29); they contain strained quartz crystals elongated parallel to both the D_2 fold axial planes and the slaty cleavage, and are interpreted to be either older or contemporaneous with the D_2 deformation. Quartz crystals in the younger veins are generally unstrained and granoblastic. Some of the earlier quartz-carbonate veins are probably coeval with the gold mineralization and they are commonly associated with the introduction of disseminated carbonate which may form pervasive halos around the veins (Plate 26). However, most of the veins appear to immediately postdate the introduction of the gold, sulphides and albite; some contain minor amounts of albite and clinozoisite, as well as minute flakes of pyrobitumen, with optical and physical characteristics suggesting a maturation equivalent to meta-anthracite (Y.J. Kwong, written communication, 1983). In rare instances, small amounts of finely disseminated carbon are also present in the altered wallrocks immediately adjacent to quartz veins. Late veins and disseminations of calcite and ankerite are also widespread in the Idaho zone; unlike the earlier albite and quartz veining the late carbonate veining is generally not folded.

Studies of fluid inclusions from various quartz veins in the Idaho zone suggest the presence of three generations of low-salinity, CO_2-rich fluids with homogenization temperatures of approximately 320°C, 225° to 275°C and 150° to 190°C respectively (J.B. Murowchick, University of Alberta, written communication, 1985). Nesbitt *et al.* (1986) conclude from oxygen isotope studies that emplacement of quartz veins in the deposit involved deeply circulating meteoric waters that were highly enriched in ^{18}O and somewhat enriched in δD relative to local meteoric water. Their work also suggested that the serpentinites in the Coquihalla serpentine belt adjacent to the mine were affected by these fluids.

Although the mineralization at Carolin mine is probably contemporaneous with the regional D_2 deformation, a post-Middle Cretaceous to pre-Late Eocene event (J.W.H. Monger, verbal communication, 1986), its precise age is unknown. However, in its setting, mineralogy and wallrock alteration, the Carolin deposit and other occurrences in the Coquihalla gold belt exhibit many similarities to the Bralorne deposit in the Bridge River camp which has been dated between 91 and 43 Ma (Leitch and Godwin, 1988). Moreover, the Bridge River camp is associated with the Cadwallader fault which may form part of the Yalakom fault system; the latter could represent a northwesterly extension of the Hozameen fault (Monger, 1985). Thus the mineralization in the Bridge River camp and the Coquihalla gold belt may have been coeval and originally adjacent; subsequent separation of the two mineralized areas possibly occurred during early transcurrent movements along the Hozameen-Yalakom fault system that resulted in approximately 70 kilometres of dextral offset followed by later offset along the Fraser faults.

GEOCHEMISTRY OF THE NO. 1 AND NO. 2 OREBODIES

The geochemistry of several ore zones in the Carolin deposit was studied by analysing 50 core samples from drill holes IU49 and IU53. These inclined holes were drilled from underground and totalled 130 metres in length. Hole IU49 was 35 metres long and drilled upwards (Figure 29B); it intersected the entire pyrite-rich No. 2 orebody. Hole IU53 was drilled downwards and cut a repeated hangingwall section of the underlying pyrrhotite-rich No. 1 orebody (Figure 29B). The objectives of this geochemical study were to determine the variations in major and trace element content throughout the holes and compare these variations to observed mineralogical changes. The analytical results for holes IU49 and IU53 are presented in Appendices 11A, 11B and 11C.

Four sulphide-rich auriferous zones were intersected which are designated zones A, B, C and D (Figures 29B, 31A and 31B). The 9-metre-wide Zone A represents the No. 2 orebody intersection, while zones B, C and D, which total 18 metres in thickness, are structural repetitions of hangingwall portions of the No. 1 orebody. Pervasive albitization and sporadic carbonate alteration are evident throughout the drill holes, in both the ore zones and the surrounding hostrocks. However, the ore zones are distinguished mineralogically by the general abundance of sulphides and quartz veining, while the adjacent wallrocks are marked by intense chloritic and sericitic alteration.

The downhole variation of selected elements is shown on Figures 31A and 31B. In addition to the elements shown, analyses were completed for Cu, Hg, Sb, Pb, CO_2, P_2O_5, Al_2O_3, TiO_2, MnO and total iron (expressed as Fe_2O_3) (Appendices 11A, 11B, and 11C). Copper was very weakly anomalous (up to 310 ppm) in some mineralized zones. Lead and strontium showed no anomalous values, while antimony consistently showed enrichment (up to 20 ppm) in the hangingwall portions of all four gold-bearing zones.

Univariate statistics were determined from the raw analytical results and correlation matrices indicate that the gold in the ore has a positive correlation with Na_2O, CaO, S, Sb, Mo, Cu, As and Ag, and a negative correlation with Al_2O_3, H_2O and BaO. No statistically significant correlation between Au and SiO_2, Fe_2O_3, TiO_2, MnO or Pb is apparent. In the No. 2

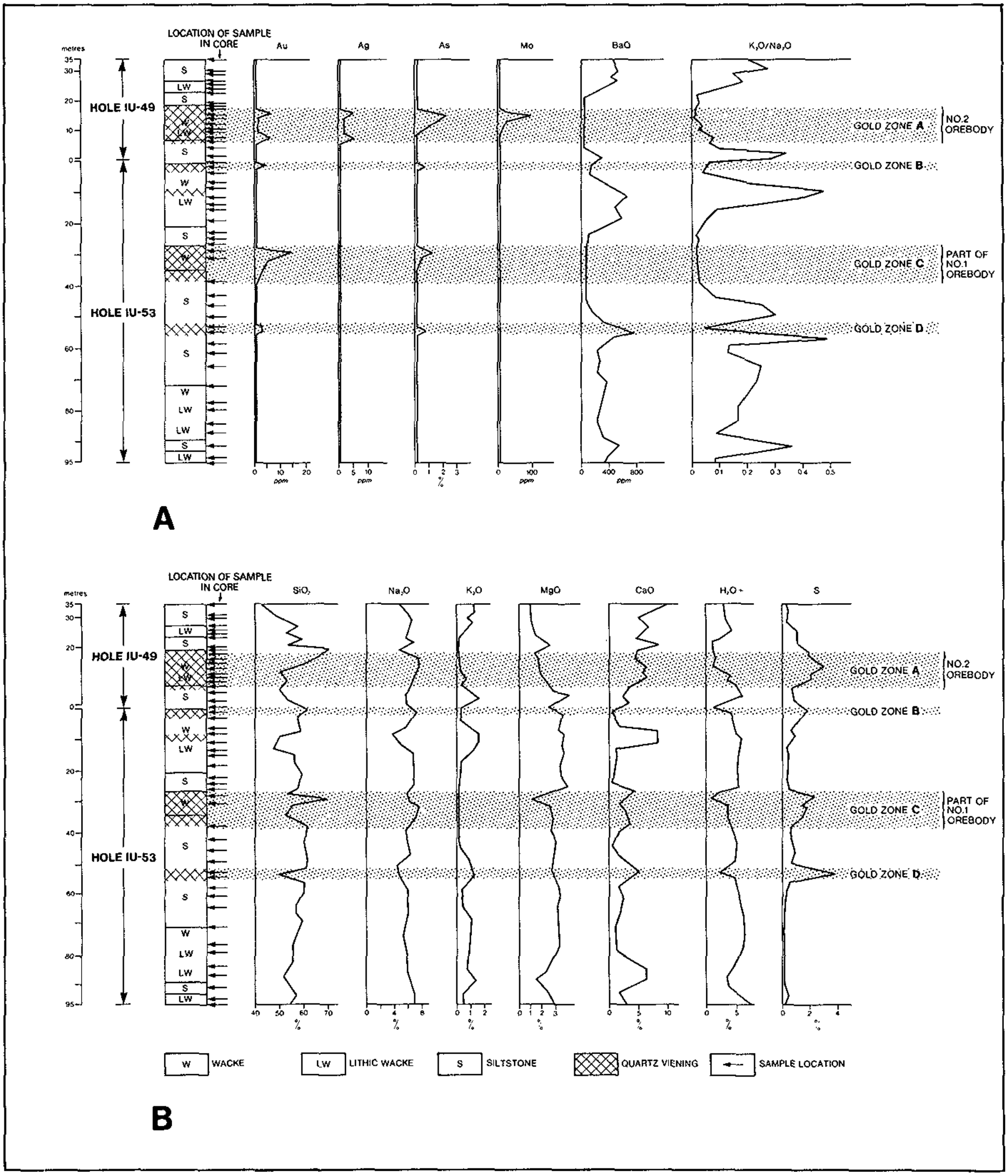


Figure 31A. Geology, trace element geochemistry and K_2O/Na_2O ratios of holes IU49 and IU53, Carolin mine.

Figure 31B. Geology and major element geochemistry of holes IU49 and IU53, Carolin mine. Note auriferous zones A, B, C and D.

orebody (Zone A, Figure 31A), the gold and silver are preferentially concentrated at the footwall and hangingwall and a positive correlation between the two elements is obvious. The hangingwall section of this orebody is also associated with anomalous molybdenum and arsenic (Figure 31A); by contrast, zones B, C and D in the No. 1 orebody do not contain silver or molybdenum, although they are characterized by high gold and arsenic values.

Compared to unmineralized Ladner siltstones and wackes outside the mine area, which average approximately 2.5 to 4 per cent Na_2O (Ray *et al.*, 1986), most of the 130-metre drill-hole section is enriched in sodium (Figure 31A). Increases in sodium generally correspond with decreases in potassium, suggesting that albitization led to the breakdown and removal of the original potassium feldspar in the rocks. The close association between albitization and mineralization is illustrated by the sharp decrease in K_2O/Na_2O ratios as the ore zones are approached (Figure 31A).

Auriferous zones A, B and C are surrounded by potassium and barium depletion envelopes that are generally twice as wide as the associated ore zones. The positive correlation between the two elements suggests that the barium was originally contained within potassium feldspar. All four auriferous sulphide-rich horizons show increases in sulphur and decreases in water (Figure 31B); the latter may reflect the lower chlorite and sericite content of the ore compared to the wallrocks. Higher levels of magnesium and potassium in the adjacent wallrocks mark areas of more intense chloritic and sericitic alteration. The entire wallrock section drilled between the No. 1 and 2 orebodies is intensely chloritic and generally marked by increased magnesium values (Figure 31B). This chloritic envelope is separated from the No. 1 orebody by a thin (2 to 3 metre) zone which is chlorite-poor, but contains abundant quartz veining.

The distribution of elements within and adjacent to gold-bearing zones A, B and C shows many common characteristics, but the two samples from Zone D in the lowermost part of the No. 1 orebody are geochemically unusual. Mineralization in Zone D is associated with a decrease in SiO_2 and increases in CaO, BaO and K_2O. It is uncertain whether this reflects geochemical differences in the original sedimentary hostrock, or whether the pyrrhotite-rich No. 1 orebody contains two mineralogically and geochemically distinct zones.

GEOCHEMICAL ENVELOPES ASSOCIATED WITH THE CAROLIN DEPOSIT

Seventy-two lithogeochemical samples of Ladner Group wacke and siltstone were systematically collected from a wide area around the Carolin deposit to determine whether large-scale elemental zoning is associated with the gold mineralization; the locations of the samples are shown on Figure 32. They were analysed for a number of major and trace elements; the analytical data are given in Appendices 12A and 12B and the univariate statistical results are presented in Appendix 13. A correlation matrix (Appendix 14) indicates that gold has a strong positive correlation with As, CaO, Ag, Cu and Na_2O, and a strong to moderate negative correlation with SiO_2, K_2O and Ba. Loss on ignition, which mostly represents CO_2 (Appendix 12A) also has a strong sympathic relationship with gold.

The study revealed that TiO_2, MnO, Cu, Pb, Zn, Co, Ni, Mo, Cr, Hg, Sb, Bi, Cd and Sr show little or no systematic change in concentration throughout the sampled area, and are not apparently influenced by the gold mineralization. Failure to detect increased values of antimony and copper above the deposit is probably due to the low concentration and sporadic distribution of these elements within the ore. However, some other elements, notably Au, As, BaO, K_2O, Na_2O, SiO_2, MgO and CaO, showed systematic variation patterns and form enrichment or depletion zones within or around the deposit.

The surface exposure of the Carolin deposit is outlined by a lithogeochemical gold anomaly measuring 40 by 80 metres (Figure 33B), while arsenic, which is only sporadically present in the ore, forms a weaker anomaly (500 to 18 200 ppm As) only 50 metres in length (Figure 33A). Elongate zones of calcium enrichment (Figure 33E) and barium (Figure 33C), silica (Figure 33D) and magnesium depletion also correspond with the deposit. The increase in calcium values reflects the presence of carbonate veins and disseminations in the ore, while the barium depletion zone ($<$100 ppm BaO) probably results from breakdown of potassium feldspar during the mineralizing process. Despite quartz veining in the ore, the samples collected in this study show that the deposit is associated with silica depletion (38 to 53 per cent SiO_2) relative to the country rocks (53 to 69 per cent SiO_2). However, this may reflect a sampling bias as the relatively small size of each sample meant that both quartz veins and intensely quartz-veined hostrocks were not collected for analysis. The magnesium content of the hostrocks (2.5 per cent to 5 per cent MgO) is generally higher than that in the deposit (0.6 to 2.5 per cent MgO). The elevated magnesium content is believed to reflect the wide envelope of chloritic alteration that surrounds the deposit.

Potassium and sodium display the most extensive anomalous envelopes around the deposit (Figures 33F and G). Siltstones and wackes from the Ladner Group outside the mine area average 1.5 to 2 per cent K_2O and 2.5 to 4 per cent Na_2O (Ray *et al.*, 1986), while similar rocks from the mineralized zones contain between 6 and 10 per cent Na_2O and generally less than 0.4 per cent K_2O (Appendix 12A). The Carolin gold deposit is surrounded by a zone of potassium depletion measuring 150 by 250 metres (Figure 33F), and a sodium enrichment envelope approximately 500 metres long and 300 metres wide (Figure 33G). Unlike many other epigenetic gold deposits (Boyle, 1979), mineralization is associated with a sharp decrease in K_2O/Na_2O ratios (Figures 31A and 33H).

All zones of geochemical depletion and enrichment, except sodium, are sharply truncated by the easterly striking Richardson fault. However, both the sodium enrichment and chloritization envelopes related to the Carolin orebodies extend north of the Richardson fault (Figures 33G and 34) which may indicate the presence of a downthrown, down-plunge, northerly extension of the deposit.

MINERAL ALTERATION AROUND THE CAROLIN DEPOSIT

Detailed thin-section examination of the 72 rock samples collected for the lithogeochemical study revealed that the

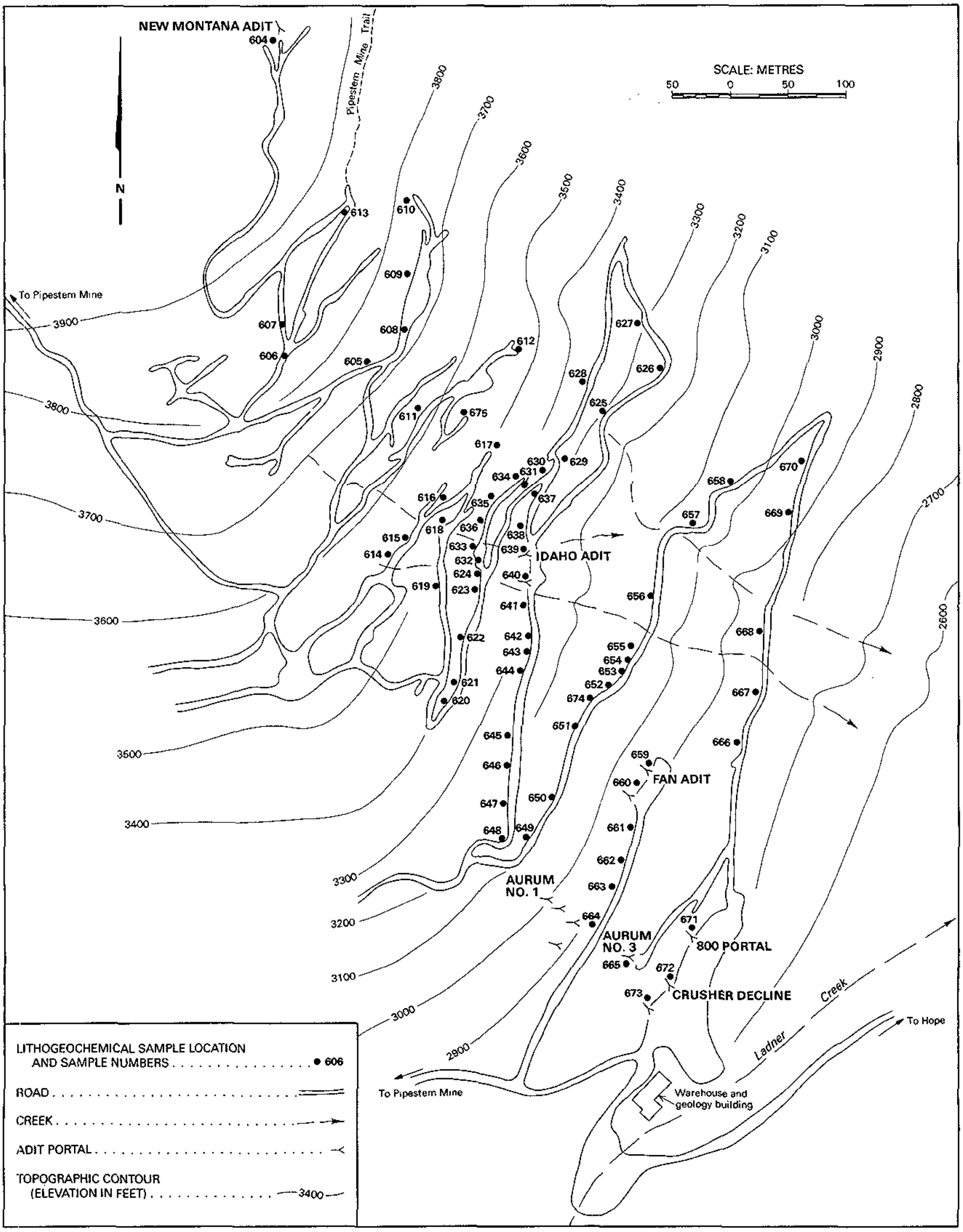


Figure 32. Location of 72 lithogeochemical samples collected at Carolin mine.

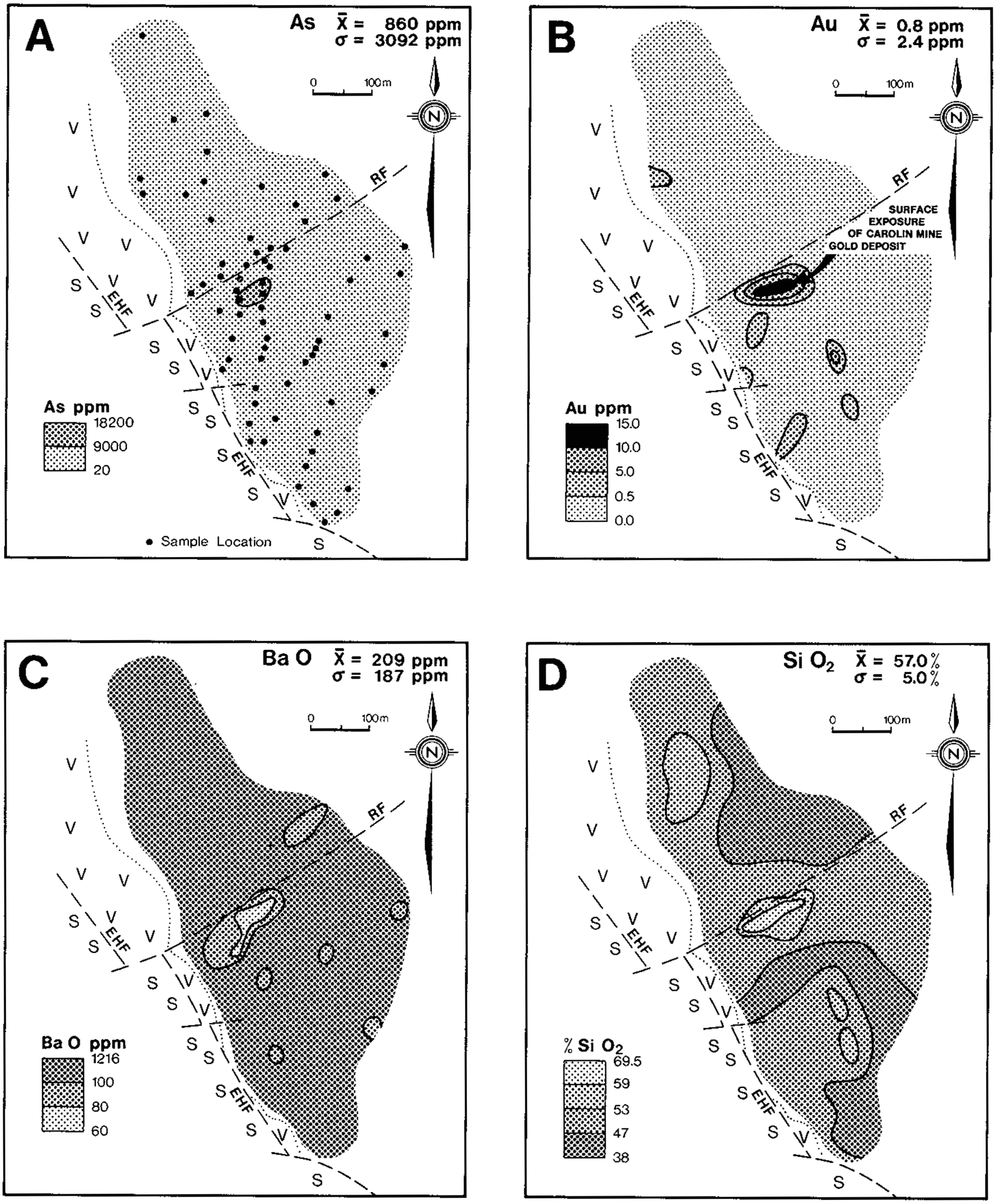
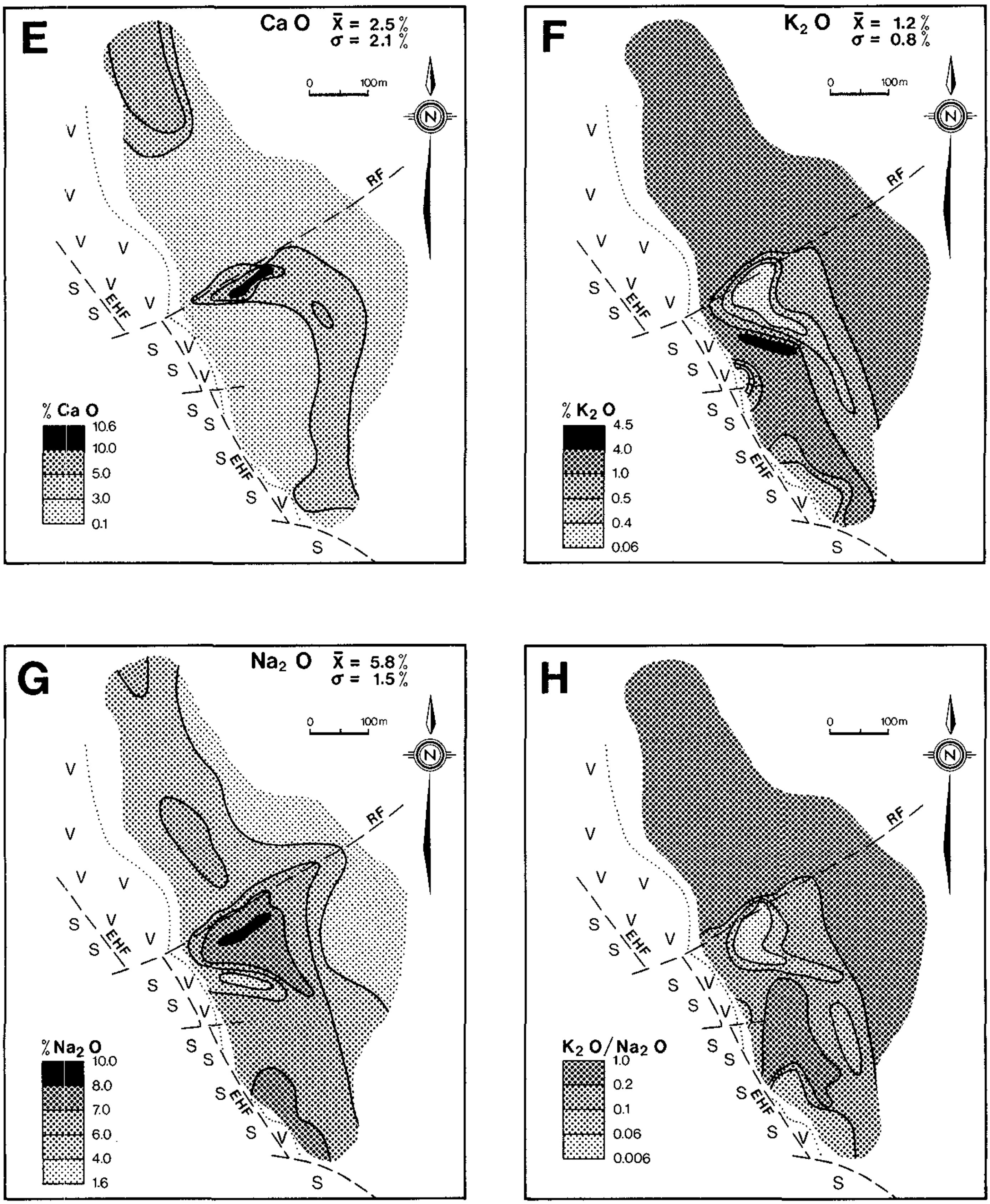


Figure 33. Element zoning associated with the Carolin mine deposit. Hand-generated contoured plots of 72 surface lithogeochemical samples of Ladner Group rock. A = arsenic; B = gold; C = barium; D = silica; E = calcium; F = potassium; G = sodium; H = potassium/sodium ratios. S = Coquihalla serpentine belt; V = Spider Peak formation; EHF = East Hozameen fault.


E
Ca O $\bar{X}$ = 2.5 %
σ = 2.1 %
0 100m
N
RF
V
S
EHF
% Ca O
10.6
10.0
5.0
3.0
0.1
F
K_2 O $\bar{X}$ = 1.2 %
σ = 0.8 %
% K_2 O
4.5
4.0
1.0
0.5
0.4
0.06
G
Na_2 O $\bar{X}$ = 5.8 %
σ = 1.5 %
% Na_2 O
10.0
8.0
7.0
6.0
4.0
1.6
H
K_2 O / Na_2 O
1.0
0.2
0.1
0.06
0.006

Carolin deposit is surrounded by an elongate, discontinuous envelope of mineral alteration up to 200 metres wide and 600 metres long that variably overprints the Ladner Group hostrocks. Four concentric zones of alteration are recognized (Figures 34 and 35A). These have gradational boundaries with one another and are variable in width. They are characterized by different mineral assemblages and/or mineral textures and are designated from outermost to innermost as zones 1, 2, 3 and 4. The two inner alteration zones (3 and 4) are intimately associated with each other and are restricted in area; the intense, coarse-grained nature of the alteration makes it easily identifiable in hand specimen. By contrast, the two outer alteration zones (1 and 2) are more extensive (Figure 34), but the alteration is finer grained and generally only recognizable in thin section. Consequently the existence of alteration zones 1 and 2 was not recognized during the initial geological mapping around the deposit (Ray, 1983; Shearer and Niels, 1983).

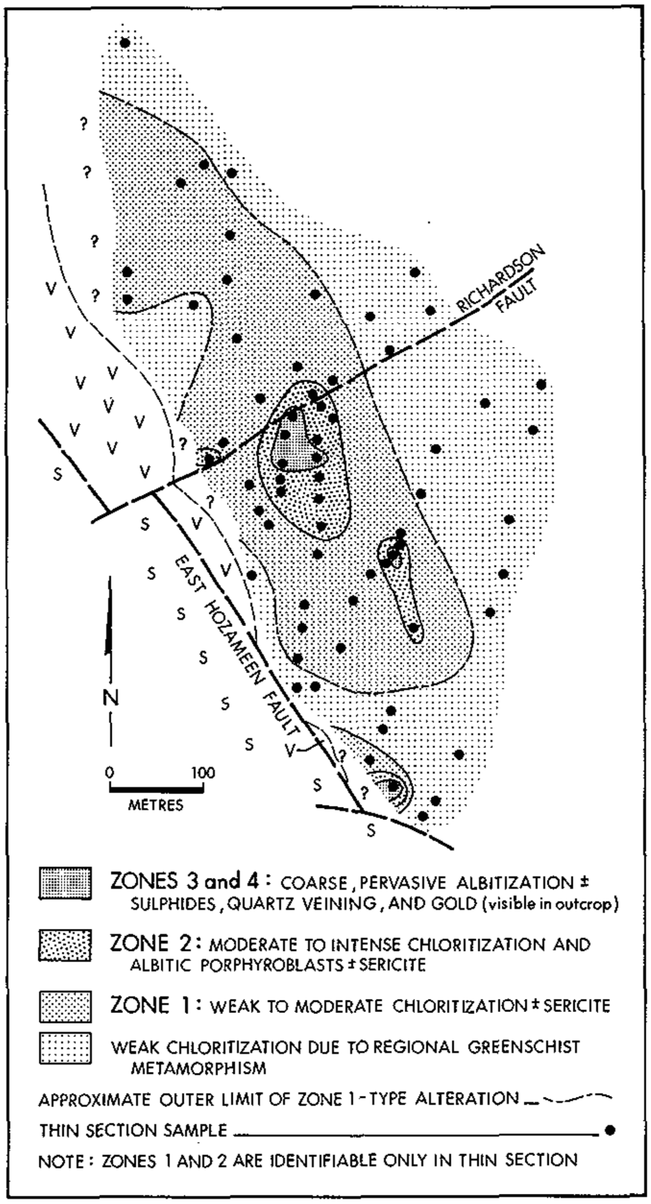


Figure 34. Distribution of mineral alteration zones associated with the Carolin deposit (hand-generated contouring from thin section modal estimates). S = Coquihalla serpentine belt; V = Spider Peak formation.

Zone 1, the outer and most extensive alteration envelope (Figure 34), is characterized by pervasive chloritization. Its outer limits cannot be precisely defined due to the variable chloritic alteration associated with the regional greenschist facies metamorphism in the district. Generally, the original clastic grains of twinned plagioclase (An_{25-35}) are clearly recognizable in the regionally metamorphosed Ladner Group wackes and siltstones outside the mine area. Within Zone 1, however, detrital quartz is generally the only recognizable original component. The groundmass in these rocks is partially or completely replaced by fine-grained chlorite and the original feldspars are altered to exceedingly fine grained sericite, kaolinite, epidote and carbonate. Ilmenite within Zone 1 is rimmed or replaced by leucoxene, and actinolite is present in minor quantities (Figure 35A).

Zone 2 reaches 75 metres in width (Figure 34) and the alteration is marked by the crystallization of fine-grained quartz, plagioclase, actinolite and epidote, and extensive chloritization and sericitization of the groundmass. One characteristic feature of Zone 2 is the appearance of isolated porphyroblasts of twinned albitic plagioclase (An_{3-12}) up to 0.5 millimetre in length within the fine-grained chloritic and

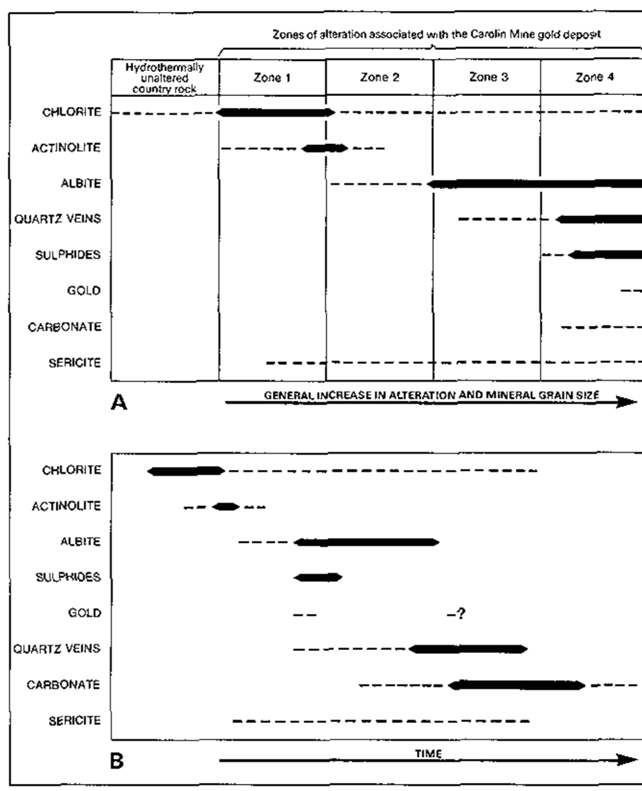


Figure 35. A: Schematic illustration of the four zones of mineral alteration associated with the Carolin orebody. B: Paragenesis of the mineral alteration assemblages associated with the Carolin orebody.

sericitic groundmass; these porphyroblasts are partially replaced by late sericite and carbonate. Original detrital quartz grains are still recognizable but locally the rocks contain recrystallized, fresh quartz, elongate parallel to the foliation.

The transition from Zone 2 to Zone 3 is marked by a decrease in chlorite and sericite, and an increase in both the albite content and mineral grain size (Figure 35A). Zone 3 alteration extends up to 75 metres beyond the orebodies; albitization is pervasive and also occurs as veins; it increases in intensity toward the ore contacts. Locally the rocks are cut by quartz and carbonate veins, and contain carbonate disseminations.

Zone 4 is the central and least extensive alteration type and essentially confined to the orebodies themselves. Like Zone 3, it is marked by intense albitic alteration and quartz veining, but is distinguished by the presence of up to 15 per cent sulphides, which include pyrrhotite, pyrite and arsenopyrite. Locally these rocks carry disseminations and veins of calcite and ankerite. Minor chlorite is widespread and sericite replacement along fractures is common locally. Although these rocks are sodium-rich, x-ray studies have not detected paragonite (Y.J. Kwong, written communication, 1986).

The paragenesis of the alteration assemblage is shown on Figure 35B; thin-section studies suggest the following general sequence: (1) chloritization together with some sericitization and weak kaolinization; (2) the introduction of quartz, albite, sulphides and gold, (3) continuing introduction of albite and quartz, (4) emplacement of multiple phases of quartz ± carbonate veins with local envelopes of disseminated carbonate followed by (5) the late emplacement of veins and disseminations of calcite and ankerite. Weak sericitization and chloritization apparently took place throughout the entire sequence (Figure 35B).

CONCLUSIONS ON CAROLIN MINE

The Carolin orebodies are epigenetic turbidite-hosted gold deposits. Mineralization is marked by the introduction of sulphides, albite, quartz and carbonate and by sporadic trace enrichment of gold, antimony, molybdenum, zinc and copper. Sulphides, which average 6 to 8 per cent of the ore, are mainly pyrrhotite, arsenopyrite and pyrite. Generally, gold is intimately associated with the pyrite, arsenopyrite and trace quantities of chalcopyrite.

Gold mineralization is both lithologically and structurally controlled. It is hosted in wackes, siltstones and conglomerates in the basal part of the Jurassic Ladner Group, close to its unconformable contact with spilitized greenstones of the Triassic Spider Peak Formation and their faulted contact with ultramafic rocks of the Coquihalla serpentine belt. In the mine area, the Ladner Group and Spider Peak Formation were tectonically inverted and subsequently deformed into large-scale upright to asymmetric D_2 folds. Mineralization is apparently contemporaneous with the regional D_2 folding which is believed to be a post-Middle Cretaceous to pre-Late Eocene event (J.W.H. Monger, oral communication, 1986). The age and source of the gold mineralization are unknown although the adjacent Hozameen fault probably provided a conduit for introduction of the mineralizing fluids.

The gold and sulphides are preferentially concentrated in the more competent and permeable sedimentary beds along the thickened hinge region of a disrupted, asymmetric antiformal D_2 fold. The three separate orebodies are saddle shaped and plunge gently northward, subparallel to the D_2 antiformal axis. The deposit is pyrite-rich in its upper parts and pyrrhotite-rich at depth. This zoning suggests the deposit is upright, and younger than the D_1 tectonic overturning that affected the hostrocks.

The ore zones, which reach a maximum thickness of 30 metres, are characterized by sulphides, intense albitic and moderate carbonate, chlorite and seritic alteration, multiple phases of quartz-carbonate veins and late carbonate veining. The general paragenesis of the sulphides is: (1) arsenopyrite and some gold, (2) pyrite, pyrrhotite and some gold, (3) rare and sporadic traces of sphalerite, and (4) traces of chalcopyrite and gold. A pre-sulphide magnetite phase in the ore is apparently unrelated to the mineralizing event. Gold usually forms grains less than 0.02 millimetre in size and visible gold is rare. The gold-silver ratio in the deposit averages 1:10.

Both the deposit as a whole, and the individual ore zones, are enveloped by various geochemical enrichment and depletion halos that largely mirror zones of mineral alteration. Distinct potassium and barium depletion envelopes are related to the breakdown of potassium feldspar during albitization; they are generally twice as wide as the associated ore zones. On a mine scale, the Carolin deposit is enveloped by zones of potassium depletion and sodium enrichment that extend up to several hundred metres into the country rocks. The widespread pervasive albitization and accompanying destruction of potassium feldspar that occurred during mineralization is also reflected by a sharp drop in $K_2O:Na_2O$ ratios. The deposit also coincides with narrow, but distinct zones of calcium enrichment and silica depletion, but gold in the individual orebodies shows no statistical correlation with these elements.

A halo of mineral alteration several hundred metres wide surrounds the deposit. This comprises a chlorite ± sericite outer zone, and an albitic inner zone; the latter includes the sulphide-rich zones carrying the gold. The paragenesis of the alteration assemblages is: (1) chlorite, sericite and minor kaolinite, (2) albite, quartz, sulphides, carbonate and gold, (3) continuing albitization and silicification, followed by (4) multiphase quartz ± carbonate veining, silicification and disseminated carbonate alteration, and finally (5) the local introduction of calcite and ankerite as disseminations and veins.

Most of the quartz ± carbonate veins appear to immediately postdate the introduction of the gold, sulphides and albite. Nevertheless, they are considered to be part of the mineralizing event. Consequently, the 150° to 320°C temperatures obtained from studies of fluid inclusions in quartz veins (Nesbitt *et al.*, 1986; J.B. Murowchick, University of Alberta, written communication, 1986) are interpreted to indicate minimum temperatures for the Carolin mineralization. The hydrothermal system responsible for the Carolin orebodies deposited gold over an area of about 3000 square metres. However, the related geochemical and mineral alteration in the country rocks affected an outcrop area at least 40 times this size (approximately 130 000 square metres).

Lithological sampling to outline other areas of sodium enrichment represents a viable exploration tool for locating similar deposits in the district. The potassium and barium depletion envelopes that surround the individual ore zones represent valuable drill targets; they could be used to guide exploration for possible down-plunge extensions of the Carolin deposit north of the Richardson fault.

Pipestem Mine (MINFILE 92HNW011) (Past Producer No. 4, Figure 23)

The Pipestem mine is situated about 3 kilometres northwest of Carolin mine (Figure 40A), on the divide between Ladner and Siwash creeks at an elevation of approximately 1220 metres (4000 feet). Mineralization is associated mainly with quartz veins that cut tuffaceous fossiliferous wacke horizons within the upper part of the Ladner Group succession. The property was worked in the 1920s and 1930s (Cairnes, 1920, 1924, 1929); the workings included several open cuts, one shaft 10 metres deep, at least four adits and extensive exploratory crosscuts, drifts and raises. The most extensive workings were started in 1932 on the No. 4 level and a mill was built immediately below the No. 4 adit portal (Figure 43) (B.C. Minister of Mines, Annual Report 1936). Several shipments of crude ore and concentrate were shipped, but production records are incomplete. The British Columbia mineral inventory database (MINFILE) records a total production of approximately 8.5 kilograms of gold from 1498 tonnes of ore milled between 1935 and 1937 (Tables 4 and 7). However the large size of some of the mineralized raises driven from the No. 3 and 4 levels, together with the high grade of the concentrate found in the old mill circuits (J.T. Shearer, personal communication, 1983), suggests that total gold production was probably higher than the 8.5 kilograms reported in MINFILE.

Following the closure of the mine in 1937, no serious work was undertaken in the area until the 1970s and 1980s when Carolin Mines Ltd. constructed roads to the minesite, reopened some of the adits and completed a geochemical, geophysical and diamond-drilling program (Shearer, 1982a). In addition, the author completed a surface geological map of the mine area (Figure 43) and mapped the No. 4 level underground workings using a base map supplied by Carolin Mines Ltd. (Figure 44).

GEOLOGY AND MINERALIZATION

The detailed geology of the Pipestem mine area and the No. 4 level workings is shown on Figures 43 and 44, respectively. The gold-sulphide mineralization is associated mainly with quartz veins and irregular quartz breccias (Plate 30) that formed within shatter zones cutting competent tuffaceous and fossiliferous wacke units within the upper, predominantly argillaceous part of the Ladner Group succession (Figure 28). These wacke beds are unique in containing megafossils of Late Jurassic age and in being the only coarse clastic sedimentary rocks in the district that are within the upper part of the Ladner Group succession. Consequently, the Pipestem mine mineralization is farther away from the basal Ladner Group unconformity and Hozameen fault than the other wacke-hosted occurrences in the Coquihalla gold belt.

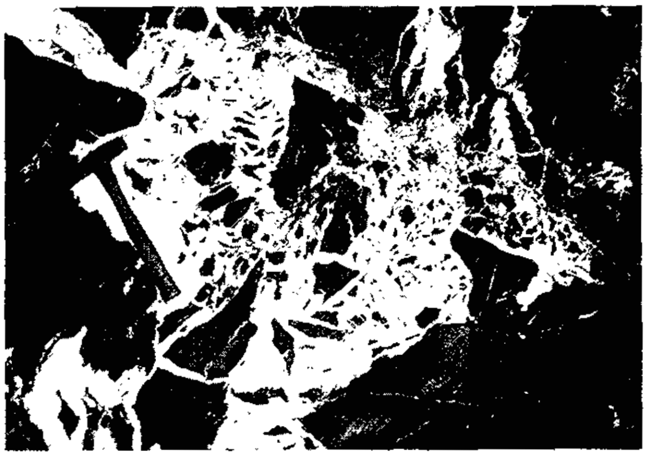


Plate 30. Pipestem mine. Quartz breccia zone within altered, sulphide-bearing Ladner Group tuffaceous wackes. Underground, Level 4 workings.

The mine area is mostly underlain by grey to black, locally organic-rich, pyritic slaty argillites intercalated with lesser amounts of well-bedded siltstone. A number of northwesterly striking bands of tuffaceous, fossiliferous wacke occur within this argillaceous sequence. These bands are 5 to 45 metres thick and are the principal host to the gold mineralization. Most of the wacke interbeds appear to have limited strike extent (Figure 43), however, at least one fossiliferous wacke unit has been traced to the northwest for approximately 900 metres where it outcrops, together with other thin wacke horizons, near the Home X gold occurrence (Figure 40A).

The Ladner Group rocks in the Pipestem mine area have undergone a complex, poorly understood history of structural deformation. Bedding-cleavage intersection measurements indicate the existence of several D_2 fold closures (Figure 43); these folds have steeply dipping, southwesterly striking axial planes and subhorizonal axes (Figures 20D, E and F). The rocks are cut by several north to northwesterly striking faults; the slaty argillites are locally intensely kink folded and fractured and, near the No. 2 adit portal, they are cut by numerous narrow, folded quartz veins. Very little unequivocal graded bedding was seen in the mine area and this, together with insufficient structural data, makes it uncertain whether the tuffaceous wacke horizons represent several individual units or fold repetition of a single bed.

The tuffaceous wackes are medium to very coarse grained, massive to poorly bedded rocks that are cut locally by a pronounced fracture cleavage; this cleavage is best developed close to the wacke-argillite contacts. Within the No. 3 and 4 level workings the wackes locally comprise 1 to 10-centimetre beds of coarse sedimentary lithic material interbedded with thinner (0.2 to 2 centimetres) dark partings of strongly cleaved argillite. The unaltered wackes are a light green-grey, blue-grey or buff colour, but the hydrothermally altered rocks adjacent to the veins are dark green to black. Fossil belemnites (Cairnes, 1929), as well as bivalves and their casts, are visible at several localities (Figure 43). However, fossil distribution is irregular; in some wacke horizons fossils are very rare or absent, while in others, particularly toward the presumed stratigraphic base of the unit, they are densely packed.

The unaltered tuffaceous wackes at Pipestem mine are generally quartz poor; characteristically they contain numerous broken subangular plagioclase crystals together with abundant (up to 35 per cent) angular fragments of altered feldspar-porphyritic and aphanitic acid volcanic rock. Commonly this tuffaceous material is mixed with variable amounts (up to 80 per cent) of broken bivalve shell fragments and rounded grains of recrystallized dolomite. Less common clast lithologies include altered greenstone (up to 10 per cent) with lesser amounts of chert, argillite, feldspar and strained quartz crystals. The lime-rich rocks are commonly cut by veins of secondary carbonate orientated normal to the bedding and the rock matrix is often replaced by variable amounts of epidote, chlorite and carbonate. The northwestern margins of some wacke horizons contain scattered barren pyrite cubes up to 1.5 centimetres across and some narrow, irregular, unmineralized quartz veins (Figure 43).

The sedimentary rocks are intruded by several narrow sills and dykes up to 4 metres thick. These include a highly altered hornblende-bearing diabase intrusion outcropping about 60 metres northeast of the No. 3 adit portal, as well as several porphyritic felsic sills (Figures 43 and 44). The latter resemble the minor felsic intrusions spatially associated with some gold occurrences in the Siwash Creek area and are generally leucocratic, moderately altered and carry large phenocrysts of quartz and/or albitic plagioclase. The margins of one felsic sill, which intrudes wackes approximately 150 metres south-southwest of the No. 3 adit portal, contain thin quartz veins and pyrite, but no gold. Many of the felsic sills have faulted contacts and are cut by irregular quartz veins; the quartz veins within a faulted felsic sill approximately 60 metres northeast of the No. 3 adit portal contain clusters of white scaly aggregates which x-ray diffraction studies indicate to be a mixture of sericite, chlorite and the sodium-rich mica, paragonite (Y.J. Kwong, personal communication, 1982).

Auriferous, sulphide-bearing quartz veins and stringers are exposed in the surface trenches on the Pipestem property (Figure 43), but the best mineralization is exposed underground in the No. 3 and 4 level workings (Figure 44). Cairnes (1929) reports the presence of both visible and microscopic gold. In the trenches the black, hydrothermally altered hostrock wackes are cut by irregular white quartz veins up to 0.5 metre in thickness. These veins have sharp contacts and are both crosscutting and parallel to the fracture cleavage in the hostrocks. The veins and the heavily chloritized wallrocks contain variable amounts of coarsely crystalline pyrite with some cubic crystals exceeding 1.25 centimetres in size. Arsenopyrite, together with minor sericite and chlorite, occurs sporadically.

The gold-bearing quartz-sulphide mineralization on Levels 3 and 4 is preferentially concentrated along either the faulted contacts between the wackes and argillites, or along fracture-related shatter zones in the main wacke units (Figure 44). Discrete but fragmented quartz veins up to 0.4 metre wide and quartz stringer swarms and quartz breccia zones up to 1.5 metres in width are present (Plate 30). These are discontinuous along strike; some quartz breccia systems pinch and swell and others are cut by late faulting.

The quartz in the veins, stringers and breccias is white and varies from massive to vuggy; the latter variety contains small cavities lined with fine-grained quartz crystals. Locally the veins also contain clots of pale, altered feldspar and traces of sericite, carbonate and chlorite. The breccia zones consist of sharply angular, silicified and sulphide-bearing fragments of chloritized Ladner Group rocks enclosed within a massive to weakly vuggy matrix of white quartz. Clasts are mostly matrix supported and are generally 0.5 to 5 centimetres in diameter, but locally exceed 15 centimetres across.

The irregular, impersistent quartz stringer zones are generally barren. However, some of the thicker quartz veins and breccia zones are surrounded by wallrock alteration envelopes that vary from a few millimetres up to 0.4 metre wide and which carry erratic gold values. This alteration, which affects both the wallrock and the sedimentary clasts in the breccias, is characteristically dark coloured and contains up to 40 per cent disseminated, coarsely crystalline pyrite with sporadic arsenopyrite and traces of pyrrhotite. Sulphides are generally more abundant in the alteration envelopes, and poorly developed in the quartz veins. Shearer (1982a) reports that drilling on the property intersected some chloritic and sericitic wallrock alteration, together with albite-calcite veinlets.

GEOCHEMISTRY OF THE MINERALIZATION AT PIPESTEM MINE

Trace element analyses from eight sulphide-bearing samples collected from both the trenches and the No. 3 and 4 level underground workings are shown in Appendix 15. They

TABLE 7.
REPORTED ANNUAL PRODUCTION FROM THE PIPESTEM MINE*

Year	Tonnes milled	Gold production (g)	Silver production (g)
1935	277	2 115	218
1936	953	5 070	746
1937	318	1 275	187
Totals	1 498	8 460	1 151

* *(Data taken from MINFILE, 092HNW011.)*

include samples of quartz vein, quartz breccia and pyritic wallrock alteration. The highest gold values occur in the sulphide-rich wallrock alteration envelopes rather than in the quartz veins, but not all the altered wallrock samples (for example, sample PS 7) contain economic gold values.

There is a positive correlation between gold and arsenic, and the mineralization is associated with the sporadic trace enrichment of mercury. The gold-silver ratio of the auriferous samples varies between 1:1 and 10:1; gold-silver ratios determined on the meagre production data (Table 7) average 7:1. Atomic absorption spectroscopy indicates that two of the most auriferous samples (PS 3 and 5) are anomalous in tungsten, but no quantitative values for this element are available.

CONCLUSIONS ON PIPESTEM MINE

The highest gold values at Pipestem mine are concentrated in narrow, sulphide-rich wallrock alteration envelopes that surround poorly mineralized to barren quartz veins, stringers and breccia zones. The mineralization is hosted by fossiliferous and tuffaceous wackes of Late Jurassic age, that are interbedded with a predominantly argillite sequence in the upper portion of the Ladner Group succession.

The sulphide mineralogy is comparatively simple and comprises abundant coarse pyrite with variable amounts of arsenopyrite and some minor pyrrhotite. Trace amounts of chalcopyrite are very rare and there are no reports of sphalerite in the ore. The quartz veins are both massive and vuggy, but unlike those at the Emancipation mine, the carbonate content is very low. Gold and arsenic have a positive sympathetic relationship, and the mineralization is associated with the trace enrichment of mercury and possibly tungsten.

Interpretation of the geology and morphology of the mineralized zones at Pipestem mine is inhibited by the complex structure of the mine area which remains poorly understood. Clarification of the structural history is a prerequisite for successful exploration as the mineralization probably follows shatter zones developed where fault planes intersect folded wacke horizons. The controlling folds, like those at Carolin mine, are probably D_2 structures; at Pipestem mine they are upright, with southwesterly striking axial planes and subhorizontal axes (Figure 20D, E and F). However, the precise orientation of the controlling fractures and the plunge of the ore shoots are unknown. Unfortunately, the geology mapped on No. 4 level (Figure 44) cannot be positively correlated with the surface (Figure 43). The western extensions of the No. 4 level penetrate a thick, mineralized wacke unit that may occupy a major fold hinge (Figure 44), but neither the thick unit nor the fold structure are recognized on surface.

WARD MINE (MINFILE 92HNW015) (PAST PRODUCER NO. 5, FIGURE 23)

Total production from the Ward mine is reported as 4.2 kilograms of gold from an unknown quantity of ore milled (Table 4). There is little detailed information available on the geology, production, precise location or full extent of the mine workings. The following synthesis is based on various British Columbia Minister of Mines Annual Reports (MMAR), a brief report by Bateman (1911) and observations made in the course of this project.

The Ward claims (Ward and No. 2 Ward) were located on the east side of the south fork of Siwash Creek, close to its confluence with the middle and north forks (MMAR, 1917, page F227). The Roddick and Emigrant claims were situated west and south of the Ward property respectively (Figure 23). In 1911, a six-stamp mill was operating on the Ward property (MMAR, 1917) and Bateman (1911) reported work being conducted on an open cut and three adits, one of which was approximately 90 metres in length. The ore was carried from the open cut to the mill in 1-ton cars by a gravity-drive cableway 150 metres long. The remains of a mill and several small, collapsed adit portals are still discernible in the Siwash Forks area.

The Ward claims are largely underlain by poorly to moderately bedded, dark, pyritic slaty argillites of the Ladner Group. These are intercalated with very rare, thin beds of wacke and siltstone which locally exhibit well-developed graded bedding. In the Siwash Forks area the Ladner Group rocks are deformed by upright D_2 folds, and are intruded by numerous light-coloured felsic sills and dykes that are mostly 1 to 5 metres wide, although some exceed 150 metres in width. Some of these intrusives are strongly altered and are soft and deeply weathered. The sills and dykes include both equigranular and feldspar porphyry varieties; gold is spatially associated with the latter which Bateman described as "quartz-syenite-porphyry". These porphyritic intrusions resemble the felsic sills at the Pipestem mine approximately 6 kilometres to the south. Many of the felsic sills on the Ward claims have irregular, chilled margins and narrow aureoles of weak thermal alteration are developed in the adjacent argillites. Elsewhere the sills are fault bounded and the contacts marked by rust-stained veins of white quartz up to 0.6 metre wide. Many sills are also cut by irregular quartz stringers, quartz-filled tension gashes, or more regular, intersecting sets of quartz veins generally up to 5 centimetres wide. These veins contain small vuggy cavities lined with quartz crystals and sparse amounts of disseminated pyrite. Bateman reports that fine gold occurs both in the quartz and the porphyry intrusions and is generally coated with a film of iron oxide; globules of mercury were also noted in some of the pyritic gangue. However, it should be noted that similar early reports of mercury occurring in the Aurum mine mineralization were not substantiated by later analyses (Cairnes, 1929).

GOLD OCCURRENCES IN THE COQUIHALLA GOLD BELT

In addition to the five past-producing mines, the Coquihalla gold belt contains at least 25 gold occurrences all spatially associated with the Hozameen fault system (Figure 23). The following synopsis of each occurrence is based either on early publications, such as those by Cairnes, (1920, 1924, 1929), the British Columbia Minister of Mines Annual Reports (MMAR), unpublished assessment reports and the British Columbia mineral inventory database (MINFILE), or on observations made during this survey. However, previously published data concerning the claim names, geology, mineralization and location of some occurrences are vague or contradictory.

Broken Hill (Minfile 92HSW035) (Occurrence No. 6, Figure 23)

The Broken Hill occurrence is on the Morning group of claims, east of the Coquihalla River on a steep slope overlooking Dewdney Creek, at an elevation of approximately 760 metres (2500 feet) (Cairnes, 1920, 1924). Surface stripping revealed several quartz ± carbonate veins cutting Ladner argillites close to their contact with greenstones of the Spider Peak Formation. The largest vein is hosted by north-northeast-striking slaty argillites and is up to 3 metres wide over a strike length of 60 metres. It is irregularly mineralized with arsenopyrite, some pyrite and traces of galena. A single sample collected from across a wider, but sulphide-poor section of the vein contained no gold or silver (Cairnes, 1924).

The argillites are intruded by two strongly altered, calcite-rich andesite dykes that are 2.5 and 4.5 metres wide respectively and about 50 metres apart. The wider dyke is in contact with the quartz vein and Cairnes (1924) speculated that the dykes are genetically related to the mineralization.

South Fork Group (Occurrence No. 7, Figure 23)

This group of claims was located west of the Aurum property and covers part of the upper basin of Fifteen Mile Creek; the principal workings are along the south branch of the south fork of Ladner Creek, at elevations of 975 and 1000 metres (3200 and 3300 feet). The property lies within the Coquihalla serpentine belt and is mostly underlain by serpentinite which is cut by irregular lenses and dykes of altered diorite up to 6 metres wide. The principal workings were two adits with portals 100 metres apart and comprising 170 metres of drifts and crosscuts. These workings followed a talc and carbonate-bearing shear, 15 to 24 metres wide, which reportedly carried sporadic but conspicuous amounts of free gold. However, a sample of talcose rock collected from the lower adit contained no economic mineralization (Cairnes, 1929).

Fifteen Mile Group (Occurrence No. 8, Figure 23)

This group of nine claims was located within the drainage basin of Fifteen Mile Creek which is mostly underlain by ultramafic rocks of the Coquihalla serpentine belt, close to their contact with the Hozameen Group. A series of narrow, northwesterly striking talcose shears was outlined (Cairnes, 1929). The uppermost shear averages 15 centimetres in width and contains crushed talcose gouge at the contact between a diorite dyke and sheared serpentinite. No significant sulphide mineralization was noted by Cairnes, although occasional free gold was reported.

The next underlying shear, which was known as the "main seam" is up to 15 metres wide, although gold values are reportedly confined to a 60-centimetre thickness of talcose rock. The mineralized zone lies within altered serpentinites close to their contact with a decomposed diorite dyke 60 metres wide. The gold occurs mainly as polished films on slickensided surfaces of talc or talcose serpentinite, but is also associated with chalcocite in small nodular masses of "white rock" (Cairnes, 1929) that contain coarse crystalline pyroxene and some garnet. This pyroxene-garnet-bearing rock is also reportedly present at the South Fork occurrence. Unlike most gold elsewhere in the district, the gold on the Fifteen Mile property has a distinct red colour, probably due to the presence of copper.

Snowstorm (Pittsburg) (Minfile 92HNW006) (Occurrence No. 9, Figure 23)

The Snowstorm-Pittsburg group of claims adjoined the original Idaho claims, and was located on the northwestern slope of the west fork of Ladner Creek, covering the contact between the Spider Peak Formation and the Ladner Group. The following description is largely summarized from Cairnes (1920, 1924). Most of the early work was done on the Pittsburg claim, approximately 90 metres above Ladner Creek. Work completed in the early 1920s included driving a 12-metre adit and making a series of open cuts to trace a northwesterly striking mineralized zone along the fractured contact between greenstones of the Spider Peak Formation and Ladner Group slaty sedimentary rocks. The adit was driven along one of three mineralized fracture zones within the greenstones, approximately 60 metres southwest of the greenstone-slate contact. This "Contact vein" strikes northwest, dips steeply northeast and was traced onto the adjoining Idaho claims. It mostly follows the greenstone-slate contact, but at its highest elevation it lies entirely within slaty sedimentary rocks of the Ladner Group. The width of the Contact vein varies considerably, as does the amount of vein quartz present. Near the adit it averages 4 to 6 metres wide and contains abundant quartz stringers similar in composition to those at the Emancipation mine. In other places the zone contains solid vein quartz over 3 metres wide. Cairnes reports obtaining pannable gold from the vein, and notes the sporadic presence of pyrite, pyrrhotite and arsenopyrite.

Close to the adit portal the Contact vein is intersected by a second mineralized structure, the "West vein", which is an elongate, curvilinear shatter zone within the greenstones of the Spider Peak Formation. In places it is represented by a single quartz vein "several feet in width" while elsewhere it is marked by a less well defined sulphide-rich, quartz-poor zone.

A third mineralized zone, the "North vein" also intersects the Contact vein but is hosted entirely by the Ladner slates. It contains large amounts of vein quartz and the wallrock slates are silicified and contain pyrite and arsenopyrite.

In summary, the Snowstorm-Pittsburg property covers three sporadically mineralized fracture zones whose development was controlled by brittle faulting along the contact between the more competent Spider Peak greenstones and less competent Ladner slates. The sporadic development of vein quartz in the fracture zones, together with the wallrock alteration, and the tendency of the zones to intersect and pass horizontally and vertically from the greenstone into the slates, is strikingly similar to the vein systems at the Emancipation mine.

MONTANA (MINFILE 92HNW008) (OCCURRENCE NO. 10, FIGURE 23)

This property consisted of six claims and one fraction that extended northwest from the Idaho claims, toward the area west of Pipestem mine. Cairnes (1924, 1929) reported that an open cut exposed a number of 5-centimetre-wide quartz veins cutting greenstones of the Spider Peak Formation, about 20 metres southwest of their contact with Ladner Group slates. The veins yielded rich specimens of free gold and the wallrocks contain pyrite. The nearby slates were also cut by a calcareous "lead", 1 metre thick, containing pyrite and pyrrhotite.

It should be noted that in MINFILE, the Montana occurrence has previously been incorrectly grouped with the Georgia 2 occurrence. However, the latter is situated farther north on the Spider Peak group of claims (Figure 10 *in* Cairnes, 1929).

RUSH OF THE BULL (MINFILE 92HNW009) (OCCURRENCE NO. 11, FIGURE 23)

This occurrence lies on the Rush of the Bull Fraction which was located north of both the Rush of the Bull No. 1 and Montana claims (Cairnes, 1920). It is situated at an elevation of approximately 1370 metres (4500 feet) close to the old Pipestem trail that connected the Idaho claims to Pipestem mine. The Ladner Group slates are cut by two quartz veins averaging 10 centimetres in thickness; both the veins and the adjacent wallrocks are mineralized with coarse arsenopyrite and some free gold. Cairnes (1924) notes that the slates near the showing are intruded by several felsic feldspar porphyry dykes and sills similar to those present at Pipestem mine and the Siwash Creek–Ward mine area.

MCMASTER ZONE (OCCURRENCE NO. 12, FIGURE 23)

The McMaster zone is characterized by wacke-hosted, gold-sulphide-albite-quartz-carbonate mineralization, identical to that at the Carolin mine (Plates 31 and 32). It is located approximately 2.5 kilometres southeast of Spider Peak and 2.0 kilometres northwest of Carolin mine. It was discovered in 1975 (Griffith, 1978; Shearer, 1982a) by Precambrian Shield Resources Limited following completion of a program of geochemical soil sampling; subsequent work included trenching and drilling seven shallow holes. Carolin Mines Ltd. gained control of the property in 1976.

During the present survey, part of the property was geologically mapped by pace and compass traverses (Figure 36) and some sulphide-bearing outcrops were sampled and assayed (Appendix 16).

GEOLOGY AND MINERALIZATION

The geology of the McMaster zone is shown on Figure 36. The mineralization, like that at Carolin mine, is hosted by folded and faulted, coarse clastic sedimentary rocks belonging to the lower part of the Ladner Group succession, less than 100 metres from its unconformable contact with the

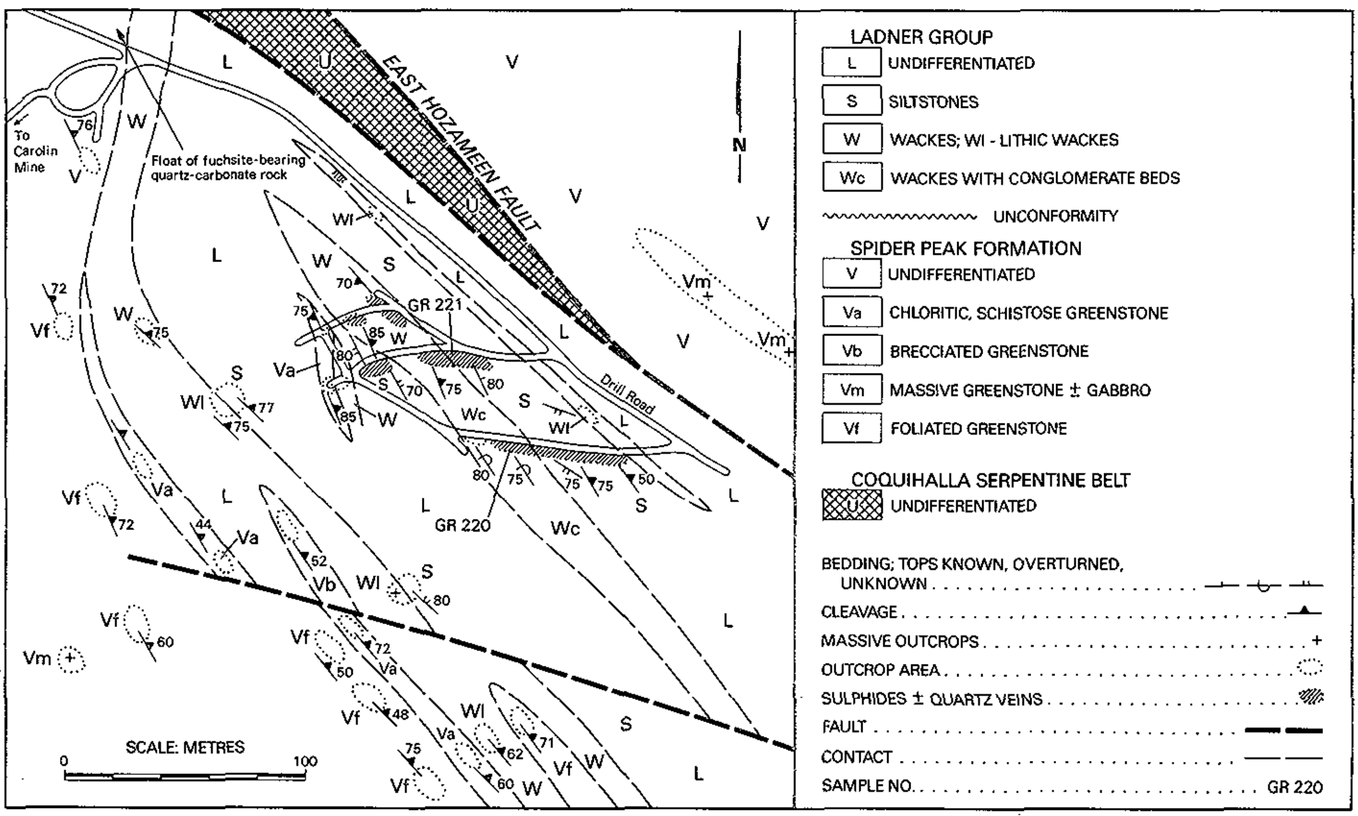
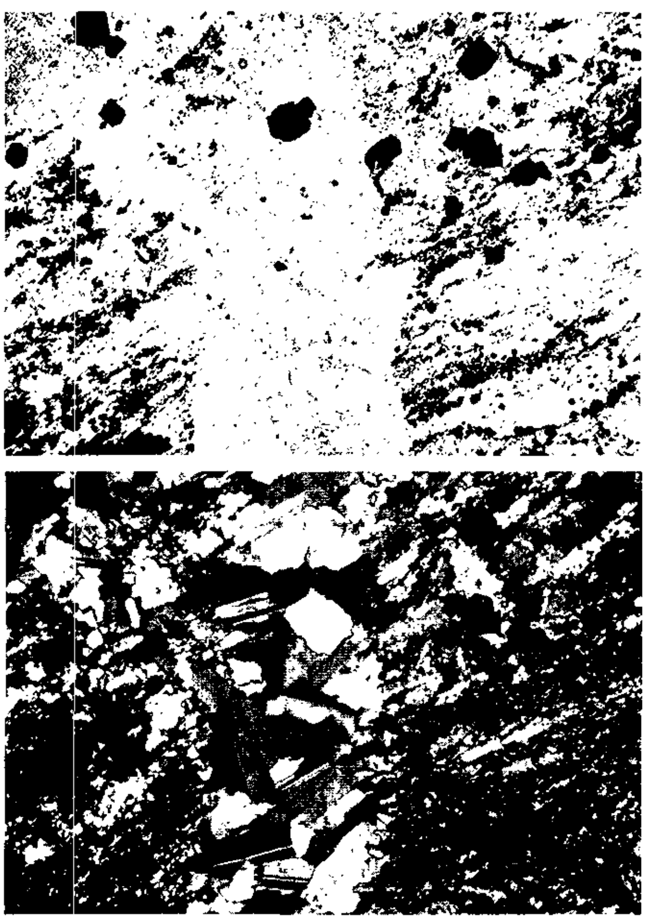


Figure 36. Geology of the McMaster Zone occurrence.

Spider Peak Formation. To the northeast the Ladner Group is in fault contact with greenstones and gabbros of the Spider Peak Formation and ultramafic rocks of the Coquihalla serpentine belt. These fault contacts are not exposed but underlie a valley that trends northwestward to McMaster Pond (Figure 40A). Scattered angular boulders of fuchsite-bearing quartz-carbonate rock (listwanite), up to 3 metres long, were mapped in this valley, northwest of the showings (Figure 36; Plate 8). To the southwest, the unconformable contact between the Ladner Group and Spider Peak Formation is locally faulted and sheared. The Spider Peak rocks include both massive and strongly cleaved, schistose greenstones together with some thin beds of volcanic sandstone.

The Ladner Group rocks in the vicinity of the McMaster zone are predominantly an interbedded succession of locally graded siltstones, wackes and coarse volcanic-lithic wackes with some thin discontinuous beds of argillite, volcanic sandstone and conglomerate (Plate 14). The conglomerates contain deformed pebbles and cobbles up to 25 centimetres in length within a fine-grained silty matrix. Clast lithologies include volcanic greenstones, altered gabbros, pale-coloured acid volcanics, quartzites and lesser amounts of coarse-grained granitic rocks. The siltstones and bedded wackes contain slump and flame structures that suggest deposition by



Plates 31 and 32. McMaster Zone. Photomicrographs (PPL, Plate 31; X Nicols, Plate 32) showing fine-grained, layered sulphide-albite-quartz-gold-bearing mineralized wackes crosscut by a vein of fresh, coarser grained albite. Sample GR 220 (for location *see* Figure 36).

westerly directed paleocurrents. Many of the metasediments are overturned and young northeastwards; the bedding-S_2 cleavage intersections indicate that they occupy the inverted, steeply dipping southwestern limb of a D_2 antiform that verges to the northeast.

Thin, elongate units of brecciated, altered and strongly cleaved greenstone occur within the Ladner Group. These are believed to represent fault-bounded slices of Spider Peak Formation (Figure 36), similar to those outcropping close to the Carolin deposit.

The mineralized wackes are strongly albitized and chloritized, and form quartz-veined outcrops that weather to a black and rust-stained colour. The alteration and gangue mineralogy are identical to that seen at Carolin mine, both in hand specimen and thin section (Plates 31 and 32). Mineralized outcrops contain up to 10 per cent sulphides which generally comprise pyrrhotite, pyrite and arsenopyrite, together with both pervasive albite and albite veins as well as at least two generations of irregular, randomly orientated quartz veins. Late quartz-carbonate veins and carbonate disseminations are also present.

GEOCHEMISTRY OF THE McMASTER ZONE MINERALIZATION

The analytical results obtained from two grab samples collected from sulphide-bearing quartz-veined outcrops of the McMaster zone are shown in Appendix 16 (for sample location *see* Figure 36). The higher gold values are associated with enrichment in arsenic and depletion in barium. There is no evidence of anomalous mercury associated with the mineralization.

CONCLUSIONS ON THE McMASTER ZONE

The mineralization in the McMaster zone is similar in its mineralogy, alteration features, hostrock lithologies and overall structural and stratigraphic setting to that at Carolin mine. Consequently, future exploration on the property should be directed toward orebodies of the Carolin type that have a saddle reef morphology and are surrounded by halos of specific geochemical enrichment and depletion.

Exploration should include detailed structural mapping to outline D_2 fold hinges in the Ladner Group, together with lithogeochemical sampling to delineate areas of sodium, antimony, arsenic and gold enrichment. Drill core should be routinely analysed to detect possible ore-related zones of potassium and barium depletion.

GOLDEN CACHE (MINFILE 92HNW048) (OCCURRENCE NO. 13, FIGURE 23)

This occurrence outcrops on the Golden Cache No. 1 claim, which was the southernmost of three claims forming the Gem group (Cairnes, 1920, 1924). The claims adjoined the Rush of the Bull Fraction to the north, at the head of the middle fork of Ladner Creek, and largely followed the Ladner Group/Spider Peak Formation contact. The occurrence includes six narrow west-northwesterly striking, steeply dipping quartz veins that cut an unidentified hostrock. Cairnes reports the veins are sparingly mineralized with pyrite and arsenopyrite, and that they carry low gold values.

Murphy (Occurrence No. 14, Figure 23)

The Murphy gold occurrence is exposed at an elevation of about 1460 metres in a roadcut approximately 400 metres north-northwest of McMaster Pond (Figure 40A). It was discovered in 1982 by prospector D. Murphy, while investigating a gold geochemical anomaly in soils, outlined by Carolin Mines Ltd. The mineralization consists of fine free gold associated with sparse amounts of pyrite and arsenopyrite in a quartz vein between 5 and 25 centimetres wide. The vein can be traced discontinuously for 20 metres within altered greenstones of the Spider Peak Formation, within 2 metres of the steeply dipping East Hozameen fault which separates the greenstones from strongly sheared talcose serpentinites of the Coquihalla serpentine belt. Approximately 100 metres to the southeast the fault contains a thin (5 to 15 metres) slice of fuchsite-bearing quartz-carbonate rock (listwanite). The auriferous quartz vein strikes subparallel to the East Hozameen fault but dips very gently northeastwards (between 5 and 15°) into the hillside. The dark brick-red soil over the occurrence contains appreciable quantities of pannable gold.

The vein pinches and swells along strike and comprises white quartz containing small vugs lined with clear quartz crystals; the sulphides in the vein are visually estimated to be less than 2 per cent by volume. Gold is most commonly seen as a fine coating on chocolate-brown alteration products comprising a mixture of goethite, hematite and lepidocrocite with some remnant pyrite. Elsewhere, fine gold is associated with both pyrite and arsenopyrite and, in rare instances, it is free in the quartz. The gold and sulphides occur at both the vein margins and centres, but there is no noticeable wallrock alteration. Trace element analyses on a sample of sulphide-bearing vein quartz are shown in Appendix 17. Despite the anomalous arsenic content, the sample shows no enrichment in either gold, silver, mercury or antimony.

Gem (Minfile 92HNW010) (Occurrence No. 15, Figure 23)

The Gem gold occurrence outcrops on the northernmost of three claims forming the Gem group where a decomposed quartz vein, 2 metres wide and containing fragments of silicified country rock, was exposed in three trenches. Pyrite and arsenopyrite are present in both the vein and the wallrocks, particularly the hangingwall which is a west-northwesterly striking, steeply dipping felsic sill. The quartz vein strikes toward the Pipestem mine which lies farther north on adjoining claims. No mention of the country rocks around the Gem occurrence is made by Cairnes (1920, 1924), however, the presence of the felsic sill and the location of the occurrence in relation to the Pipestem mine, suggest that the Gem vein is hosted by the Ladner Group, rather than the Spider Peak Formation. Cairnes reports that the most northerly of the three surface showings is overlain by red soil that contains pannable gold. This appears similar to the brick-red, gold-bearing soil present at the Murphy occurrence.

Star (Minfile 92HNW014) (Occurrence No. 16, Figure 23)

This occurrence outcrops on the Star group, which comprised three claims (Star, Ladner No. 1 and Ladner No. 2) located immediately north of the Pipestem mine (MMAR, 1933). Four trenches exposed a northwest-striking shear zone 2 metres wide over a reported strike length of 200 metres. The shear contains 1.2 metres of quartz and 80 centimetres of pyritized Ladner Group slate. An assay of 1.7 grams per tonne gold (0.05 ounce per ton) was recorded and locally the soil contained pannable gold.

Home X (Minfile 92HNW013) (Occurrence No. 17, Figure 23)

The Home X property originally comprised eight claims located north of the Pipestem property. Several trenches in the Ladner slates exposed numerous quartz veins up to 15 centimetres wide that contain pyrite, arsenopyrite and low gold values (MMAR, 1933).

Some old workings on the Home X ground close to the Carolin-Pipestem mines road, about 600 metres northwest of Pipestem mine, were examined during this survey. There appeared to be one or possibly two collapsed adit portals, with a small dump containing large fragments of quartz-veined black slaty argillite. Black, poor to moderately bedded Ladner slaty argillites, cut by irregular quartz veins up to 10 centimetres wide, are exposed close to these workings. The veins contain sparse amounts of pyrite and traces of arsenopyrite concentrated in fractures that both cross the quartz veins and follow the vein contacts. A sample of quartz-veined, sulphide-bearing argillite from the dump was assayed but contained no enrichment in gold, arsenic, antimony or mercury.

The Ladner argillites hosting Home X mineralization lie adjacent to several thin, fossiliferous tuff and wacke horizons that are probable northwesterly strike extensions of the units hosting the Pipestem mine veins.

Georgia No. 2 and Norm (Minfile 92HNW008 and 056) (Occurrence No. 18, Figure 23)

The exact location of the Georgia No. 2 occurrence is uncertain; early published details are not specific and attempts by J.T. Shearer (personal communication, 1982) and the author to locate the occurrence were unsuccessful. MINFILE incorrectly lists the Georgia No. 2 within the Montana group of claims, when in fact it formed part of Spider Peak claim group (Cairnes, 1929). Both these claim groups are located in the Spider Peak area and originally comprised four claims and two small fractions that extended northwesterly along the divide between Hillsbar (now Qualark) Creek and the north fork of Siwash Creek. The four claims covered ultramafic rocks and listwanites of the Coquihalla serpentine belt, and greenstones of the Spider Peak Formation. The occurrence is reported to lie close to the southwestern boundary of the Georgia No. 2 claim at an elevation of 1310 metres (4300 feet) (Cairnes, 1929). A trench exposed a mineralized, easterly striking and northerly dipping fault cutting Spider Peak greenstones. This fault contains sparsely disseminated sulphides, but there is uncertainty concerning the gold values obtained on the property. Cairnes (1929) reports, that 2.5 tons of ore shipped to the Tacoma smelter assayed $9.00 in gold, while MMAR (1925) mentions that 37 ounces (1151 grams) of gold was won from approximately 2 tons of presumably hand-sorted ore. However, Cairnes also notes that this small operation probably removed most of the ore.

The Norm claims lie close to the Georgia No. 2 occurrence on the southwestern slopes of Spider Peak. Unpublished reports by Cochrane (1975), Montgomery and Symonds (1976) and Dion and Cochrane (1978) indicate that the large fault slice of quartz-veined listwanite exposed approximately 500 metres southwest of Spider Peak is associated with soils containing pannable gold, and geochemical soil anomalies up to 3.3 ppm gold. However only low gold values were obtained from rock-chip samples.

Emigrant (Minfile 92HNW005) (Occurrence No. 19, Figure 23)

The Emigrant group, which consisted of six claims and one fraction was located south of the Ward claims along the south fork of Siwash Creek (MMAR, 1917). The geology and style of mineralization are similar to that reported at the Ward mine. The area is largely underlain by Ladner argillites and the gold mineralization is associated with felsic porphyry sills and dykes, and occurs mostly in quartz-filled tension veins that either cut the porphyry or occupy the faulted dyke margins.

At least three adits were driven on the west side of the south fork of Siwash Creek, at an elevation of approximately 610 metres (2000 feet) (MMAR, 1917). The upper No. 1 adit was driven in a northwesterly direction, and at 21 metres intersected a quartz vein 35 centimetres wide that reportedly carried gold. The No. 2 adit, driven parallel to the No. 1 and 27 metres below it, intersected the footwall of the same vein at a distance of 125 metres from the portal but had to be abandoned due to flooding. No. 3 adit was then driven west from the No. 2 portal and cut the vein at a distance of 131 metres. The vein on the No. 2 level is approximately 6 metres wide, dips 25° northwest and contains white quartz which is ribboned with bands of slate. Assays on five samples taken across a vein 3.5 metres wide ranged from 2.7 to 16.4 grams per tonne gold (MMAR, 1917).

Roddick (Minfile 92HNW004) (Occurrence No. 20, Figure 23)

The Roddick occurrence outcrops on Crown-granted Lot 78 situated approximately 500 metres south of the confluence of the north and south forks of Siwash Creek (MMAR, 1917). It lies between the Emigrant and Ward properties, adjacent to a small northeasterly flowing tributary of the south fork of Siwash Creek. This tributary was originally called Roddick Creek, however, on the current 1:50 000 topographic map (92H/11) it is unnamed, and the name "Roddick Creek" is assigned to another northeast-flowing tributary approximately 1 kilometre to the southeast.

The geology and gold mineralization on the Roddick claim are similar to that on the Ward and Emigrant properties. Ladner Group argillites, interbedded with thin wacke horizons, are intruded by feldspar porphyry dykes and sills that are spatially related to the gold mineralization. Bateman (1911) reports that a porphyry dyke 7.5 metres wide is associated with narrow lenses and stringers of quartz that cut both the dyke and the slate wallrocks. The quartz veins reportedly carry iron oxides and yielded some rich specimens of free gold.

Gold Queen (Minfile 92HNW016) and Dolly Varden (Occurrence No. 21, Figure 23)

Few details are known concerning the location of the Gold Queen occurrence, except that it is situated close to the confluence of the middle and south forks of Siwash Creek. By 1901, approximately 150 metres of tunnelling and underground crosscuts had been driven on the property (MMAR, 1901, 1903). These reportedly cut sulphide mineralization containing some gold values (up to $8.00 per ton). The geology of the property is similar to that at the Emigrant and Ward, and the gold and sulphides are probably hosted in quartz stringers associated with felsic porphyry intrusions.

It is uncertain whether the Gold Queen and Dolly Varden are the same occurrence staked under different names, or whether they represent two distinct but adjacent properties. The Dolly Varden was staked in 1911 (Bateman, 1911) and was located between the middle and north forks of Siwash Creek, at an elevation of 520 metres. Development work included a number of trenches along a 190-metre-long porphyry dyke that intrudes the Ladner Group. One contact of the dyke is marked by a quartz vein 30 to 60 centimetres wide. Narrow quartz stringers splaying from the vein cut both the porphyry and the adjacent Ladner slaty argillites. Pyrite, chalcopyrite and trace galena are reported in the vein stringers and the porphyry, and the overlying soils contain pannable gold (Bateman, 1911).

Marvel (Minfile 92HNW019) (Occurrence No. 22, Figure 23)

The precise location of this occurrence is uncertain and details on its geology are not recorded. MINFILE locates the property on the east side of the north fork of Siwash Creek. This area is underlain by Ladner argillites intruded by felsic porphyry sills; the mineralization on the Marvel property is probably similar to that at the Ward mine. MMAR (1906) records the installation of a six-stamp Merrill mill on the Marvel ground and the driving of a tunnel into the hillside, with encouraging results.

Spuz G (Minfile 92HNW053) and Rodd A (Occurrence No. 23, Figure 23)

The Spuz group of claims were staked in October 1975 for Longbar Minerals Ltd. and extended along the Hozameen fault from the Hidden Creek area, southwards toward Siwash Creek. The Rodd A claims adjoined the Spuz group to the southwest and lay north of the confluence of the north and south forks of Siwash Creek. Between 1976 and 1981, when excitement over the discovery of the Carolin mine deposit was at its peak, considerable exploration work was done on the claims on behalf of Longbar Minerals Ltd. and Aquarius Resources Ltd. (Cochrane 1976, 1979; Cochrane *et al.*, 1978; Cardinal, 1982). This work included geological mapping, soil sampling, trenching and some diamond drilling. Some new gold showings were found during the course of the work including the various Spuz and Rodd A occurrences and the Monument vein. Many of these occurrences, like those farther south on the Ward, Emigrant and Roddick properties, are associated with strongly altered, felsic to intermediate porphyry dykes and sills that intrude the Ladner Group.

The Spuz G/Rodd A occurrence is situated on the west side of the north fork of Siwash Creek, approximately 2 kilometres north-northwest of its confluence with the south fork (for precise location *see* Figure 43C in Cochrane *et al.*, 1978.) The area is underlain by Ladner Group slaty argillites that are intruded by numerous sills of felsic porphyry. Two trenches, cut 60 metres apart to investigate a gold geochemical anomaly in soils, exposed two moderately foliated and silicified sills. Pannable gold was obtained from crushed samples taken from the sills and from narrow, irregular quartz veinlets that cut the adjacent slates; these veinlets also contain scheelite. A thin fault slice of sheared fuchsite-bearing carbonate rock was also exposed in one trench (Cochrane *et al.*, 1978).

A minor unnamed gold-scheelite occurrence is exposed in a switchback section of drillroad approximately 400 metres south-southeast of the Spuz G/Rodd A occurrence (Figure 43D, Cochrane *et al.*, 1978). A soil geochemical anomaly in gold is underlain by two westerly dipping, north-northwesterly striking sills, 2.5 metres wide, separated from each other by 1 metre of sheared Ladner slate. The highly fractured and altered sills are medium grained, and probably of granodiorite composition (Cochrane *et al.*, 1978). The hangingwall argillites are cut by an irregular network of quartz veins; pannable gold was obtained from the altered sills and some narrow fractures contain quartz and scheelite.

Another gold soil anomaly lies approximately 900 metres south of the Spuz G/Rodd A occurrence, but no visible gold is reported (Cardinal, 1982). The Ladner argillites are intruded by at least one, and possibly two, flat-lying, strongly fractured and altered felsic sills that include some mafic phases; locally these rocks contain abundant iron carbonate. The contact of one sill is marked by a quartz vein, and the intrusions are locally cut by numerous quartz-filled tension veinlets. These veinlets contain both massive and vuggy quartz but generally carry no sulphides. The veins vary from highly irregular to reticulate.

Unnamed Gold Occurrence (Occurrence No. 24, Figure 23)

An unnamed gold occurrence is located close to the Hozameen fault, approximately 6 kilometres northeast of Yale township and 500 metres northwest of the Spuz G/Rodd A occurrence (Cochrane *et al.*, 1978; Cochrane, 1979). A gold geochemical anomaly in the soil overlies altered Ladner argillites and part of a fault slice of fuchsite-bearing quartz-carbonate rock (listwanite) 25 metres thick and 500 metres long. Three closely spaced fractures splay out from the nearby Hozameen fault system and the strongly sheared slates adjacent to the listwanites are weakly talcose and contain disseminated sulphides. Gold was panned from the fuchsite-bearing carbonate rocks (Cochrane *et al.*, 1978) and whole-rock and trace element analyses on two fuchsite-bearing grab samples (Appendices 5A and 5B) indicate they are noticeably enriched in magnesium (due to the abundance of magnesite) and arsenic.

Monument (Minfile 92HNW054) (Occurrence No. 25, Figure 23)

The gold and scheelite-bearing Monument quartz vein crops out about 3 kilometres southeast of Stout, close to Bigjon Lake[5] (Figure 41B). It lies approximately 175 metres east of the Hozameen fault and is hosted by Ladner Group slaty argillites interbedded with thin horizons of tuffaceous wacke and siltstone. In 1977, Longbar Minerals Ltd. conducted a mapping and exploratory drilling program and a total of 12 holes were drilled on the Monument vein (Cochrane *et al.*, 1978). The geology of the vein is shown on Figure 37, and the following description is based on the report by A.L. Littlejohn (Cochrane *et al.*, 1978), together with observations by the author.

The steeply dipping Monument vein trends northerly, subparallel to both the Ladner Group bedding and the Hozameen fault, and varies from 0.3 to 3 metres wide. It generally has sharp contacts with the black argillitic and siltstone hostrocks and mainly comprises massive white quartz that locally contains small rounded to elongate vuggy cavities lined with tiny crystals of clear quartz. The elongate vugs are orientated parallel to the vein contacts and reach 2.5 centimetres in length and 0.5 centimetre in width. The quartz vein is strongly fractured in places, and contains minor amounts of altered pink feldspar and carbonate. It also locally includes angular xenoliths of brecciated and silicified country rock up to 15 centimetres in diameter and, in its southern portion, encloses an elongate sliver of silicified argillite between 10 and 30 centimetres thick. A 1-metre-wide, dark-coloured zone of weak silicification is locally present in the argillites and siltstones immediately adjacent to the vein.

The Monument vein has a stike length of 400 metres, but has been separated into four segments by a set of northerly trending dextral crossfaults (Figure 37) that are probably related to the nearby Hozameen fault system. Some of the slaty argillite wallrock, particularly immediately west of the vein, contains northerly trending silicified shear zones that carry minor amounts of sulphides. Strongly altered, narrow felsic sills, similar to those elsewhere on the Spuz claims, are also found in close association with the quartz vein (Figure 37). These sills, like the Monument vein, predate the episode of dextral faulting. Cochrane *et al.* (1978) speculated that the vein and the nearby felsic sills are genetically and temporally related, particularly as the sills are geochemically anomalous in gold. One grab sample from the northernmost sill, east of the vein (Figure 37), assayed 0.1 gram per tonne gold (Cochrane *et al.*, 1978).

[5] Informal name used by Cardinal (1982).

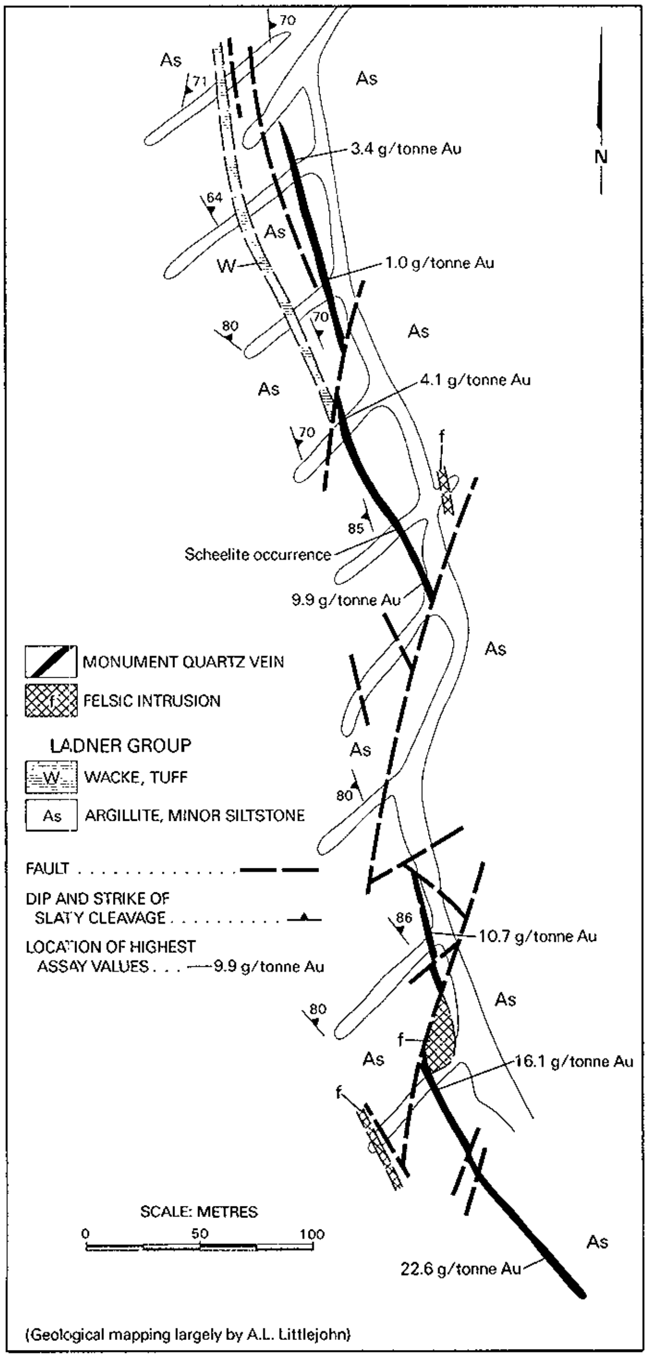


Figure 37. Geology of the Monument quartz vein (adapted after Cochrane *et al.*, 1978, and from observations of the author).

Minor mineralization is found in both the nearby, thin tuffaceous wacke horizons and the subparallel silicified shear zones in the argillites. The silicified zones contain fine-grained pyrite and traces of chalcopyrite; crushed rock samples yielded traces of panable gold but the assay values were low. The thin tuffaceous wacke horizons contain pyrite, pyrrhotite and minor chalcopyrite.

Surface exposures of the Monument vein contain visible gold, particularly near the vein margins and close to the major offsetting fault in the central portion of the vein. Gold occurs both as small nuggets 0.5 to 2.0 millimetres in diameter within vugs or enclosed in the quartz, and as small thin flakes on shear surfaces along the vein contacts. Sparse amounts of pyrite and arsenopyrite are also present in the vein, generally concentrated at the contacts of argillite xenoliths. The pyrite occurs as fine-grained aggregates and euhedral crystals, while arsenopyrite forms small, elongate, subhedral and randomly orientated crystals. Minor amounts of galena and native copper were panned from some crushed samples, and scheelite is present within a zone 10 centimetres wide along the eastern contact of the vein at one locality (Figure 37).

The highest assay values recorded at various locations along the vein, from chip and grab sampling by Cochrane *et al.* (1978), are shown in Figure 37. These show an overall southerly trend of increasing gold values, the highest assay being 22.6 grams per tonne gold over a width of 1.75 metres. Twelve inclined holes were drilled into the Monument vein; results demonstrate that the vein, which is vertical to steeply easterly dipping on surface, flattens with depth. Eight of the holes cut vein intercepts varying from 0.3 to 3.1 metres, but the remaining holes did not intersect the vein. Weighted gold assay values ranged from a low of 1.0 gram per tonne gold over a core length of 30 centimetres to a maximum of 15.4 grams per tonne gold over 3.1 metres. Visible gold with minor galena and chalcopyrite are present in the vein, together with some possible marcasite. Fuchsite is present in thin quartz veins cutting the slates, and in one altered sill.

Spuz AN (Minfile 92HNW055) (Occurrence No. 26, Figure 23)

The Spuz AN occurrence is hosted in altered Ladner Group slaty argillites close to the Hozameen fault, approximately 700 metres north of the Monument vein (Cochrane *et al.*, 1978). A trench was put down across four north-northwesterly striking shear zones that contain gouge material and quartz pods. Selective silicification, together with a network of thin quartz stringers, is seen in some sedimentary horizons. Very fine grained, disseminated pyrite, minor chalcopyrite and trace amounts of pannable gold are associated with the silicified zones.

Majestic (Minfile 92HNW033) (Occurrence No. 27, Figure 23)

The precise location and status of this occurrence are uncertain. MINFILE shows the Majestic occurrence is located just north of Hidden Creek, approximately 5 kilometres southeast of Spuzzum, but no geological description of the mineralization is available; an adit of unknown length is reported on the property.

The occurrence is believed to be hosted by Ladner Group sediments just east of the Hozameen fault. At the point where the fault crosses Hidden Creek it contains a thin, elongate slice of serpentinite and the Ladner rocks immediately east of the fault are mainly slaty argillites interbedded with thin wacke horizons (Figure 41B). These sediments are cut by numerous felsic sills similar to those at the Ward, Spuz and Emigrant properties, however, it is uncertain whether the Majestic gold occurrence is related to these intrusions.

Gold Coin (Minfile 92HNW032) (Occurrence No. 28, Figure 23)

The precise location of this occurrence is uncertain, and no geological description of the property, which was developed by a tunnel, is recorded. The occurrence is reportedly situated northeast of Hidden Creek, approximately 3 to 4 kilometres east of the Hozameen fault; it is presumably hosted within the Ladner Group. Recent exploration work in this vicinity is described in an unpublished assessment report by Cardinal and Fowler (1981).

Gold Cord (Minfile 92HNW031) and Pride of B.C. (Occurrence No. 29, Figure 23)

MINFILE locates the Gold Cord occurrence on Gilt Creek, close to where it crosses the Hozameen fault. However, no geological description of the occurrence is available. The Gilt Creek area is underlain by highly deformed Ladner argillites which are faulted against altered greenstone of the Hozameen Group to the west (Figure 41B). Recent exploration in this area is described in an unpublished report by Cardinal and Fowler (1981).

The Pride of B.C. occurrence is located farther east up Gilt Creek, approximately 500 metres (1600 feet) above the Fraser River (MMAR, 1916). Two adits, 24 and 6 metres in length, were driven and the MMAR (1918) reported "the opening up of good milling ore". Recent mapping and exploration work were completed by Aquarius Resources Ltd. (Cardinal and Fowler, 1982). The adits are situated about 70 metres apart and lie approximately 750 metres east of the Hozameen fault. The northerly adit was driven adjacent to a northeasterly striking fault that cuts Ladner argillites and thin wacke horizons; these rocks are intruded by quartz feldspar porphyry sills. A grab sample from the adit contained only traces of gold and silver (Cardinal and Fowler, 1982).

Unnamed Placer Gold Occurrence (Occurrence No. 30, Figure 23)

During this survey, old placer workings were seen in a small creek on the west side of the Anderson River valley, approximately 5 kilometres east-northeast of Hells Gate (UTM 616175E; 5517150N). The placer occurrence is at an elevation of approximately 580 metres (1900 feet) and lies close to the presumed trace of the Hozameen fault (Figure 41B). There is no outcrop near the workings, but ribbon cherts of the Hozameen Group are exposed up-slope to the west, and siltstones of the Ladner Group crop out some distance down-slope to the east. The derelict remains of a portable sluice box, tools and gold pans were seen in the narrow streambed which contains float of both white quartz vein material and Ladner siltstones. Several colours of fine gold were panned by the author from the stream sediment at this locality.

OTHER MINERAL OCCURRENCES

Copper-Molybdenum

During this mapping program one small, previously unreported copper-molybdenum occurrence was discovered approximately 5 kilometres east of Stout (Figure 41B). In this area the hornfelsic Ladner siltstones within the thermal aureole of the Needle Peak pluton are cut by swarms of felsic sills and dykes. One suite of equigranular, more siliceous, dacitic sills is associated with weak pyritization which overprints the adjacent wallrocks. Locally, particularly close to the pluton margin, the siltstones are strongly mineralized with disseminated pyrite associated with weak silicification and iron carbonate alteration. Abundant boulder float of pyritized siltstone and fault-brecciated granodiorite is also seen in the area at the entrance to a linear valley (UTM 620500E; 5499300N) which follows a northeast-trending fault cutting both the Needle Peak pluton and the Ladner Group rocks. Grab samples from the sulphide-rich outcrops and float were assayed for base and precious metals without significant results. However, at one outcrop in this locality (UTM 620100E; 5498500N), less than 100 metres from the contact of the Needle Peak pluton, the hornfelsic, sulphide-rich siltstones are cut by folded and sheared vuggy quartz veins up to 8 centimetres wide. These veins contain minor amounts of visible pyrite, chalcopyrite and coarse flakes of molybdenite. An analysis of one grab sample from a molybdenite-bearing quartz vein is given in Appendix 18.

The nearby Needle Peak pluton contains some disseminated pyrite, and weak sericitic and carbonate alteration together with small vuggy cavities lined with quartz crystals; assays of altered granodiorite show no enrichment in gold or silver.

Minor Mineral Occurrences Southeast of the Coquihalla River (Zinc, Placer Platinum, Placer Gold and Nephrite)

Placer platinum and gold are reported in the stream gravels of Sowaqua Creek, approximately 8 kilometres above its confluence with the Coquihalla River (MMAR, 1922). Additional details on the property are provided by Cairnes (1929); the early exploration work included sinking at least three shafts into the stream bed, the deepest of which was 18 metres long and did not reach bedrock. Operations reportedly yielded values of $4400 in gold and $600 in platinum (Cairnes, 1929). Most of the platinum and gold is confined to the finer grained glacial deposits that underlie the coarser grained streambed material and Cairnes speculated that the precious metals originated from outside the Sowaqua Creek basin. However, as the creek drains areas underlain by ultramafic and gabbroic rocks of the Coquihalla serpentine belt, the platinum may be locally derived and the Coquihalla serpentine belt may warrant evaluation for platinum-group potential.

A little placer gold production has been reported along the shores of Serpentine Lake, situated on the divide between the Coquihalla River and Sowaqua Creek (Figure 40A). A talcose shear zone, within serpentinite and diorite close to the northeast margin of the serpentine belt, reportedly contains small lenses of sphalerite, pyrrhotite, pyrite and chalcopyrite up to 15 centimetres wide (Cairnes, 1929).

Poor quality nephrite and talc are found sporadically along the West Hozameen fault.

DISCUSSION AND CONCLUSIONS

The gold deposits and occurrences in the Coquihalla gold belt vary considerably in their mineralogy, morphology, geochemistry and hostrock lithologies which makes it difficult to recognize common relationships and controls. For example, the past producers are hosted by several different lithologies: Carolin and Pipestem in sedimentary wackes of the Ladner Group, Emancipation in volcanic greenstones of the Spider Peak Formation, Aurum in talcose shears within the East Hozameen fault adjacent to the Coquihalla serpentine belt, and the Ward[6] in felsic sills that intrude the Ladner Group. Of the 25 gold occurrences listed in Table 8, only two (South Fork and Fifteen Mile) unequivocally lie within the Coquihalla serpentine belt[7]; the remainder are situated east of, but mostly close to the East Hozameen fault. Of the remaining occurrences, four are hosted by the Spider Peak Formation, twelve by sedimentary rocks of the Ladner Group, and possibly five others are associated with albite-rich felsic sills that intrude the Ladner Group (Table 8). The hostrock of the remaining occurrence, the Golden Cache, is unknown.

The morphology of the deposits and occurrences also varies from discrete quartz ± carbonate veins as seen at Emancipation, and irregular quartz breccias and quartz stringer zones at Pipestem, to the diffuse, quartz-albite-sulphide-carbonate-rich pervasive mineralization at the McMaster zone and Carolin mine. Most of the gold-bearing veins in the belt, such as those at the Murphy and Monument occurrences, are sulphide-poor and show little or no sign of extensive wallrock alteration. By contrast, the vein systems at the Pipestem and Emancipation mines are sporadically associated with sulphide-rich, auriferous alteration envelopes.

The available geochemical data suggest the gold mineralization throughout the belt is commonly associated with an enrichment in arsenic and sporadic antimony. Anomalous mercury values are not reported at any property except the Pipestem mine, where trace enrichment (up to 800 ppb Hg) is found in some samples (Appendix 15). Most occurrences have not been analysed for tungsten, but a sporadic trace enrichment in this element is present at the Emancipation and Carolin mines, and scheelite is reported in the Monument vein. Trace enrichment in molybdenum occurs at Carolin mine, and one sample (GR 100) of wallrock alteration adjacent to the Boulder vein at the Emancipation mine contained anomalous (820 ppb) tellurium (Appendix 9). Pervasive albitization characterizes the mineralization at Carolin mine and the McMaster zone; sporadic enrichment in sodium is also present in the barren wallrock alteration at Emancipation mine (Appendix 8) and around the Aurum mine (Figure 33G). The Aurum mineralization is the only major example in the belt where gold occurs within the East Hozameen fault; it is hosted by a talcose shear along the eastern margin of the Coquihalla serpentine belt.

[6] No geological description of the Ward mine exists. The assumption that the mineralization is hosted in felsic sills is based on the geology in the Ward mine area.

[7] The Norm and another unnamed occurrence (*see* Occurrence No. 24, Table 8) may also be hosted in listwanites of the Coquihalla serpentine belt).

The South Fork and Fifteen Mile occurrences (Table 8) are unique in that the free, red-coloured gold is associated with chalcocite and garnet-pyroxene-bearing rocks, and they are the only two occurrences in the belt to be unequivocally hosted within the Coquihalla serpentine belt. This suggests that they may be genetically and temporally unrelated to the mineralization elsewhere in the belt.

Between Hidden Creek and the Siwash Creek area (Figure 23) the mineralization is distinct in that at least five occurrences (Table 8; Figure 38A) are intimately associated with albite-rich felsic sills within the Ladner Group. The age of the sills is unknown and it is uncertain whether these occurrences are temporally related to other prospects in the belt. These minor felsic intrusions may also have played a genetic role in the Monument, Ward and even the Pipestem mineralization. Another feature of the sill-associated gold is that it is located farther from the Hozameen fault system (between 450 and 1000 metres east; Table 8; Figure 38A) than most of the other occurrences.

Despite the previously described variations in mineralization throughout the Coquihalla gold belt some generalizations are possible. In nearly all cases the introduction of the gold was accompanied by variable amounts of silica (generally as quartz veining), and three deposit types are recognized:

(1) Fracture-controlled, gold-bearing quartz ± carbonate vein systems. These are mostly narrow, irregular and discontinuous, and include the majority of the minor gold occurrences shown on Figure 23. However, the vein systems at the Emancipation and Pipestem mines and at the Monument occurrence are wider and more extensive.

(2) Sulphide-rich orebodies up to 30 metres thick, hosted within folded, coarse clastic sedimentary rocks in the basal part of the Ladner Group succession. The gold is associated with abundant pyrrhotite, pyrite and arsenopyrite, widespread albitic, chloritic and carbonate alteration together with thin, irregular quartz ± carbonate veining. This type of mineralization is only seen at Carolin mine and the McMaster zone.

(3) Native gold in talcose shears within the East Hozameen fault, immediately adjacent to the eastern margin of the Coquihalla serpentine belt. The mineralization at the Aurum mine is the only reported example of this type.

Important controlling relationships exist between the hostrock lithologies and the distance of the mineralization from both the East Hozameen fault and the basal Ladner Group unconformity. The hostrock type and distance from the East Hozameen fault of the five producers and sixteen occurrences for which reliable data are available (Table 8) are plotted on Figure 38A. This shows that although gold occurs over 1 kilometre east of the Coquihalla serpentine belt, most occurrences and deposits are concentrated within 400 metres of the East Hozameen fault. Furthermore most of the gold production in the Coquihalla gold belt was derived from deposits located less than 200 metres east of the fault (Figure 38B).

Figure 39A shows the close spatial relationship between the basal Ladner Group unconformity and the various deposits and occurrences (Table 8). This relationship is further demonstrated on Figure 39B which shows that over 99 per cent of the gold production from the belt took place within 200 metres of Ladner Group/Spider Peak Formation contact. Thus the main controls to mineralization in the Coquihalla gold belt are:

(1) The presence of competent rocks that favour the development of fracture-induced permeability. Consequently, the area between the Emancipation mine and Spider Peak, where the lower, wacke-rich, coarse clastic unit of the Ladner Group is both best developed and exposed, contains most of the sediment-hosted gold occurrences, including the Carolin deposit.

(2) Close proximity (<200 metres) to the Spider Peak Formation/Ladner Group contact. In many places the unconformity is marked by shearing, brittle fracturing and fault-associated quartz veining, due to competency differences between the greenstones and sedimentary rocks. This is well illustrated at Emancipation mine and the Snowstorm (Pittsburg) occurrence.

(3) Close proximity (<200 metres) to the East Hozameen fault and serpentine belt margin. As demonstrated on Figures 38B and 39B, over 99 per cent of gold production has come from deposits situated less than 200 metres from both the fault and the basal Ladner Group unconformity. The Hozameen fault structure has probably played an important role as a conduit for ore-forming fluids.

TABLE 8.
COQUIHALLA GOLD BELT: DATA ON THE LITHOLOGIES AND DISTANCES FROM BOTH THE HOZAMEEN FAULT AND LADNER GROUP–SPIDER PEAK FORMATION UNCONFORMITY

Number listed in Figures 23, 38A & 39A	Property Name	Hostrocks	Distance from the East Hozameen fault	Distance from the Ladner Group unconformity
1	Emancipation	Spider Peak Formation	25 m east	25 m west
2	Aurum	Talc zone in East Hozameen fault	0 m	10-25 m west
3	Carolin	Wackes in the basal Ladner Group	150 m east	120 m east
4	Pipestem	Wackes in the upper part of the Ladner Group	650 m east	450 m east
5	Ward	Felsic sills intruding the Ladner Group?	c. 1000 m east	—
6	Broken Hill	Ladner Group	c. 300 m east	c. 50 m east
7	South Fork	Talcose rocks within the Coquihalla serpentine belt	c. 500 m west	—
8	Fifteen Mile	Talcose rocks within the Coquihalla serpentine belt	c. 1100 m west	—
9	Snowstorm	Spider Peak Formation	c. 400 m east	c. 60 m west
10	Montana	Spider Peak Formation	c. 300 m east	c. 20 m west
11	Rush of the Bull	Ladner Group	?	?
12	McMaster	Wackes in the basal Ladner Group	300 m east	100 m east
13	Golden Cache	?	?	?
14	Murphy	Spider Peak Formation	2 m east	425 m west
15	Gem	Ladner Group?	?	?
16	Star	Ladner Group	?	?
17	Home X	Wackes and argillites in the upper part of the Ladner Group	700 m east	550 m east
18	Georgia No. 2 and Norm	Spider Peak Formation (Georgia No. 2) Listwanites in the Coquihalla serpentine belt (Norm)	?	?
19	Emigrant	Felsic sills intruding the Ladner Group?	950 m east	—
20	Roddick	Felsic sills intruding the Ladner Group	c. 950 m east	—
21	Gold Queen and Dolly Varden	Felsic sills intruding the Ladner Group	c. 900 m east	—
22	Marvel	Felsic sills intruding the Ladner Group	c. 950 m east	—
23	Spuz G and Rodd A	Felsic sills intruding the Ladner Group	c. 450 m east	—
24	Unnamed occurrence	Listwanite within the Hozameen fault?	c. 10 m west	—
25	Monument	Ladner Group (Felsic sills nearby)	175 m east	—
26	Spuz A-N	Ladner Group	c. 100 m east	—
27	Majestic	Ladner Group close to the Hozameen fault	?	—
28	Gold Coin	Ladner Group?	3-4 km east	—
29a	Gold Cord	Ladner Group	c. 100 m east	—
29b	Pride of B.C.	Ladner Group	c. 750 m east	—
30	Unnamed placer occurrence	Ladner Group close to the Hozameen fault	0 m	—

(4) The Carolin mineralization is also partly controlled by the presence of large-scale D_2 antiformal folds having disrupted, fractured limbs and hinges that provided local permeability for the gold-bearing hydrothermal solutions.

Of these four controlling features, the presence of favourable host lithologies appears to be the most important. At Pipestem mine, for example, mineralization is found within favourable tuffaceous wacke horizons even though they are situated a considerable distance east of the basal Ladner Group unconformity and the Hozameen fault.

The geology, mineralization, wallrock alteration and tectonic setting of the Coquihalla gold belt exhibit many similarities to the Bralorne deposit in the Bridge River camp of British Columbia (Leitch and Godwin, 1988) and to the Mother Lode gold belt in the Sierra Nevada of California (Clark, 1970; Schweickert, 1981; Bohlke and Kistler, 1986). Gold-bearing veins in the Mother Lode district tend to be controlled by minor discordant fault structures concentrated along and close to segments of the Melones fault zone. This fault forms a major suture marked by linear ultramafic belts, some fuchsite-bearing listwanite rocks and a complex history of recurrent tectonic movements (Clark, 1970; Moores and Day, 1983). Also, like the Hozameen fault system which separates Methow trough clastic sequences from ophiolitic assemblages, the Melones fault zone separates two contrasting crustal units; to the east are continent-derived clastic sequences (Shoo Fly complex) and to the west are highly deformed oceanic and island arc assemblages of the Calaveras Formation (Schweickert, 1981; Harwood, 1983; Sharp, 1984).

The auriferous mesothermal veins of the Coquihalla and Sierra Nevada both include massive, vuggy and ribbon-textured quartz with sporadic arsenopyrite, and they are locally associated with wallrock alteration halos that include carbonate, chlorite, albite and pyrite (Lindgren, 1895; Knopf, 1929; Clark, 1970). Although the ultimate source of the gold in the two regions is uncertain, inclusion and isotopic studies suggest the fluids responsible for the Mother Lode and Coquihalla mineralization were deeply circulated (Bohlke and Kistler, 1986; Nesbitt *et al.*, 1986); in the latter case the fluids are believed to have moved up and been controlled by the East Hozameen fault (Murowchick *et al.*, 1986).

The presence of quartz breccias, ribbon-textured quartz veins, slickensliding and strong structural controls to the ore

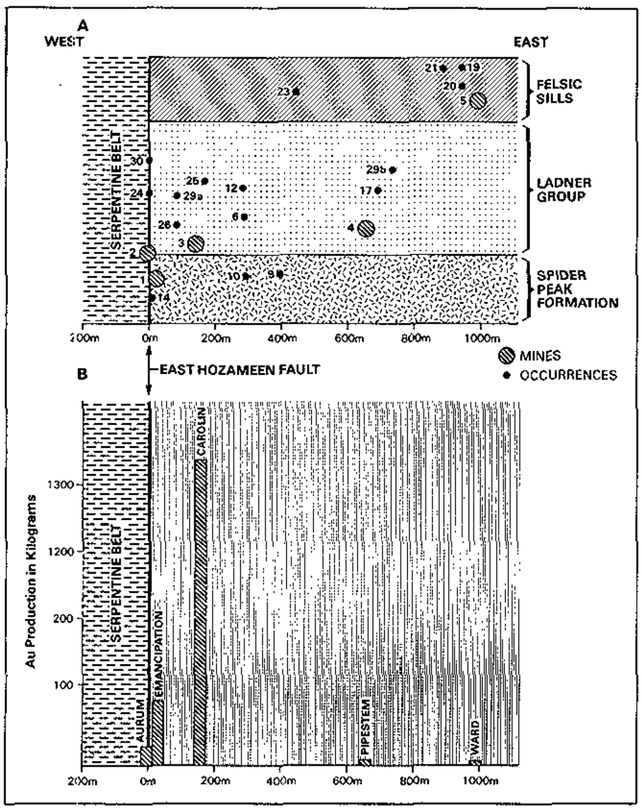


Figure 38. Coquihalla gold belt. A: Relationship between host-rock lithologies of various gold mines and occurrences, and their distance from the East Hozameen fault. Numbers listed in Table 8. B: Relationship between gold production from the Coquihalla gold belt and distance from the East Hozameen Fault.

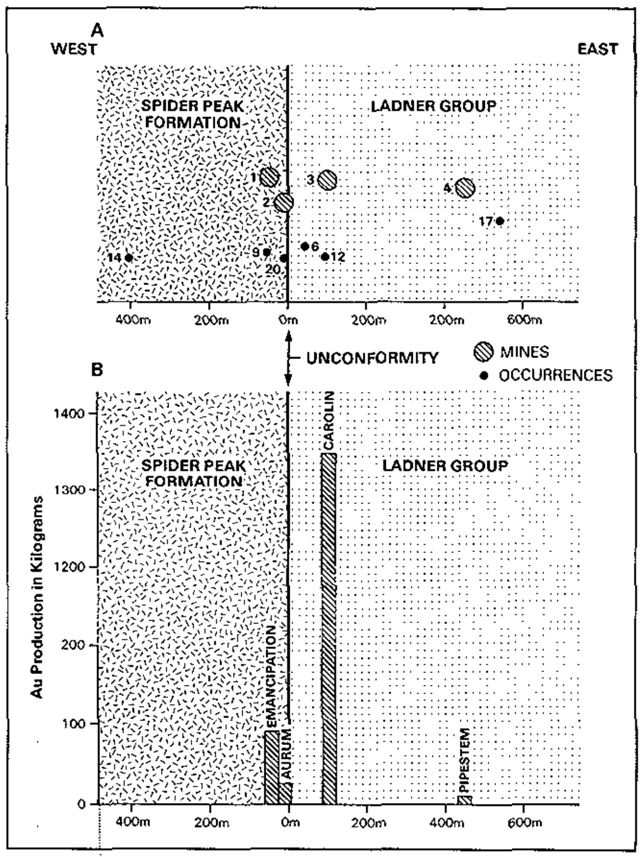


Figure 39. Coquihalla gold belt. A: Relationship between gold mineralization and distance from the Ladner Group–Spider Peak Formation unconformable contact. B: Relationship between gold production from the Coquihalla gold belt and distance from the Ladner Group–Spider Peak Formation unconformable contact. Numbers listed in Table 8.

suggest that mineralization in both the Coquihalla and Mother Lode districts was intimately associated with recurrent tectonic movements. Radiometric evidence indicates the gold mineralization in the Sierra Nevada was introduced over a 30 million year interval (Bohlke and Kistler, 1986) and a similar long time span is postulated for the Coquihalla gold belt deposits during recurrent movements along the Hozameen fault system.

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APPENDIX 1.
ANALYSES OF HOZAMEEN GROUP VOLCANIC GREENSTONES (UNIT PJHg) COMPARED TO AVERAGE BASALT[18]
(all values in per cent except where stated in ppm)

Sample Number	SiO_2	TiO_2	Al_2O_3	Total Fe (as Fe_2O_3)	MgO	CaO	Na_2O	K_2O	MnO	Zr (ppm)	Y (ppm)	Cr (ppm)	Total
GR 260[1]	50.38	0.99	15.25	9.50	6.25	10.31	3.16	0.92	0.18	41	32	294	96.94
GR 267[2]	49.26	0.65	12.45	9.40	9.79	11.44	2.86	0.56	0.17	10	13	375	96.58
GR 272[3]	48.40	0.45	13.93	10.19	9.18	10.47	2.65	0.95	0.21	10	19	343	96.43
GR 316[4]	48.90	1.42	14.74	11.07	6.79	10.90	2.78	0.14	0.19	58	29	128	96.93
GR 330[5]	52.15	0.76	13.53	13.40	7.37	5.69	1.50	0.34	0.16	73	38	38	94.90
GR 331[6]	50.96	0.90	13.22	14.73	5.79	7.94	2.78	0.41	0.22	67	19	61	96.94
GR 332[7]	48.23	0.85	13.88	13.10	7.77	9.40	3.00	0.30	0.24	59	21	280	96.77
GR 334[8]	48.89	2.04	14.33	12.35	7.26	7.06	3.30	1.62	0.20	120	22	210	97.05
GR 335[9]	50.24	1.31	13.72	13.66	6.42	7.83	4.03	0.30	0.22	81	34	170	97.73
GR 336[10]	47.83	0.64	15.61	13.04	7.13	8.96	3.10	0.35	0.20	44	6	300	96.86
GR 337[11]	49.12	1.05	15.30	9.64	7.71	9.68	3.38	0.45	0.17	80	10	89	96.50
GR 338[12]	49.32	1.33	15.62	9.74	8.30	11.27	2.56	0.08	0.17	73	17	330	98.39
GR 339[13]	47.99	1.86	15.29	10.60	7.99	9.41	3.23	0.43	0.17	108	19	260	96.97
GR 340[14]	49.51	2.57	15.95	11.02	5.18	9.08	2.91	0.66	0.28	143	12	85	97.15
GR 341[15]	48.50	3.64	15.04	12.84	4.72	8.48	4.11	0.29	0.18	223	25	18	97.81
GR 342[16]	47.25	0.28	15.45	8.90	10.75	9.18	2.36	0.98	0.23	29	15	430	95.38
Average of above[17]	49.18	1.30	14.58	11.45	7.4	9.19	2.98	0.55	0.19	76	21	213	96.82
Average basalt[18]	49.20	1.84	15.74	10.92	6.73	9.47	2.91	1.10	0.20	—	—	—	98.11

Massive greenstone samples collected from the following localities:
[1] West shore of Bigjon Lake, 2.8 km southeast of Stout.
[2] Gilt Creek road, 1.8 km east-southeast of Alexandra Bridge, Trans-Canada Highway.
[3] Gilt Creek road, 1.7 km southeast of Alexandra Bridge.
[4] 3.5 km north-northeast of Alexandra Bridge.
[5-7] 2.2 km northeast of Alexandra Bridge.
[8-10] Gilt Creek road, 2 km east of Alexandra Bridge.
[11] Gilt Creek road, 1.9 km east-southeast of Alexandra Bridge.
[12] Hidden Creek road, 2.5 km south-southeast of Spuzzum.
[13] Hidden Creek road, 3.2 km southeast of Spuzzum.
[14] Hidden Creek road, 3.3 km southeast of Spuzzum.
[15] Hidden Creek road, 3.5 km southeast of Spuzzum.
[16] B.C. Hydro line, 1.8 km northeast of Alexandra Bridge.
[17] Average of 16 samples (1-16) above.
[18] Average of 330 basalt samples (Le Maitre, 1976).

Analytical methods used in this bulletin:
Major elements by flame AAS. Precision for major and trace elements averages 5-10% relative error, depending on element concentration.
Zr, Y, Sr, Cr, P_2O_5 by XRF.
CO_2 and S by Leco induction furnace, volumetric.
Ag, Co, Cu, Mo, Pb, Zn, As, Sb, Ni by flame AAS.
H_2O by gravimetric method.
Hg by cold vapour/AAS.
Ba by emission spec.
Au-ppm = Fire assay and gravimetric finish; ppb = Fire assay and AA finish.
W by colorimetric.
Te by hydride generation/AAS.

APPENDIX 2A.
MAJOR ELEMENT ANALYSES OF SELECTED SERPENTINITE SAMPLES (UNIT Us) FROM THE COQUIHALLA SERPENTINE BELT
(all values in per cent)

Sample Number	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MgO	CaO	Na_2O	K_2O	MnO	$+H_2O$	$-H_2O$	CO_2	P_2O_5	S	Cr	Ni	Total
GR 12[1]	39.29	0.03	1.67	5.06	2.65	36.73	0.03	<0.06	<0.01	0.07	12.1	0.96	0.35	0.08	0.05	0.16	0.21	99.44
GR 27[2]	39.41	0.03	1.15	5.73	1.08	38.29	0.14	<0.06	<0.01	0.09	12.0	0.79	0.10	0.08	0.02	0.15	0.24	99.30
GR 29[3]	36.30	0.42	5.99	4.27	3.00	36.20	0.05	<0.06	<0.01	0.21	12.2	0.60	0.10	0.08	0.03	0.24	0.14	99.83
GR 42[4]	40.61	<0.01	0.90	4.91	1.96	38.57	0.06	<0.06	<0.01	0.09	12.2	0.10	0.10	0.08	0.16	0.18	0.24	100.16
GR 80[5]	41.15	<0.01	0.32	4.23	1.03	39.41	<0.01	<0.06	<0.01	0.07	12.3	0.57	0.01	0.08	0.16	0.18	0.27	99.78
GR 91[6]	38.40	<0.01	1.06	4.67	0.93	38.32	1.79	<0.06	<0.01	0.11	12.2	0.75	1.10	0.08	0.07	0.17	0.23	99.88
GR 120[7]	35.40	0.04	0.59	5.47	3.49	37.26	0.18	<0.06	<0.01	0.16	10.5	0.62	6.20	0.08	0.12	0.10	0.24	100.45
GR 121[8]	39.64	0.12	3.34	3.36	4.31	35.80	<0.01	<0.06	<0.01	0.12	12.3	0.73	0.41	0.08	0.03	0.08	0.17	100.49
GR 142[9]	40.78	<0.02	1.09	4.01	3.14	37.86	0.07	<0.06	<0.01	0.09	10.9	0.52	1.19	0.08	0.13	0.21	0.20	100.27
GR 160[10]	40.70	0.04	1.49	3.84	3.40	36.42	0.36	<0.06	<0.01	0.12	12.5	0.86	0.28	0.08	0.04	0.20	0.23	100.56
GR 163[11]	38.30	<0.02	1.28	5.99	1.69	38.49	<0.02	<0.06	<0.01	0.11	12.6	0.76	0.14	0.08	0.13	0.23	0.23	100.03
GR 164[12]	39.68	0.03	1.20	5.30	2.01	38.38	0.04	<0.06	<0.01	0.10	11.5	0.79	0.29	0.08	0.13	0.20	0.23	99.96
Average of above[13]	39.14	0.06	1.67	4.74	2.39	37.64	0.23	<0.06	<0.01	0.11	11.9	0.67	0.85	0.08	0.08	0.17	0.22	100.01

[1] Antigorite-rich serpentinite with pseudomorphs after olivine and orthopyroxene; Emancipation mine.
[2] Antigorite-rich serpentinite with rare enstatite remnants; quarry 300 m southeast of Carolin mill.
[3] Antigorite-rich serpentinite; road cut 400 m southeast of Carolin mill.
[4] Antigorite-rich serpentinite with some bastite pseudomorphing enstatite; quarry on Fifteen Mile Creek close to Coquihalla River.
[5] Antigorite-rich serpentinite; 500 m east of Serpentine Lake.
[6] Antigorite-rich serpentinite with rare orthopyroxene remnants, pseudomorphs after olivine and some carbonate veins; northwest shore of Serpentine Lake.
[7] Serpentinite with antigorite pseudomorphs after olivine; 300 m northwest of Carolin mill.
[8] Antigorite-rich serpentinite cut by chrysotile veins; 300 m northwest of Carolin mill.
[9] Antigorite and bastite-rich serpentinite; abandoned CP railway line, 1100 m south-southeast of Emancipation mine.
[10] Antigorite-rich serpentinite, pseudomorphs after olivine; Pipestem mine road, 2 km southeast of Spider Peak.
[11] Antigorite-rich serpentinite with carbonate and chrysotile veins; Pipestem mine road, 2 km southeast of Spider Peak.
[12] Antigorite-rich serpentinite; Pipestem mine road, 2.5 km southeast of Spider Peak.

APPENDIX 2B.
TRACE ELEMENT ANALYSES OF SELECTED SERPENTINITE SAMPLES (UNIT Us) FROM THE COQUIHALLA SERPENTINE BELT

Sample Number	BaO	Zr	Y	Nb	Co	Cu	Au (ppb)	Ag	Zn	As
GR 12	5	2	<3	<5	59	11	<20	<0.5	43	NA
GR 27	3	7	<3	<5	59	8	<20	<0.5	50	NA
GR 29	7	30	7	<5	55	100	<20	<0.5	59	NA
GR 42	14	9	<3	<5	58	12	<20	<0.5	47	NA
GR 80	6	5	<3	<5	58	8	<20	<0.5	28	NA
GR 91	5	6	<3	<5	56	16	<20	<0.5	53	NA
GR 120	11	20	<3	<5	74	16	<20	<0.5	66	NA
GR 121	17	6	<3	<5	49	5	<20	<0.5	41	NA
GR 142	3	13	<3	<5	21	25	<20	<0.5	91	8
GR 160	3	14	<3	<5	57	13	<20	<0.5	94	4
GR 163	3	14	<3	<5	50	27	<20	<0.5	90	2
GR 164	4	15	<3	<5	55	18	<20	<0.5	75	6

All values in ppm except where shown in ppb.
NA = Not analysed for element.

APPENDIX 3.
ANALYSIS OF ALTERED GREENSTONE DYKE INTRUDING SERPENTINITE NEAR CAROLIN MINE

Sample Number	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MgO	CaO	Na_2O	K_2O	MnO	$+H_2O$	$-H_2O$	S	CO_2	Au (ppm)	Total
GR 183	39.11	1.12	7.49	10.76	0.95	4.78	33.71	0.05	0.01	0.20	1.57	0.12	0.41	0.08	<0.02	100.36

All values (except Au) in per cent.

APPENDIX 4.
ANALYSES OF GABBRO-MICROGABBRO ROCKS (Ug) WITHIN THE COQUIHALLA SERPENTINE BELT COMPARED TO AVERAGE GABBRO[15]
(all values in per cent)

Sample Number	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MgO	CaO	Na_2O	K_2O	MnO	CO_2	$+H_2O$	$-H_2O$	P_2O_5	S	Total
GR 43[1]	50.19	1.66	13.15	1.31	9.03	7.16	9.66	4.09	0.06	0.19	0.10	2.24	0.18	0.08	0.15	99.25
GR 81[2]	48.73	1.37	14.44	1.21	8.25	6.92	11.09	3.60	0.12	0.18	0.14	0.16	0.12	0.08	0.03	96.44
GR 90[3]	49.07	1.53	14.57	1.06	9.33	6.91	10.36	4.02	0.13	0.20	0.13	2.10	0.13	0.08	0.01	99.60
GR 143[4]	49.77	1.93	14.12	2.54	9.61	5.63	9.19	4.27	0.17	0.20	0.27	1.99	0.06	0.37	0.01	100.13
GR 144[5]	46.64	1.66	14.31	2.10	8.65	6.12	14.08	3.13	0.24	0.19	0.47	1.32	0.14	0.20	0.01	99.27
GR 145[6]	48.64	1.88	14.63	1.33	9.84	6.77	9.24	4.12	0.23	0.20	0.20	2.16	0.10	0.08	0.02	99.43
GR 146[7]	43.59	1.32	13.11	2.23	8.32	7.25	19.27	2.20	0.18	0.19	0.67	1.57	0.23	0.08	0.01	100.23
GR 155[8]	51.36	1.64	13.92	2.16	9.48	4.86	8.93	4.93	0.23	0.20	0.40	1.27	0.07	0.23	0.01	99.69
GR 156[9]	49.85	1.48	14.07	3.59	7.83	6.06	10.11	3.82	0.13	0.19	0.31	1.82	0.10	0.21	0.01	99.60
GR 156A[10]	49.18	1.56	14.56	2.25	8.87	6.03	10.37	3.72	0.10	0.19	0.27	1.66	0.07	0.23	0.01	99.08
GR 161[11]	51.24	1.56	13.57	1.41	9.98	5.72	8.54	4.40	0.19	0.20	0.14	4.11	0.11	0.18	0.01	101.37
GR 162[12]	50.06	1.94	13.85	1.64	10.70	5.13	7.77	4.56	0.18	0.21	0.07	2.77	0.16	0.08	0.01	99.14
GR 165[13]	52.69	1.24	14.06	1.59	8.39	5.47	7.58	5.79	0.19	0.19	0.17	1.75	0.09	0.08	0.01	99.30
Average of above[14]	49.31	1.60	14.03	1.88	9.09	6.16	10.47	4.05	0.16	0.19	0.26	1.92	0.12	0.15	0.02	99.42
Average gabbro[15]	50.14	1.12	15.48	3.01	7.62	7.59	9.58	2.39	0.93	0.12	0.07					

[1] Altered augite hornblende gabbro; quarry on Fifteen Mile Creek close to Coquihalla River.
[2] Altered augite hornblende gabbro; 500 m east of Serpentine Lake.
[3] Altered porphyritic augite hornblende gabbro; 500 m north of Serpentine Lake.
[4] Altered microgabbro; 300 m northwest of Fifteen Mile Creek–Coquihalla River confluence.
[5] Highly altered microgabbro; Fifteen Mile Creek, 400 m from its confluence with Coquihalla River.
[6] Microgabbro; 450 m northwest of Emancipation mine.
[7] Microgabbro; 500 m southwest of Fifteen Mile Creek–Coquihalla River confluence.
[8] Hornblende gabbro; 2 km northeast of Sowequa Creek–Coquihalla River confluence.
[9] Altered hornblende gabbro; 2.5 km northeast of Sowequa Creek–Coquihalla River confluence.
[10] Altered hornblende gabbro; 2.5 km northeast of Sowequa Creek–Coquihalla River confluence.
[11] Altered microgabbro; Pipestem mine road, col, 2 km southeast of Spider Peak.
[12] Altered microgabbro; Pipestem mine road, col, 2 km southeast of Spider Peak.
[13] Altered microgabbro; Pipestem mine road, 2.5 km southeast of Spider Peak.
[15] Average of 173 gabbro samples (Le Maitre, 1976).

APPENDIX 5A.
MAJOR ELEMENT ANALYSES OF FUCHSITE-BEARING QUARTZ CARBONATE (LISTWANITE) ROCKS (UNIT Um) WITHIN THE COQUIHALLA SERPENTINE BELT
(all values in per cent)

Sample Number	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MgO	CaO	Na_2O	K_2O	MnO	$+H_2O$	$-H_2O$	CO_2	P_2O_5	S	Cr	Ni	Total
GR 153[1]	38.68	0.19	3.51	0.77	4.44	22.38	0.85	0.31	0.67	0.74	0.79	0.16	26.5	0.08	0.02	0.14	0.13	100.36
GR 154[1]	39.44	0.08	2.71	0.26	4.41	21.47	2.02	1.28	0.11	0.08	0.27	0.16	27.8	0.08	0.05	0.09	0.12	100.43

[1] Quartz magnesite rock with abundant fuchsite; tectonic slice within the Hozameen fault 5 km southeast of Stout (close to unnamed gold occurrence No. 24, Figure 23).

APPENDIX 5B.
TRACE ELEMENT ANALYSES OF FUCHSITE BEARING QUARTZ CARBONATE (LISTWANITE) ROCKS WITHIN THE COQUIHALLA SERPENTINE BELT

Sample Number	BaO	Zr	Y	Nb	Co	Cu	Au	Ag	Zn	As	Hg (ppb)
GR 153	69	13	<2	<10	35	22	<0.3	0.8	69	700	<20
GR 154	42	5	<2	<10	37	7	<0.3	0.5	70	976	<20

All values in ppm except Hg in ppb.

APPENDIX 6.
ANALYSES OF THE SPIDER PEAK FORMATION VOLCANIC GREENSTONES (UNIT TV) COMPARED WITH AVERAGE SPILITE[1] AND BASALT[2]

Sample Number	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MgO	CaO	Na_2O	K_2O	MnO	$+H_2O$	$-H_2O$	CO_2	P_2O_5	S	Zr	Y	Cr	Total
GR 53[3]	48.01	1.63	16.19	0.85	9.67	7.97	4.28	4.66	0.78	0.18	4.21	0.20	0.57	0.08	0.01	107	41	251	99.29
GR 85[4]	50.77	1.53	14.48	1.69	7.31	6.24	6.97	5.46	0.43	0.19	2.47	0.99	0.87	0.08	0.01	92	37	228	99.47
GR 111[5]	53.53	1.17	16.05	0.88	8.05	6.25	3.35	5.93	0.08	0.15	3.09	1.24	0.35	0.08	0.02	62	27	215	100.21
GR 112[6]	50.86	1.16	13.93	0.74	8.67	5.66	6.91	5.70	0.08	0.18	2.47	0.99	2.40	0.08	0.30	63	31	125	100.13
GR 130[7]	48.58	1.79	14.81	1.78	10.10	7.33	6.86	4.58	0.06	0.19	3.34	0.20	0.01	0.08	0.11	96	39	69	99.84
GR 139[8]	51.12	1.22	16.64	1.22	8.44	6.59	3.57	6.01	0.15	0.16	3.59	0.26	0.70	0.08	0.22	74	23	77	99.97
GR 140[9]	46.26	1.81	13.27	0.64	8.84	6.60	7.40	3.51	0.69	0.17	4.14	0.25	4.90	0.08	0.04	107	45	165	98.61
GR 148[10]	49.08	1.87	14.38	1.72	9.01	7.36	8.87	4.09	0.08	0.19	2.38	0.18	0.38	0.20	0.51	122	43	182	100.31
GR 148A[11]	48.65	1.86	13.90	1.53	9.11	7.41	8.75	3.98	0.09	0.20	2.23	0.22	0.41	0.23	0.49	102	39	182	99.09
GR 149[12]	50.29	1.67	14.73	0.92	9.03	7.85	5.76	4.74	0.17	0.19	3.13	0.14	0.87	0.08	0.01	80	31	119	99.58
Average of above[13]	49.71	1.57	14.84	1.19	8.82	6.93	6.27	4.87	0.26	0.18	3.10	0.46	1.15	0.11	0.17	90	35	161	99.65
Average spilite[1]	49.65	1.57	16.00	3.85	6.08	5.10	6.62	4.29	1.28	0.15	3.49	NA	1.63	0.26	NA				
Average basalt[2]	49.20	1.84	15.74	3.79	7.13	6.73	9.47	2.91	1.10	0.20	0.95	0.43	0.11	0.35	NA				

[1] Average of 92 spilite samples (Vallance, 1960).
[2] Average of 330 basalt samples (Le Maitre, 1976).
[3] Vesicular, pillowed greenstone; Carolin mine vicinity.
[4] Augite-bearing greenstone; 1.5 km east of Serpentine Lake.
[5] Massive greenstone; 1300 m northwest of Emancipation mine.
[6] Massive greenstone; 1300 m northwest of Emancipation mine.
[7] Augite-bearing greenstone with aquagene brecciation; Carolin mine vicinity.
[8] Greenstone with tectonic brecciation; from drill core 900 m south of Pipestem mine.
[9] Massive greenstone; from drill core 900 m south of Pipestem mine.
[10] Massive greenstone; 600 m south-southeast of Emancipation mine.
[11] Massive greenstone; 650 m south-southeast of Emancipation mine.
[12] Weakly layered and pillowed greenstone; 600 m southeast of Emancipation mine.
[13] Average of 10 samples (3–12) above.

APPENDIX 7A.
MAJOR ELEMENT ANALYSES OF MINOR FELSIC INTRUSIONS (UNIT p) WITHIN THE LADNER GROUP
(all values in per cent)

Sample Number	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MgO	CaO	Na_2O	K_2O	MnO	$+H_2O$	CO_2	P_2O_5	S	Total
GR 23[1]	57.87	1.00	18.50	0.50	3.64	2.53	2.85	6.80	0.69	0.04	1.87	2.61	0.23	0.46	99.59
GR 95[2]	53.52	1.12	19.66	1.22	5.38	3.89	1.07	7.07	0.25	0.03	3.15	1.78	0.23	0.68	99.05
GR 136[3]	57.59	0.83	17.37	0.55	4.87	3.93	2.39	6.40	0.16	0.07	0.67	1.65	0.18	0.11	96.77
GR 329[4]	64.51	0.86	17.75	2.28	1.95	1.43	0.41	8.61	0.34	0.07	NA	0.10	NA	NA	98.31
GR 333[4]	60.56	0.52	16.24	0.64	2.55	1.83	3.53	6.17	1.27	0.05	NA	4.31	NA	NA	97.67

[1] Feldspar porphyry sill with minor pyrite: Carolin mine road, 1.1 km northeast of Carolin mine.
[2] Feldspar-porphyritic, quartz-deficient sill: Emancipation mine road, 1.1 km north-northeast of Emancipation mine.
[3] Feldspar porphyry with rare quartz phenocrysts: Coquihalla valley, 350 m south-southwest of confluence of Ladner Creek and Coquihalla River.
[4] Feldspar porphyry sill: 4 km northeast of confluence of Gilt Creek and Fraser River.

APPENDIX 7B.
TRACE ELEMENT ANALYSES OF MINOR FELSIC INTRUSIONS (UNIT p) WITHIN THE LADNER GROUP

Sample Number	Au (ppb)	Ag	As	Co	Cr	Cu	Mo	Ni	Pb	Zn	Hg (ppb)
GR 23	<20	0.5	87	11	18	30	<3	18	13	95	<10
GR 95	<20	0.5	165	18	39	56	<3	51	14	89	13
GR 136	<20	<0.5	30	13	31	9	<3	29	10	76	16

Au and Hg in ppb, all other elements in ppm.
For location of samples *see* Appendix 7A.

APPENDIX 7C.
MAJOR ELEMENT ANALYSES OF SPIDER PEAK FORMATION WITHIN THRUST SLICES AT CAROLIN MINE
(values in per cent)

Sample Number	SiO_2	TiO_2	Al_2O_3	$Fe_2O_3^T$	MgO	CaO	Na_2O	K_2O	MnO	CO_2	S	LOI	Total
GR 660	53.66	1.52	15.53	12.63	4.02	1.95	6.16	0.54	0.17	0.64	0.02	4.02	100.86
GR 674	50.12	1.65	15.24	14.23	4.42	4.16	4.83	0.49	0.22	1.68	0.10	4.83	101.97
GR 675	54.13	1.47	15.20	13.00	3.38	3.47	5.08	1.00	0.19	0.49	0.02	3.64	101.07

$Fe_2O_3^T$ = Total iron expressed as Fe_2O_3.

APPENDIX 7D.
TRACE ELEMENT ANALYSES OF SPIDER PEAK FORMATION WITHIN THRUST SLICES AT CAROLIN MINE
(all values in ppm except where designated in ppb)

Sample Number	Au	Ag	Cu	Pb	Zn	Co	Ni	Mo	Cr	Hg (ppb)	As	Sb	Ba	Sr	Bi	Cd
GR 660	0.7	<0.3	206	9	129	37	14	<4	37	192	30	<10	262	77	<5	<1
GR 674	<0.3	<0.3	370	3	137	41	17	<4	33	150	<20	<10	120	63	<5	<1
GR 675	0.3	<0.3	261	5	148	40	18	<4	27	172	<20	<10	90	98	<5	<1
GR 117	959 ppb	0.3	220	4	83	20	6	<4	9	ND	25	ND	30	ND	ND	ND

Sample Data

GR 660 and 117. Altered, weakly mineralized feldspar-porphyritic gabbro. Road cutting close to the Fan adit, approximately 200 m south-southeast of the Idaho adit.
GR 674. Altered diorite-gabbro. Road cutting approximately 75 m north-northwest of the Fan adit.
GR 675. Feldspar-porphyritic gabbro. Road cutting approximately 125 m north-northwest of the Idaho adit.
For location of samples GR 660, 674 and 675 *see* Figure 32.

APPENDIX 8.
MAJOR ELEMENT ANALYSES OF SELECTED GRAB SAMPLES FROM EMANCIPATION MINE
(values in per cent)

Sample Number	SiO_2	TiO_2	Al_2O_3	$Fe_2O_3^T$	MgO	CaO	Na_2O	K_2O	MnO	CO_2	Total
EM 2	90.54	0.06	1.04	0.67	0.32	3.61	0.45	0.02	0.02	2.89	99.62
EM 4	86.07	0.05	0.88	0.98	0.37	5.69	0.30	0.01	0.05	4.33	98.73
EM 5	31.22	0.11	1.40	1.12	0.74	37.09	0.45	0.01	0.12	27.39	99.65
EM 6	16.16	0.08	2.38	0.81	0.40	45.88	1.18	0.02	0.12	33.44	100.47
EM 7	39.58	0.02	4.03	0.57	0.38	30.10	2.17	0.01	0.12	23.00	99.98
EM 8	83.09	0.04	0.83	0.40	0.20	8.28	0.37	0.01	0.05	6.55	99.82
EM 12	86.83	0.03	1.09	1.24	1.62	3.58	0.29	0.01	0.20	5.19	100.08
EM 13	77.53	0.47	8.25	4.48	0.51	0.63	4.36	0.03	0.13	1.98	98.37
EM 14	48.98	1.52	14.82	10.28	6.60	5.05	4.86	0.14	0.18	3.83	96.26
GR 100	50.16	1.26	13.77	6.03	3.16	7.86	7.20	0.02	0.19	6.90	96.56

$Fe_2O_3^T$ = Total iron expressed as Fe_2O_3.

Sample Description

EM 2 and 4 : Quartz-rich Dyke vein.
EM 5 : Calcite-rich Dyke vein.
EM 6 : Calcite-rich Dyke vein.
EM 7 : Calcite-rich flat vein.
EM 8 : Quartz-rich flat vein.
EM 12 : Massive quartz with minor calcite from Boulder vein.
EM 13 : Brecciated quartz vein with minor sulphides on margin of Boulder vein.
EM 14 : Schistose, altered, sulphide-bearing greenstone from hangingwall immediately adjacent to the Boulder vein.
GR 100 : Silicious quartz-carbonate-albite-sulphide-altered greenstones from the hangingwall immediately adjacent to the Boulder vein.

Locations

EM 2, 4, 5, 6, 7, 8 : Underground workings near the "underhand stope" (*see* Cairnes, 1929, Figure 13).
EM 12 : Northernmost crosscut across the Boulder vein on No. 2 level.
EM 13 : Central crosscut across the Boulder vein on No. 2 level.
EM 14 : Southern crosscut across the Boulder vein on No. 2 level.
GR 100 : Surface exposure a few metres east of No. 2 adit.

APPENDIX 9.
TRACE ELEMENT ANALYSES OF SELECTED GRAB SAMPLES FROM EMANCIPATION MINE
(all values in ppm unless otherwise stated)

Sample Number	Au	Ag	Hg (ppb)	Cu	Mo	Pb	Zn	W	As	Co	Sb	Te (ppb)	S (%)	Ba	Sr
EM 2	2.7	1.1	17	6	<2	3	7	750	650	108	144	NA	0.19	10	117
EM 4	17.1	1.8	11	5	<2	3	8	600	0.37%	75	176	NA	0.24	10	231
EM 5	<0.3	0.6	26	14	<2	6	10	170	51	15	<20	NA	0.20	13	1071
EM 6	8.9	4.5	27	11	<2	4	16	115	211	10	<20	NA	0.17	28	1349
EM 7	3.4	0.5	24	6	<2	9	11	100	0.14%	12	160	NA	0.09	26	652
EM 8	*	14.3	40	5	<2	5	4	1200	406	72	56	NA	0.07	13	284
EM 12	<0.3	0.5	94	3	<2	3	5	1200	51	93	<20	NA	0.01	16	167
EM 13	<0.3	0.3	22	63	<2	4	53	750	68	75	<20	NA	1.73	41	90
EM 14	<0.3	<0.3	61	35	<2	5	80	<3	<35	39	<20	NA	0.25	28	140
GR 100	<0.3	1.2	<20	25	<2	12	83	ND	54	6	ND	820	4.39	40	NA

* Sample partially lost in furnace — circa 60 ppm Au.
Te analyses by hydride method.
NA = sample not analysed for element.

APPENDIX 10.
CAROLIN MINE PRODUCTION FROM JANUARY 1982 TO SEPTEMBER 1984[1]

	Tonnes* Milled	Grade** g/tonne	Gold*** Production (kg)
Pre-production (Jan–June 1982)	82 968	3.15	54.74
July 1982	19 985	3.12	8.39
August	20 045	3.22	28.05
September	19 521	4.01	17.35
October	27 861	3.36	35.02
November	31 042	3.32	56.73
December	33 377	3.01	52.93
Total 1982	234 799		253.21
January 1983	35 309	2.88	69.73
February	35 050	2.36	63.94
March	16 243	2.26	40.55
April	Nil	—	—
May	27 722	2.81	28.92
June	35 869	2.84	44.29
July	33 512	2.95	55.08
August	38 739	3.15	50.07
September	31 810	3.02	60.80
October	35 645	2.91	59.50
November	32 271	3.59	81.64
December	24 704	3.70	60.99
Total 1983	346 874		615.51
January 1984	19 212	4.04	67.96
February	30 591	3.98	76.38
March	33 463	3.46	79.46
April	30 014	4.01	75.14
May	34 212	3.70	73.30
June	29 362	3.70	40.37
July	25 711	2.91	40.12
August	7 148	3.01	21.92
September	7 733	3.32	10.63
Total 1984	217 446		485.28
GRAND TOTAL Jan/82–Sept/84	799 119		1354.00

[1] Data from P. W. Richardson, personal communication, 1986.
* Recalculated from short tons using conversion figure of 0.907.
** Recalculated from oz/ton using conversion figure of 34.28.
*** Recalculated from troy oz using a conversion figure of 31.103.

APPENDIX 11A.
WHOLE-ROCK ANALYSES* OF SAMPLES COLLECTED FROM DRILLHOLE IU49[1], CAROLIN MINE

Sample Number	SiO_2	Al_2O_3	$Fe_2O_3^T$	MgO	CaO	Na_2O	K_2O	TiO_2	MnO	K_2O/Na_2O	Distance up Hole (m)
IU49-1	56.14	16.22	8.43	3.70	2.33	5.27	1.46	1.03	0.07	0.28	0.5
IU49-2	54.17	17.7	9.84	4.28	1.94	5.08	1.71	1.09	0.08	0.34	2.5
IU49-3	53.56	15.67	6.93	2.56	5.82	6.12	0.59	0.81	0.15	0.09	5.0
IU49-4	50.86	15.07	6.42	1.93	7.78	7.17	0.37	0.85	0.22	0.05	7.0
IU49-5	50.36	16.66	9.34	2.35	4.71	6.92	0.52	0.96	0.14	0.07	8.0
IU49-6	48.26	15.41	8.34	2.03	5.68	6.83	0.93	0.86	0.17	0.13	9.5
IU49-7	55.67	14.12	5.21	1.73	5.49	7.72	0.13	0.68	0.14	0.01	10.5
IU49-8	50.56	14.18	6.56	1.75	7.06	7.39	0.35	0.74	0.12	0.05	12.0
IU49-9	55.21	15.50	5.75	1.50	3.95	8.03	0.28	0.89	0.12	0.03	13.5
IU49-10	65.67	14.35	3.73	0.60	1.76	7.77	0.11	0.43	0.04	0.01	14.5
IU49-11	69.94	9.41	4.89	1.49	3.02	4.02	0.11	0.62	0.05	0.02	16.5
IU49-12	71.12	11.86	2.55	1.16	2.59	6.22	0.09	0.31	0.06	0.01	17.5
IU49-13	46.24	10.33	6.16	3.03	13.21	4.91	0.13	0.57	0.19	0.03	18.5
IU49-14	63.81	14.29	6.5	1.93	2.33	6.56	0.11	0.73	0.05	0.02	22.0
IU49-15	55.20	15.32	7.48	1.90	5.71	6.04	0.54	0.79	0.15	0.09	24.0
IU49-16	56.99	14.57	5.42	1.22	6.98	5.51	1.02	0.73	0.14	0.18	25.5
IU49-17	58.89	15.72	5.35	0.89	4.98	6.49	1.29	0.89	0.13	0.19	27.0
IU49-18	65.02	13.68	6.29	0.88	2.65	5.60	0.70	0.68	0.10	0.12	29.0
IU49-19	58.15	15.31	5.57	0.70	5.83	5.40	1.68	0.94	0.11	0.31	30.5
IU49-20	43.22	12.06	4.03	0.72	18.53	4.14	1.71	0.79	0.35	0.24	34.0

[1] Hole IU49 is an inclined upward hole (*see* Figure 29B).
* Analytical results in per cent.
$Fe_2O_3^T$ = Total iron expressed as Fe_2O_3.

APPENDIX 11B.
WHOLE-ROCK ANALYSES* OF SAMPLES FROM DRILLHOLE IU53[1], CAROLIN MINE

Sample Number	SiO_2	Al_2O_3	$Fe_2O_3^T$	MgO	CaO	Na_2O	K_2O	TiO_2	MnO	K_2O/Na_2O	Distance down Hole (m)
IU53-1	60.08	12.78	5.58	2.17	3.91	6.64	0.38	0.60	0.09	0.06	0.5
IU53-2	57.52	17.34	8.34	3.50	0.93	7.84	0.26	0.71	0.07	0.03	1.9
IU53-3	58.59	16.5	7.60	3.13	1.97	6.32	1.17	0.66	0.09	0.18	7.0
IU53-4	59.62	13.43	7.55	3.77	9.32	3.70	1.73	0.74	0.13	0.47	8.5
IU53-5	47.43	14.95	7.67	3.44	9.39	4.67	1.72	0.68	0.35	0.37	125
IU53-6	56.06	17.30	8.91	3.76	1.51	6.48	1.42	0.75	0.08	0.22	14.5
IU53-7	55.34	17.36	8.40	3.55	2.33	7.07	0.62	0.78	0.12	0.09	16.5
IU53-8	59.77	16.38	8.04	3.35	0.91	6.97	0.33	0.70	0.13	0.05	21.5
IU53-9	57.47	17.55	9.07	3.96	0.44	7.31	0.28	0.80	0.10	0.04	26.0
IU53-10	52.00	12.70	10.56	3.19	5.31	6.13	0.11	0.94	0.13	0.02	27.7
IU53-11	69.80	10.76	3.11	1.16	3.37	6.25	0.17	0.35	0.06	0.03	11.0
IU53-12	54.20	17.22	9.97	2.48	1.95	8.12	0.20	0.75	0.11	0.02	31.9
IU53-13	51.20	16.51	10.71	2.87	3.67	7.31	0.17	0.75	0.14	0.02	35.0
IU53-14	60.83	13.20	6.85	2.63	4.05	5.61	0.12	0.55	0.10	0.02	39.5
IU53-15	60.11	14.58	8.76	3.25	1.90	5.94	0.12	0.74	0.10	0.02	42.0
IU53-16	60.98	15.57	7.68	2.85	1.16	6.46	0.60	0.66	0.06	0.09	46.0
IU53-17	60.94	13.39	7.05	2.94	3.80	4.37	1.13	0.58	0.10	0.26	49.5
IU53-18	59.91	14.78	6.70	2.95	3.01	4.75	1.49	0.62	0.10	0.31	53.7
IU53-19	60.97	16.21	8.30	3.52	1.60	6.07	0.52	0.70	0.10	0.08	57.6
IU53-20	49.08	14.37	10.01	2.72	4.79	4.75	2.46	0.73	0.09	0.52	51.5
IU53-21	58.33	16.24	8.27	3.54	2.37	5.89	0.80	0.71	0.11	0.13	60.3
IU53-22	57.45	15.86	7.75	3.11	2.14	6.21	0.78	0.70	0.10	0.12	63.0
IU53-23	60.16	17.37	9.49	3.44	1.35	5.51	1.39	0.74	0.10	0.25	66.2
IU53-24	56.94	17.18	9.90	3.27	1.20	5.81	1.20	0.73	0.11	0.22	73.0
IU53-25	55.15	17.53	10.50	3.32	1.57	6.12	1.00	0.66	0.13	0.16	78.0
IU53-26	57.68	15.77	9.26	2.82	2.58	5.71	1.01	0.59	0.12	0.17	80.0
IU53-27	51.51	16.12	8.69	2.39	6.59	5.76	1.06	0.74	0.18	0.18	84.0
IU53-28	58.51	16.01	7.80	2.18	2.01	6.78	0.60	0.72	0.11	0.08	90.3
IU53-29	54.73	16.71	5.02	1.29	6.40	5.93	2.08	0.82	0.10	0.35	87.0
IU53-30	54.03	17.77	9.96	3.01	2.52	6.71	0.55	0.86	0.13	0.08	95.0

[1] Hole IU53 is an inclined downward hole (*see* Figure 29B).
* Analytical results in per cent.
$Fe_2O_3^T$ = Total iron expressed as Fe_2O_3.

APPENDIX 11C.
TRACE ELEMENT AND OTHER ANALYTICAL DATA OF SAMPLES COLLECTED FROM DRILLHOLE IU49, CAROLIN MINE

Sample Number	Au	Ag	As	Cu	Hg (ppb)	Zn	Mo	Sb	Pb	BaO	Sr	Ni	Co	CO_2 (%)	S (%)	H_2O+ (%)	P_2O_5 (%)
IU49-1	0.24	<0.3	3	89	<15	93	<2	2	3	580	221	7	17	1.9	0.75	2.8	0.20
IU49-2	0.29	<0.3	2	93	<15	105	<2	1	2	681	173	5	15	1.8	0.74	3.3	0.20
IU49-3	0.20	0.8	8	63	<15	95	<2	1	4	93	204	7	15	4.9	0.37	2.5	0.30
IU49-4	11.99	4.6	0.11%	67	35	90	<2	3	4	70	250	7	18	6.5	1.17	1.3	0.44
IU49-5	1.42	1.0	590	92	<15	103	2	3	<2	80	202	7	18	5.0	1.07	1.9	0.20
IU49-6	4.24	1.2	0.43%	71	<15	97	<2	3	4	93	190	7	18	7.5	2.39	1.1	0.20
IU49-7	1.70	1.1	0.87%	43	<15	68	15	13.6	4	40	190	6	15	7.0	1.98	0.3	0.16
IU49-8	2.40	1.8	10.2%	99	23	78	16	12.3	4	63	225	7	15	7.6	3.00	0.6	0.10
IU49-9	1.29	1.1	2.11%	108	<15	78	25	16.7	4	70	168	8	15	3.1	2.02	0.4	0.17
IU49-10	11.75	2.6	2.67%	13	<15	51	80	18.5	4	45	112	5	10	2.2	1.27	0.3	0.28
IU49-11	0.10	<0.3	0.16%	79	88	76	8	4.0	4	60	142	15	15	4.2	1.49	1.1	0.04
IU49-12	0.02	<0.3	959	36	<15	32	6	1	3	38	144	6	7	4.1	0.55	0.3	0.01
IU49-13	0.07	0.8	36	55	<15	87	2	<1	7	56	398	11	10	13.4	0.76	1.0	0.26
IU49-14	0.03	0.4	25	61	15	108	<2	1	10	37	206	21	13	2.6	0.97	0.4	0.10
IU49-15	<0.02	<0.3	24	53	<15	81	<2	<1	2	240	194	12	19	4.5	0.18	2.3	0.21
IU49-16	<0.02	<0.3	13	52	17	78	<2	1	2	513	176	8	13	5.5	0.16	1.9	0.13
IU49-17	0.12	0.5	14	61	17	78	<2	<1	3	670	142	5	12	3.8	0.20	1.5	0.16
IU49-18	0.16	0.5	16	60	32	90	2	<1	6	357	124	10	18	2.4	0.64	1.6	0.12
IU49-19	<0.02	<0.3	26	55	15	72	2	<1	4	815	190	7	13	4.5	0.52	1.4	0.20
IU49-20	<0.02	<0.3	18	66	<15	69	<2	1	4	770	218	4	13	13.5	0.08	1.3	0.25

Values in ppm except where noted in ppb or %.

APPENDIX 11C — *Continued.*
TRACE ELEMENT AND OTHER ANALYTICAL DATA OF SAMPLES COLLECTED FROM DRILLHOLE IU53, CAROLIN MINE

Sample Number	Au	Ag	As	Cu	Hg (ppb)	Mo	Sb	Pb	BaO	CO_2 (%)	S (%)	H_2O+ (%)	P_2O_5 (%)
IU53-1	2.9	<0.3	1007	52	<15	<2	4	6	100	3.20	1.64	0.80	0.09
IU53-2	1.2	<0.3	24	67	<15	<2	0.9	2	60	0.80	1.20	2.20	0.16
IU53-3	<0.02	<0.3	14	68	<15	<2	<0.5	7	500	1.65	0.30	2.44	0.16
IU53-4	0.14	<0.3	14	65	<15	<2	<0.5	5	700	6.93	0.71	2.90	0.17
IU53-5	<0.02	<0.3	10	51	<15	<2	<0.5	4	500	7.22	0.08	2.80	0.21
IU53-6	<0.02	<0.3	10	65	16	<2	<0.5	2	500	1.36	0.74	2.71	0.15
IU53-7	<0.02	<0.3	15	49	<15	<2	<0.5	2	600	1.90	0.40	2.70	0.20
IU53-8	<0.02	<0.3	13	66	15	<2	0.6	4	70	0.95	0.15	2.45	0.16
IU53-9	<0.02	<0.3	14	92	<15	<2	<0.5	3	40	0.40	0.33	2.71	0.16
IU53-10	16.0	<0.3	1550	310	16	<2	1.7	3	50	6.16	2.50	1.32	0.06
IU53-11	7.4	<0.3	718	35	16	<2	<0.5	4	40	4.41	1.00	0.15	0.13
IU53-12	5.4	<0.3	649	91	19	2	<0.5	5	60	1.80	1.90	1.97	0.17
IU53-13	4.2	<0.3	16	97	<15	2	<0.5	4	50	3.70	1.31	1.63	0.17
IU53-14	<0.2	<0.3	9	57	<15	<2	<0.5	3	30	3.41	0.50	2.28	0.11
IU53-15	<0.2	<0.3	14	66	<15	<2	<0.5	4	30	1.91	0.45	2.60	0.20
IU53-16	<0.2	<0.3	13	86	16	2	<0.5	6	100	1.90	0.80	2.40	0.11
IU53-17	<0.2	<0.3	9	60	15	2	<0.5	4	300	3.15	0.52	2.13	0.53
IU53-18	2.5	<0.3	29	130	15	<2	<0.5	12	500	3.30	0.37	2.30	0.12
IU53-19	<0.2	<0.3	13	74	22	<2	<0.5	2	200	1.36	0.05	2.70	0.14
IU53-20	2.5	0.4	642	90	<15	2	2.1	34	800	6.30	4.55	1.05	0.14
IU53-21	<0.2	<0.3	21	83	22	2	<0.5	4	300	1.65	0.03	2.70	0.15
IU53-22	<0.2	<0.3	16	83	16	<2	<0.5	5	200	1.35	0.09	2.73	0.17
IU53-23	<0.2	<0.3	18	88	35	<2	<0.5	6	400	0.95	0.06	3.13	0.13
IU53-24	<0.2	<0.3	18	79	15	<2	<0.5	7	300	0.81	0.11	3.08	0.12
IU53-25	<0.2	<0.3	14	65	<15	<2	<0.5	4	250	1.10	0.09	3.15	0.11
IU53-26	<0.2	<0.3	15	66	<15	2	<0.5	2	250	1.25	0.14	2.70	0.11
IU53-27	<0.2	<0.3	14	68	<15	2	<0.5	4	300	4.91	0.08	2.45	0.19
IU53-28	0.8	<0.3	19	79	27	<2	<0.5	2	400	2.00	0.31	1.81	0.14
IU53-29	<0.2	<0.3	16	76	25	<2	<0.5	5	600	4.76	0.05	1.73	0.18
IU53-30	<0.2	<0.3	16	56	<15	<2	<0.5	2	300	2.05	0.20	3.01	0.25

All values in ppm except where noted in ppb or %.

APPENDIX 11C — *Continued.*
DESCRIPTION OF SAMPLES COLLECTED FROM DRILLHOLES IU49 AND IU53, CAROLIN MINE

IU49-1	Chloritic wacke with quartz veining and minor sulphides.
IU49-2	Chloritic siltstone with minor sulphides.
IU49-3	Siltstone with rare quartz and albite veining.
IU49-4	Wacke with quartz, albite and carbonate veining and arsenopyrite.
IU49-5	Lithic wacke with albite and quartz veining and minor sulphides.
IU49-6	Altered lithic wacke with abundant quartz veining and disseminated arsenopyrite.
IU49-7	Altered wacke with quartz and albite veining and disseminated arsenopyrite.
IU49-8	Highly altered wacke with quartz and albite veining, and disseminated arsenopyrite. Traces of graphitic material along shears.
IU49-9	Highly altered siltstone with quartz and albitic veining and abundant arsenopyrite.
IU49-10	Altered wackes with abundant quartz and albite veining and abundant arsenopyrite.
IU49-11	Highly altered wacke with minor quartz and albite veining and abundant arsenopyrite.
IU49-12	Highly altered wacke. Abundant quartz veining and minor sulphides.
IU49-13	Siltstone with dissemination and veins of carbonate. No sulphides.
IU49-14	Siltstone with minor quartz and albite veining.
IU49-15	Lithic wacke with rare sulphides.
IU49-16	Lithic wacke with rare sulphides.
IU49-17	Siltstone.
IU49-18	Siltstone.
IU49-19	Siltstone with minor quartz veining.
IU49-20	Wacke with carbonate veining.
IU53-1	Altered wacke with quartz veining and minor arsenopyrite.
IU53-2	Altered wacke with disseminated albite and sulphides.
IU53-3	Altered wacke with minor quartz veining.
IU53-4	Altered wacke with quartz and minor carbonate veining.
IU53-5	Altered wacke and lithic wacke.
IU53-6	Altered wacke with rare quartz veining and minor sulphides.
IU53-7	Altered wacke and lithic wacke.
IU53-8	Siltstone with rare carbonate veining.
IU53-9	Altered siltstone.

IU53-10	Altered wacke with disseminated sulphides, albite and quartz veining. Minor arsenopyrite.
IU53-11	Intensely altered wacke with abundant sulphides and quartz veining.
IU53-12	Altered wacke and lithic wacke. Disseminated sulphides, albite veining and some graphitic material along shears.
IU53-13	Siltstone and minor wacke with some quartz veining and sulphides.
IU53-14	Thinly bedded siltstone, minor albitic alteration.
IU53-15	Thinly bedded siltstone, minor albitic alteration.
IU53-16	Highly cleaved argillite with pyrite.
IU53-17	Bedded siltstone.
IU53-18	Poorly bedded siltstone, minor sulphides.
IU53-19	Poorly bedded siltstone.
IU53-20	Highly altered siltstone with abundant sulphides, quartz and carbonate veining.
IU53-21	Altered siltstone.
IU53-22	Bedded siltstone.
IU53-23	Bedded siltstone.
IU53-24	Altered wacke.
IU53-25	Altered wacke with disseminated albite.
IU53-26	Altered wacke.
IU53-27	Lithic wacke.
IU53-28	Altered siltstone, minor albite veining.
IU53-29	Lithic wacke, minor albite veining.
IU53-30	Lithic wacke with minor albite and carbonate veining.

All samples contain varying amounts of albitic alteration.

APPENDIX 12A.
MAJOR ELEMENT ANALYSES OF 72 LITHOGEOCHEMICAL SAMPLES COLLECTED FROM THE CAROLIN MINE AREA
(*See* Figure 32 for sample locations.)
(all values in per cent)

Sample Number	SiO_2	TiO_2	Al_2O_3	$Fe_2O_3^T$	MgO	CaO	Na_2O	K_2O	MnO	LOI	Total	CO_2*	S*
GR 604	55.25	0.51	14.83	3.80	1.46	8.53	5.96	1.19	0.070	7.92	99.5	7.24	0.06
GR 605	53.82	1.03	19.21	10.44	3.23	1.60	6.24	1.54	0.157	3.01	100.3	0.91	<0.01
GR 606	53.13	1.02	17.08	9.61	4.34	3.06	4.16	1.87	0.157	4.34	98.8	1.55	0.11
GR 607	57.94	0.92	15.76	8.57	3.95	2.08	4.94	1.20	0.108	3.00	98.5	0.70	0.05
GR 608	60.68	0.77	15.93	8.01	3.24	1.46	6.03	0.94	0.084	2.93	100.1	0.84	0.02
GR 609	54.89	0.88	18.62	10.28	3.61	1.42	5.51	1.58	0.107	3.41	100.3	0.80	0.24
GR 610	60.50	0.77	15.80	8.12	4.60	1.13	4.47	1.18	0.099	3.52	100.2	1.06	0.10
GR 611	59.18	1.01	17.13	8.15	3.18	1.44	6.33	1.35	0.120	2.85	100.7	0.91	0.07
GR 612	59.59	0.87	15.46	8.16	4.85	1.61	3.67	1.42	0.105	3.94	99.7	1.27	0.07
GR 613	52.50	0.83	16.18	6.55	2.88	6.50	5.41	1.69	0.128	6.46	99.1	4.78	0.34
GR 614	56.84	0.86	15.30	8.30	3.21	3.21	6.07	1.11	0.133	4.78	99.8	3.02	0.10
GR 615	59.38	0.90	14.95	8.44	3.40	1.94	5.22	1.21	0.142	3.04	98.6	1.13	0.18
GR 616	57.01	0.96	16.59	8.82	3.54	2.97	5.12	1.57	0.150	2.58	99.3	0.70	0.04
GR 617	56.94	0.96	17.07	8.65	3.56	2.17	5.40	1.85	0.113	2.90	99.6	0.56	0.09
GR 618	60.46	0.80	15.60	6.40	2.08	2.88	7.04	0.77	0.118	3.60	99.7	2.46	0.44
GR 619	58.79	1.03	17.52	8.56	3.56	0.66	7.45	0.49	0.147	2.58	100.8	0.70	0.01
GR 620	61.25	0.99	17.29	6.82	1.77	0.17	9.13	0.10	0.039	2.80	100.3	0.42	0.65
GR 621	59.05	1.03	17.28	8.64	3.60	0.40	6.63	1.23	0.123	2.33	100.3	0.63	0.02
GR 622	58.74	1.03	17.09	8.16	3.25	0.60	3.71	4.11	0.114	2.54	99.3	0.28	<0.01
GR 623	57.33	1.16	17.55	8.51	3.92	0.10	7.53	0.47	0.071	3.54	100.2	0.42	0.05
GR 624	58.83	0.71	17.16	8.77	4.64	2.50	2.97	1.59	0.920	4.71	102.8	4.89	0.86
GR 625	59.47	1.00	16.64	7.91	3.33	1.19	5.77	1.92	0.144	2.45	99.8	0.63	<0.01
GR 626	59.00	0.88	17.59	7.49	4.12	0.58	4.07	1.98	0.093	3.82	99.6	1.41	0.01
GR 627	61.68	0.74	14.89	8.19	4.02	0.95	4.92	0.58	0.100	3.17	99.2	0.84	0.01
GR 628	61.90	0.79	15.24	7.48	4.53	0.94	4.33	1.03	0.091	3.59	99.9	1.27	0.04
GR 629	54.59	0.93	16.65	8.69	3.22	3.21	6.86	1.08	0.168	3.73	99.1	2.11	0.09
GR 630	60.84	0.90	15.86	7.94	3.27	0.53	6.10	1.19	0.101	2.26	99.0	0.28	0.01
GR 631	64.24	0.87	15.51	6.24	1.22	1.09	7.77	0.48	0.074	2.14	99.6	1.40	0.80
GR 632	60.33	0.85	16.92	5.70	0.60	1.23	9.96	0.06	0.042	2.06	97.8	1.32	1.85
GR 633	40.66	1.41	12.92	11.51	3.80	10.59	5.74	0.13	0.194	10.27	97.2	8.81	2.87
GR 634	56.47	1.01	17.36	9.11	3.48	0.25	6.20	2.21	0.101	2.63	98.8	0.36	0.28
GR 635	48.82	1.22	14.08	13.34	3.12	5.15	6.11	0.13	0.203	8.31	100.5	7.19	0.02
GR 636	48.55	1.20	15.26	7.84	3.20	7.49	7.22	0.10	0.207	7.72	98.7	6.97	1.21
GR 637	37.99	1.47	11.78	9.88	6.35	10.02	4.65	0.88	0.179	15.52	98.7	14.75	0.70
GR 638	49.94	0.95	15.27	11.01	1.36	3.18	8.11	0.82	0.122	7.70	98.5	4.74	3.98
GR 639	52.40	1.11	15.42	9.63	1.70	3.46	7.48	0.68	0.170	6.45	98.5	4.05	3.37
GR 640	56.92	1.04	16.71	8.23	3.18	2.38	7.16	0.79	0.139	3.29	99.8	1.95	0.20
GR 641	61.15	1.00	14.98	7.41	2.90	1.36	7.11	0.36	0.091	3.62	99.9	1.59	2.08
GR 642	62.04	0.85	15.57	7.44	3.11	1.20	5.89	1.08	0.111	2.49	99.8	0.80	0.06
GR 643	69.49	0.58	13.64	3.83	1.35	0.29	1.59	4.52	0.040	3.87	99.2	2.31	0.89
GR 644	59.22	1.07	17.21	7.65	3.10	1.67	6.15	1.71	0.107	2.23	100.1	0.36	<0.01
GR 645	57.03	0.99	17.43	8.95	2.94	1.64	6.39	1.96	0.127	2.76	100.2	0.71	0.20
GR 646	57.45	1.11	18.29	8.42	3.69	1.38	6.23	1.35	0.123	2.88	100.9	0.36	0.01
GR 647	55.18	1.50	18.25	10.16	3.74	1.16	5.54	2.21	0.108	2.71	100.5	0.14	0.37
GR 648	54.88	1.05	17.69	9.37	4.30	2.02	6.11	1.57	0.138	3.38	100.5	1.14	0.17
GR 649	61.21	0.98	17.29	7.19	2.81	0.99	7.59	0.57	0.100	2.39	101.1	0.78	0.02
GR 650	59.86	0.89	15.90	8.07	3.52	2.52	5.97	1.29	0.154	2.13	100.3	0.43	0.09
GR 651	56.55	1.16	16.98	8.93	3.62	2.58	6.05	1.16	0.193	2.99	100.2	1.06	0.11
GR 652	54.56	1.19	17.43	9.27	3.92	3.13	6.09	0.73	0.131	4.01	100.4	1.70	0.11
GR 653	51.64	1.56	16.58	11.90	3.75	0.72	6.91	0.12	0.107	6.76	100.0	0.71	2.29
GR 654	55.96	1.14	15.12	8.96	3.00	3.12	6.23	0.98	0.168	5.53	100.2	2.55	2.24
GR 655	55.92	1.19	15.97	10.56	3.46	2.73	6.14	0.64	0.161	3.72	100.4	1.13	0.14
GR 656	66.11	0.58	11.56	3.60	1.84	5.40	4.14	0.99	0.081	5.33	99.6	4.33	0.04
GR 657	56.82	0.84	18.15	7.28	4.18	3.18	3.28	1.91	0.076	4.95	100.6	2.55	0.07
GR 658	57.46	0.83	17.71	8.32	4.98	1.69	2.43	2.20	0.079	4.83	100.5	1.63	0.11
GR 659	50.65	1.19	16.04	10.05	3.61	5.11	6.34	0.37	0.177	5.40	98.9	4.32	0.72
GR 660	53.66	1.52	15.53	12.63	4.02	1.95	6.16	0.53	0.174	4.20	100.3	0.64	0.02
GR 661	53.91	1.20	17.94	9.30	4.03	3.35	5.63	1.58	0.224	3.46	100.6	1.06	0.06
GR 662	63.25	0.89	15.87	6.87	2.76	0.67	7.04	0.87	0.125	1.66	100.0	<0.07	0.08
GR 663	57.58	1.08	16.73	8.30	3.58	2.45	6.09	1.39	0.147	2.40	99.7	0.50	0.12
GR 664	54.83	1.06	16.83	8.27	4.10	3.03	7.05	0.40	0.153	3.94	99.6	2.13	0.11

$Fe_2O_3^T$ = Total iron expressed as Fe_2O_3.
LOI = Loss on ignition.
* Not included in total.

APPENDIX 12A — *Continued*
MAJOR ELEMENT ANALYSES OF 72 LITHOGEOCHEMICAL SAMPLES COLLECTED FROM THE CAROLIN MINE AREA
(*See* Figure 32 for sample locations.)
(all values in per cent)

Sample Number	SiO_2	TiO_2	Al_2O_3	$Fe_2O_3^T$	MgO	CaO	Na_2O	K_2O	MnO	LOI	Total	CO_2*	S*
GR 665	58.99	0.85	15.32	6.76	3.08	3.13	7.49	0.10	0.117	4.50	100.3	2.84	1.31
GR 666	64.40	0.90	15.61	7.23	2.97	0.64	4.04	1.77	0.066	2.93	100.5	1.21	0.13
GR 667	59.95	0.78	16.90	8.17	3.89	0.98	4.42	1.48	0.091	3.19	99.8	0.78	0.03
GR 668	55.43	0.94	18.66	8.91	4.76	2.59	3.03	1.67	0.088	4.10	100.1	1.63	0.08
GR 669	56.47	0.85	17.64	8.31	5.16	2.32	2.28	2.08	0.089	5.22	100.4	2.27	0.10
GR 670	57.17	0.76	17.43	8.82	5.15	1.95	2.38	1.63	0.080	4.93	100.3	1.70	0.11
GR 671	58.99	1.03	16.83	8.23	3.14	3.20	6.26	1.09	0.148	2.39	101.3	0.71	0.07
GR 672	60.94	0.94	15.16	7.01	2.87	2.81	5.48	1.08	0.124	3.54	99.9	2.12	0.09
GR 673	56.11	1.13	18.61	7.80	4.11	0.24	7.89	0.59	0.076	4.00	100.5	0.49	1.21
GR 674	50.12	1.65	15.24	14.23	4.42	4.16	4.83	0.49	0.220	4.83	100.1	1.68	0.10
GR 675	54.13	1.47	15.20	13.00	3.38	3.47	5.08	1.00	0.190	3.64	100.5	0.49	0.02

$Fe_2O_3^T$ = Total iron expressed as Fe2O3.
LOI = Loss on ignition.
* Not inlcuded in total.

APPENDIX 12B.
TRACE ELEMENT ANALYSES OF 72 LITHOGEOCHEMICAL SAMPLES COLLECTED FROM THE CAROLIN MINE AREA
(*See* Figure 32 for sample locations)

Sample Number	Au (ppb)	Ag	Cu	Pb	Zn	Co	Ni	Cr	Hg (ppb)	As	Ba	Sr
GR 604	14	<0.3	31	10	70	16	4	27	68	<20	185	190
GR 605	128	<0.3	58	8	117	24	26	<25	302	<20	160	114
GR 606	9	<0.3	66	7	103	22	9	25	112	<20	210	172
GR 607	1000	<0.3	53	8	107	22	9	<25	198	<20	236	193
GR 608	16	<0.3	79	9	88	22	21	138	88	<20	159	90
GR 609	52	<0.3	85	8	105	25	11	<25	228	<20	159	136
GR 610	11	<0.3	56	6	131	24	45	138	182	<20	100	73
GR 611	12	<0.3	50	8	97	19	5	<25	130	<20	249	125
GR 612	25	<0.3	71	9	142	24	45	120	235	<20	107	62
GR 613	11	<0.3	57	8	85	19	6	52	38	<20	210	142
GR 614	8	<0.3	55	9	87	25	8	37	240	<20	236	94
GR 615	9	<0.3	71	9	102	23	10	29	200	<20	236	67
GR 616	<5	<0.3	100	8	103	23	19	70	44	<20	223	208
GR 617	7	<0.3	72	9	101	26	11	35	<25	<20	197	109
GR 618	<5	<0.3	65	9	123	24	9	29	<25	<20	133	125
GR 619	9	<0.3	112	10	99	20	25	121	<25	<20	90	53
GR 620	1000	<0.3	64	16	74	23	13	88	74	<20	80	38
GR 621	30	<0.3	75	8	102	22	13	29	40	<20	172	46
GR 622	1400	<0.3	81	6	92	20	3	<25	34	<20	442	58
GR 623	1400	<0.3	54	7	99	12	3	29	54	<20	80	48
GR 624	24	<0.3	81	6	57	24	7	29	62	26	80	127
GR 625	15	<0.3	91	7	105	25	10	37	30	<20	236	87
GR 626	10	<0.3	34	5	100	12	19	123	67	<20	172	38
GR 627	10	<0.3	60	5	118	15	31	90	50	<20	100	69
GR 628	<5	<0.3	69	6	128	20	38	117	34	<20	90	43
GR 629	8	<0.3	68	30	100	25	10	25	78	<20	146	69
GR 630	8	<0.3	68	5	91	18	16	33	34	<20	172	48
GR 631	19	<0.3	75	7	116	30	20	40	74	<20	90	46
GR 632	1000	0.3	108	6	78	32	9	30	81	1.04%	80	45
GR 633	11600	1.9	197	8	79	28	11	29	108	0.97%	60	269
GR 634	13	<0.3	84	14	110	27	12	<25	57	<20	365	46
GR 635	8	<0.3	95	10	101	29	9	25	64	<20	339	73
GR 636	5800	0.7	152	4	75	29	11	30	93	0.90%	70	196
GR 637	2700	<0.3	36	5	98	35	51	246	71	0.27%	80	283
GR 638	15000	2.1	102	14	52	35	7	<25	82	1.82%	60	120
GR 639	5800	0.7	113	11	122	23	3	33	68	1.10%	108	95
GR 640	6	<0.3	54	5	91	22	6	<25	36	<20	623	29
GR 641	37	<0.3	65	6	102	25	6	35	205	<20	120	99
GR 642	19	<0.3	82	7	93	19	8	<25	238	<20	90	133
GR 643	15	<0.3	45	9	94	12	12	27	25	<20	90	138
GR 644	11	<0.3	73	11	94	24	14	76	162	<20	867	195
GR 645	300	<0.3	88	7	104	25	12	43	250	<20	300	65
GR 646	134	<0.3	60	8	92	20	6	25	108	<20	146	71
GR 647	300	<0.3	69	10	108	29	10	31	170	<20	635	94
GR 648	10	<0.3	56	10	98	24	6	<25	78	<20	223	76
GR 649	1000	<0.3	78	10	86	20	7	27	45	<20	133	130
GR 650	1700	<0.3	83	8	85	25	26	31	107	<20	80	62
GR 651	19	<0.3	66	8	108	23	5	<25	92	<20	313	145
GR 652	23	<0.3	61	5	107	23	5	29	75	<20	249	67
GR 653	2400	0.3	290	5	110	34	9	86	155	<20	339	88
GR 654	2400	7.0	78	11	104	24	7	<25	30	293	197	144
GR 655	6	0.6	99	4	109	27	7	<25	110	<20	146	62
GR 656	600	<0.3	34	4	69	23	24	88	<25	<20	90	100
GR 657	300	<0.3	58	6	94	26	40	113	30	<20	274	230
GR 658	9	<0.3	68	3	106	23	46	127	30	<20	120	74
GR 659	1000	<0.3	95	7	110	28	6	25	72	290	520	195
GR 660	700	<0.3	206	9	129	37	14	37	192	30	262	77
GR 661	6	<0.3	64	4	106	24	9	30	23	<20	417	129
GR 662	12	<0.3	53	8	92	24	11	30	30	20	146	63
GR 663	300	<0.3	58	9	107	21	3	<25	40	<20	288	86
GR 664	13	<0.3	61	8	92	26	5	31	35	20	1216	92
GR 665	300	<0.3	71	10	73	28	9	31	112	<20	80	140
GR 666	102	<0.3	59	7	109	20	34	113	68	<20	90	32

Values in ppm, unless indicated otherwise.
All samples recorded <4 ppm Mo, <10 ppm Sb, <5 ppm Bi, <50 ppm Rb and <1 ppm Cd.

APPENDIX 12B — *Continued*
TRACE ELEMENT ANALYSES OF 72 LITHOGEOCHEMICAL SAMPLES COLLECTED FROM THE CAROLIN MINE AREA
(*See* Figure 32 for sample locations)

Sample Number	Au (ppb)	Ag	Cu	Pb	Zn	Co	Ni	Cr	Hg (ppb)	As	Ba	Sr
GR 667	10	<0.3	114	6	114	21	35	88	50	<20	120	92
GR 668	28	<0.3	53	8	104	20	46	143	70	<20	236	258
GR 669	<5	<0.3	96	7	114	23	44	123	65	<20	80	90
GR 670	7	<0.3	72	4	112	25	47	136	138	<20	184	85
GR 671	9	<0.3	75	14	118	28	6	<25	92	<20	172	96
GR 672	6	<0.3	76	8	94	22	11	31	75	<20	197	89
GR 673	76	<0.3	65	7	93	30	12	30	58	25	120	66
GR 674	13	<0.3	370	3	137	41	17	33	150	<20	120	63
GR 675	300	<0.3	261	5	148	40	18	27	172	<20	90	98

Values in ppm, unless indicated otherwise.
All samples recorded <4 ppm Mo, <10 ppm Sb, <5 ppm Bi, <50 ppm Rb and <1 ppm Cd.

APPENDIX 13.
UNIVARIATE STATISTICS FOR 72 LITHOGEOLOGICAL SAMPLES COLLECTED FROM THE CAROLIN MINE AREA
(*See* Figure 32)

	Mean	Standard Deviation	Maximum	Minimum
SiO_2	57.09	5.01	69.49	37.99
Al_2O_3	16.30	1.48	19.21	11.56
Fe_2O_3	8.50	1.91	14.23	3.60
MgO	3.43	0.97	6.35	0.60
CaO	2.45	2.10	10.59	0.10
Na_2O	5.78	1.55	9.96	1.59
K_2O	1.18	0.78	4.52	0.06
TiO_2	1.01	0.22	1.65	0.51
MnO	0.12	0.04	0.22	0.03
LOI	4.00	2.20	15.52	1.66
Au	0.82 ppm	2.4 ppm	15 ppm	<5 ppb
Ag	0.45 ppm	0.83 ppm	7 ppm	<0.3 ppm
As	860 ppm	3092 ppm	18200 ppm	20 ppm
Ba	212 ppm	188 ppm	1216 ppm	60 ppm

All values in per cent except where shown in ppm or ppb.

APPENDIX 14.
CORRELATION MATRIX OF LITHOGEOCHEMICAL DATA, CAROLIN MINE
(72 samples)

Al_2O_3	$Fe_2O_3^T$	MgO	CaO	Na_2O	K_2O	TiO_2	MnO	Au	Ag	As	Ba	Cu	LOI	
0.6781	0.0261	0.0986	−0.3031	0.2735	0.3107	0.0341	−0.0941	−0.2631	−0.0870	−0.2077	0.0023	−0.2162	−0.2639	SiO_2
	0.4219	0.4154	−0.2183	0.3607	0.2758	0.3903	0.1632	−0.1574	−0.0951	−0.1179	0.2191	−0.0743	−0.1471	Al_2O_3
		0.5242	0.1833	0.2103	−0.1226	0.8406	0.6958	0.2450	0.1136	0.1323	0.1410	0.5833	0.3129	$Fe_2O_2^T$
			0.1097	−0.2905	0.1589	0.4294	0.3328	−0.1732	−0.0977	−0.3112	0.1304	0.0676	0.2718	MgO
				0.0146	−0.2355	0.2540	0.5151	0.4163	0.1684	0.3349	−0.0178	0.1436	0.8093	CaO
					−0.5385	0.3796	0.2375	0.2294	0.0939	0.3187	−0.0877	0.0794	−0.0159	Na_2O
						−0.1861	−0.1832	−0.2221	−0.0898	−0.2486	0.1208	−0.2913	−0.1799	K_2O
							0.6820	0.2208	0.1163	0.1133	0.2381	0.5754	0.3470	TiO_2
								0.2187	0.1830	0.1343	0.1950	0.3943	0.3490	MnO
									0.4025	0.8824	−0.1748	0.2528	0.5166	Au
										0.2643	−0.0664	0.0626	0.2247	Ag
											−0.1994	0.1932	0.4096	As
												−0.0807	−0.1071	Ba
													0.1620	Cu

APPENDIX 15.
ANALYSIS OF SELECTED MINERALIZED GRAB SAMPLES COLLECTED FROM THE PIPESTEM MINE
(unless otherwise stated — all values in ppm)

Sample Number	Au	Ag	Hg (ppb)	Cu	Mo	Pb	Zn	As (%)	Co	Sb	S (%)	Ba	F
GR 196 (27321M)	5.6	6.4	90	220	<2	12	207	0.19	24	<10	8.75	<50	225
GR 197 (27322M)	0.1	0.3	69	36	<2	15	330	0.02	10	<10	0.40	384	175
PS 1 (27305M)	1.0	0.3	800	4	<2	10	24	0.68	31	<10	NA	<50	<60
PS 2 (27306M)	<0.3	<0.3	500	3	<2	5	17	0.18	69	<10	NA	<50	100
PS 3 (27307M)	5.5	1.3	176	21	<2	23	97	1.38	25	<10	NA	77	<60
PS 4 (27308M)	<0.3	0.3	160	6	<2	11	92	0.18	40	15	NA	<50	75
PS 5 (27309M)	33.0	3.3	166	55	<2	13	400	8.91	36	<10	NA	800	175
PS 7 (27310M)	0.3	0.5	100	172	<2	17	306	0.16	20	<10	NA	560	440

NA = Sample not analysed for element.

Sample Description

GR 196 (27321M)	Pyritic wallrock alteration (wackes) adjacent to mineralized quartz vein.
GR 197 (27322M)	Quartz vein with minor pyrite.
PS 1 (27305M)	Vuggy quartz breccia with pyrite and arsenopyrite.
PS 2 (27306M)	Sulphide-bearing quartz breccia with minor feldspar.
PS 3 (27307M)	Pyritic wallrock alteration (wackes) adjacent to quartz veins.
PS 4 (27308M)	Quartz breccia with coarse sulphides.
PS 5 (27309M)	Sulphide-rich wallrock alteration (wackes) adjacent to quartz veins.
PS 7 (27310M)	Sulphide-rich wackes with quartz stringers.

Sample Location

GR 196 (27321M)	Sample from surface trenches, Pipestem mine.
GR 197 (27322M)	Sample from surface trenches, Pipestem mine.
PS 1 (27305M)	Underground workings, No. 4 level.
PS 2 (27306M)	Underground workings, No. 4 level.
PS 3 (27307M)	Underground workings, No. 4 level.
PS 4 (27308M)	Underground workings, No. 4 level.
PS 5 (27309M)	Stope, No. 3 level.
PS 7 (27310M)	Stope, No. 4 level.

APPENDIX 16.
ANALYSES OF MINERALIZED GRAB SAMPLES COLLECTED FROM THE McMASTER ZONE

Sample Number	Au	Ag	Hg (ppb)	Cu	Mo	Pb	Zn	As (%)	Co	Bi	Sb	Ba	F	S (%)
GR 220	3.6	1.9	43	113	3	28	29	1.65	43	4	<10	<50	110	6.6
GR 221	0.1	0.7	38	82	2	5	19	0.01	37	ND	<10	186	140	0.4

All values in ppm except as noted.

Sample Description

GR 220: Sulphide and albite-rich wacke with quartz veining.
GR 221: Altered, weakly mineralized siltstone with quartz veinlets.
For sample location, *see* Figure 36.

APPENDIX 17.
ANALYSIS OF GRAB SAMPLE SULPHIDE-BEARING QUARTZ VEIN, MURPHY GOLD OCCURRENCE

Sample Number	Au	Ag	Cu	Pb	Zn	Co	Ni	Mo	Hg (ppb)	As (%)	Sb
GR 320 (28706)	<0.3	<0.3	40	10	7	4	16	<3	60	0.14	<20

All values except Hg and As in ppm.

APPENDIX 18.
ANALYSIS OF CHALCOPYRITE-MOLYBDENITE-BEARING QUARTZ VEIN
(all values in ppm except as otherwise stated)

Sample Number	Au	Ag	Cu (%)	Pb	Zn	Co	Ni	Mo	Cr	As	Sb	Bi
GR 296	<0.3	3.9	0.13	2	32	119	4	312	<2	5	17	<2

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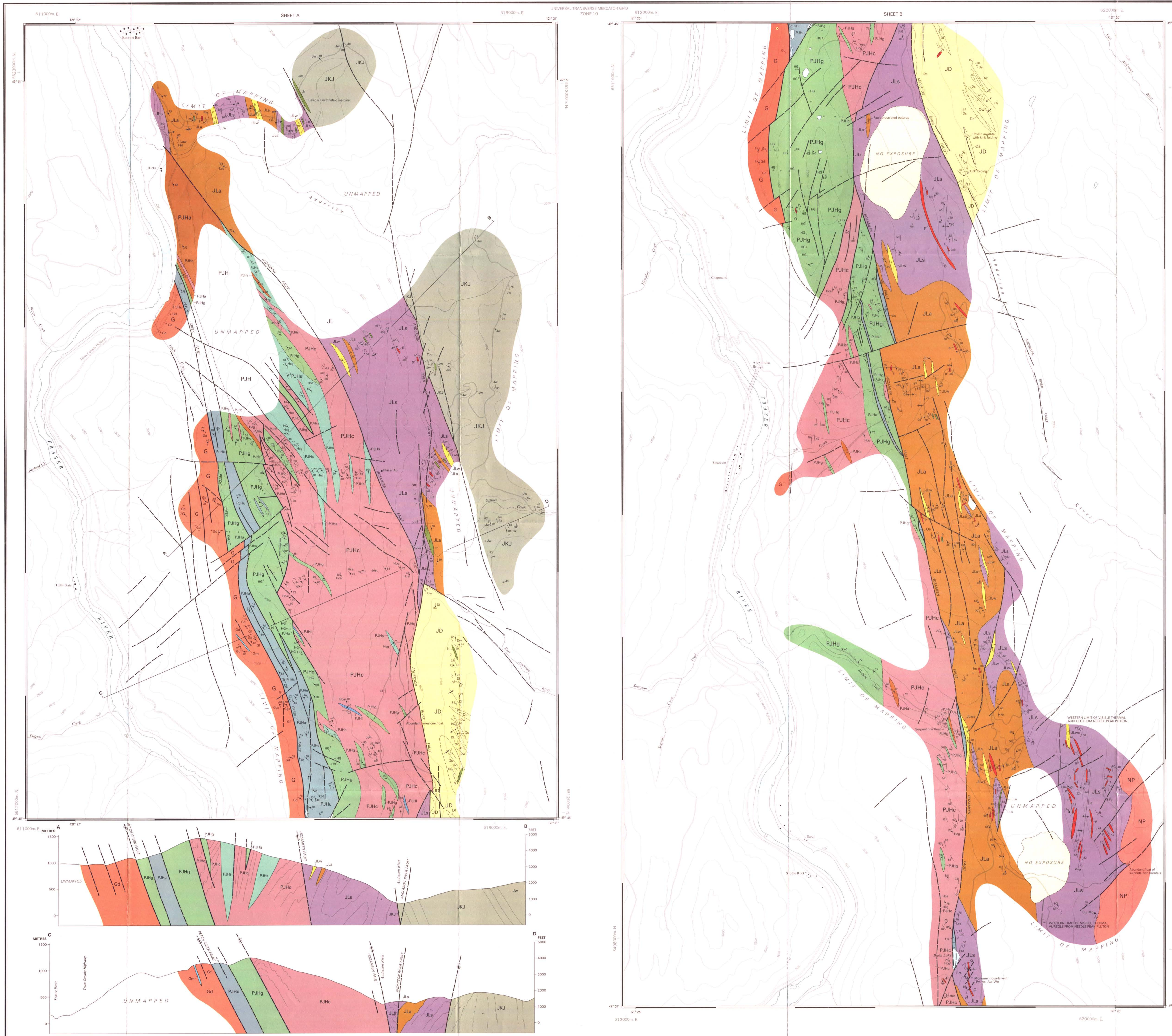
TO ACCOMPANY BULLETIN 79



Province of British Columbia
Ministry of Energy, Mines and Petroleum Resources
GEOLOGICAL SURVEY BRANCH

FIGURE 41

GEOLOGY OF THE COQUIHALLA GOLD BELT AND HOZAMEEN FAULT (NORTH HALF)

GEOLOGICAL MAPPING BY G.E. RAY
ASSISTED BY P. DESJARDINS

SCALE 1:20 000

METRES 500 0 500 1000 1500 METRES

LEGEND

EXTENSIVE AREAS OF POOR EXPOSURE

ROCKS WEST OF THE HOZAMEEN FAULT SYSTEM

UNCERTAIN AGE

MINOR INTRUSIONS INTO THE HOZAMEEN GROUP

- d — *Diorite to gabbro sills and dykes*
- F — *Feldspar-quartz porphyry sills and dykes*
- Q — *Quartz vein*

CUSTER-SKAGIT GNEISS AND YOUNGER INTRUSIONS

- G — *Undifferentiated; Gd-massive to weakly foliated granodiorite to quartz monzonite; Gf-moderately to intensely foliated gneiss of either quartz monzonite, granodiorite or quartz diorite composition; some augen gneiss with local cataclastic and mylonitic fabrics; Ggs-gneiss containing garnet ± sillimanite*
- Gm — *Marble*

PERMIAN TO JURASSIC

HOZAMEEN GROUP (PJH)

- PJHs — *Volcaniclastic sedimentary rocks, tuff and siltstone; Hsl-with thin limestone interbeds; Hsa-with argillite interbeds; Hsc-with chert interbeds; Hsg-with thin volcanic, greenstone units*
- PJHa — *Argillite; Hac-argillite and minor chert*
- PJHl — *Limestone*
- PJHc — *Chert; Hca-with minor argillite interbeds; Hcg-with minor greenstone interbeds*
- PJHg — *Greenstone; HG-gabbro*
- PJHu — *Serpentinite (Petch Creek serpentine belt)*

ROCKS WITHIN THE HOZAMEEN FAULT SYSTEM (COQUIHALLA SERPENTINE BELT)

UNCERTAIN AGE

- U — *Undifferentiated mafic and ultramafic rocks; Us-serpentinite; Ug-gabbro, microgabbro and minor greenstone; Um-fuchsite-bearing quartz-carbonate rock ("listwanite")*

ROCKS EAST OF THE HOZAMEEN FAULT SYSTEM

UNCERTAIN AGE

MINOR INTRUSIONS

- f — *Undifferentiated felsic sills and dykes generally of monzonite to granodiorite composition*
- fm — *Felsic sills with some mafic portions*
- p — *Feldspar ± quartz porphyry-bearing felsic sills and dykes*
- h — *Mafic and ultramafic sills, dykes and small stocks generally ranging in composition from quartz diorite to gabbro to hornblendite*
- Q — *Quartz vein*

SEDIMENTARY ROCKS (POSSIBLY UPPER JURASSIC DEWDNEY CREEK GROUP)

- JD — *Undifferentiated tuff and wacke; Dw-tuffaceous wacke and ash tuff; Dl-lapilli tuff and lithic wacke; Ds-siltstone; Da-argillite*

EOCENE

NEEDLE PEAK PLUTON

- NP — *Granite and granodiorite*

UPPER JURASSIC AND LOWER CRETACEOUS

DEWDNEY CREEK AND JACKASS MOUNTAIN GROUPS

- JKJ — *Undifferentiated tuff and sedimentary rocks; Jw-tuffaceous wacke, ash and lapilli tuff with some sandstone, minor siltstone and argillite; Jc-polymictic conglomerate with minor sandstone*

LOWER TO UPPER JURASSIC

LADNER GROUP (JL)

PREDOMINANTLY ARGILLITE

- JLa — *Argillite; Lao-organic-rich, pyritic slaty argillite; Las-argillite with minor siltstone interbeds; Law-argillite with minor wacke interbeds*

PREDOMINANTLY SILTSTONE

- JLs — *Siltstone; Lsa-siltstone with minor argillite interbeds; Lsw-siltstone with minor wacke interbeds; Lsc-siltstone with minor conglomerate interbeds; Lsl-siltstone with some coarse lithic clasts*

PREDOMINANTLY WACKE

- JLw — *Wacke; Lwl-lithic and tuffaceous wacke; Lwa-wacke with minor argillite interbeds; Lws-wacke with minor siltstone interbeds; Lwc-wacke with minor conglomerate interbeds*

PREDOMINANTLY CONGLOMERATE

- JLc — *Conglomerate; Lcm-conglomeratic mudstone; Lcb-green-coloured sedimentary breccia and conglomerate; Lcw-conglomerate interbedded with wacke; Lcs-conglomerate interbedded with siltstone*

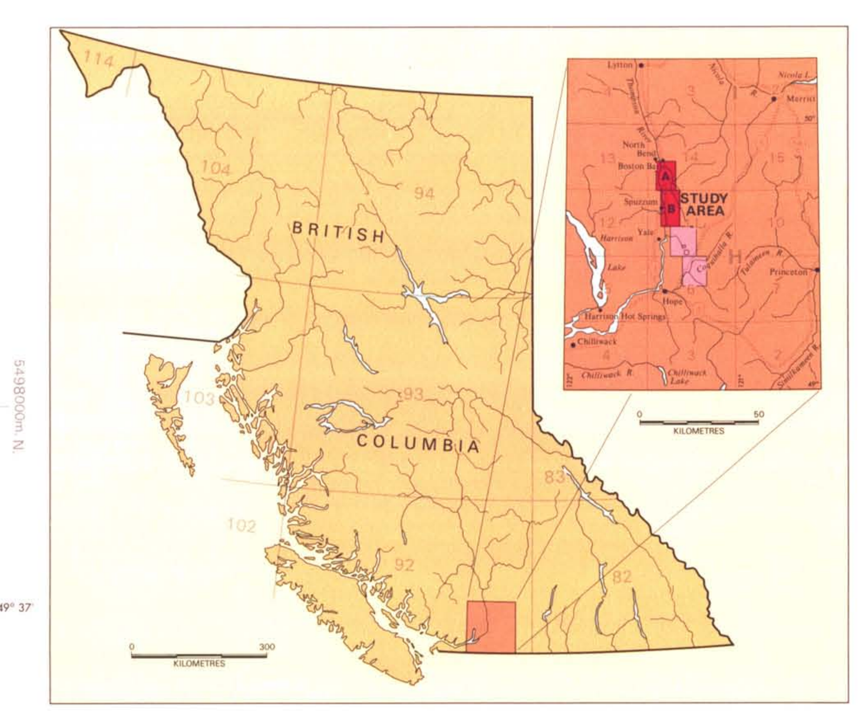
LOWER TRIASSIC(?)

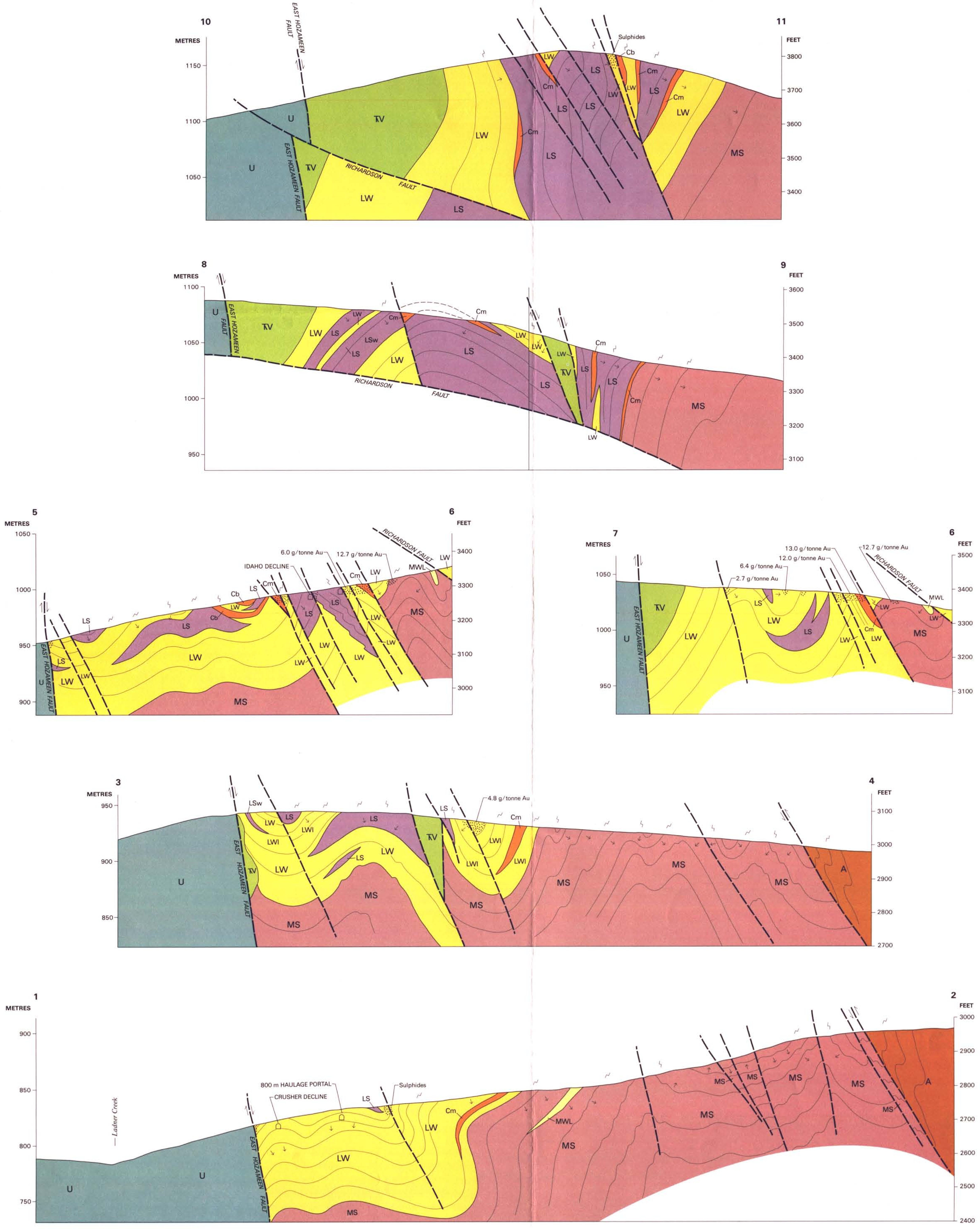
SPIDER PEAK FORMATION

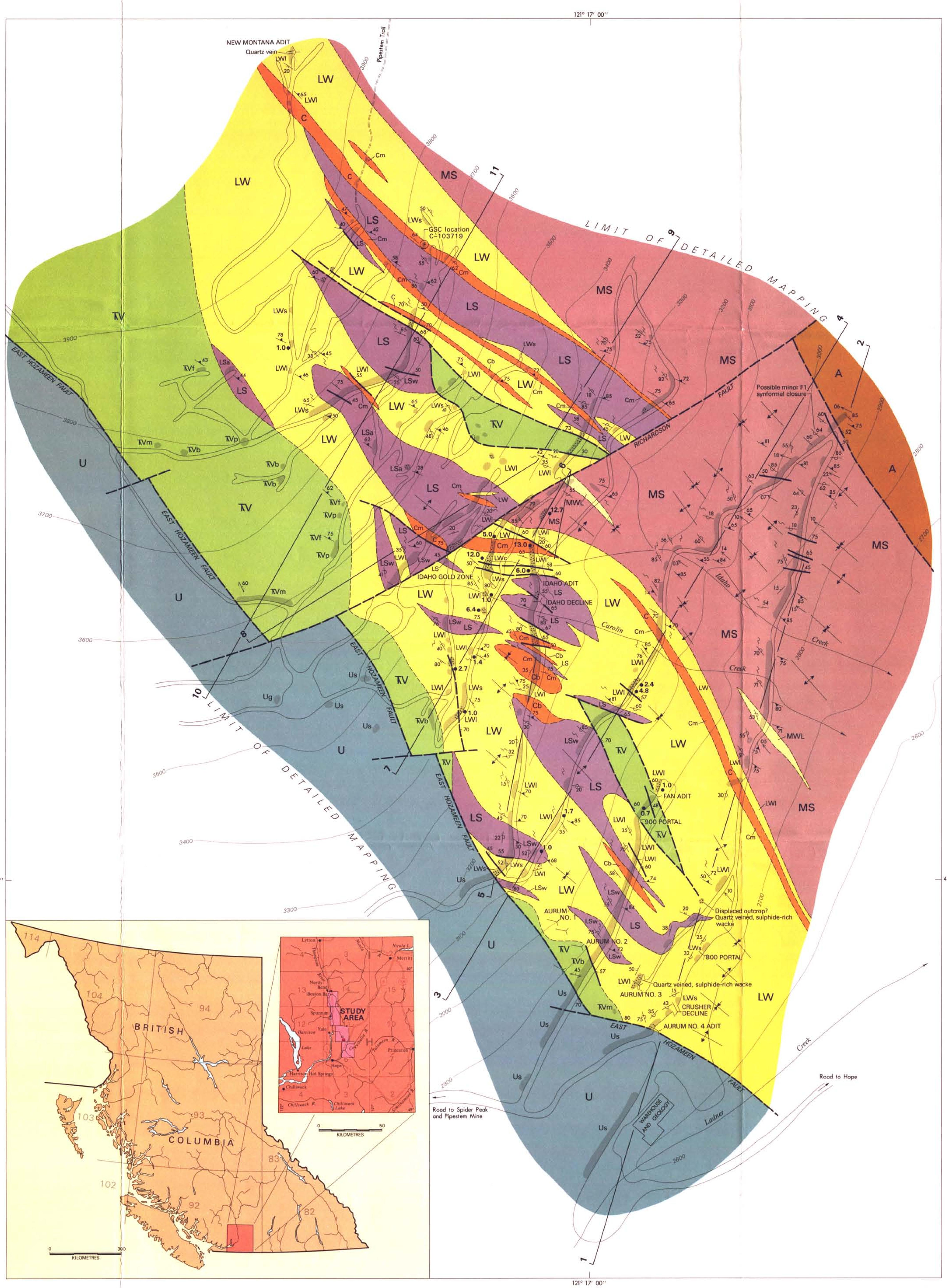
- TrV — *Undifferentiated; Vm-massive greenstone; Vf-foliated greenstone; Vp-greenstone with pillow structures; Vb-brecciated greenstone; Vs-volcanic sandstone, siltstone, or wacke; Vc-conglomerate; Vg-gabbro; Va-argillite*

SYMBOLS

- Strike and dip of bedding: tops known, tops unknown
- Bedding: Inclined, vertical, overturned
- Strike and dip of cleavage: Inclined, vertical
- Strike and dip of foliation in the Custer-Skagit gneiss
- Strike and dip of primary (volcanic?) layering in the Spider Peak Formation
- Younging direction in Spider Peak Formation (determined from pillows)
- Younging direction in sedimentary rocks (*see* sections A-B; C-D)
- Massive, unbedded, or unfoliated outcrop
- Float
- Plunge of lineation — 20
- Fold vergence determined from bedding-cleavage intersections or small-scale folds
- Minor fold with plunge of fold axis
- D_2 antiform, D_2 synform
- Geological contact: defined, assumed
- Fault: defined (with dip where observed), assumed
- Mineralized outcrop (pyrite = Py, pyrrhotite = Po, gold = Au, arsenopyrite = As, chalcopyrite = Cu, molybdenite = Mo, scheelite = Wo)
- Limit of visible thermal aureole associated with the Needle Peak pluton
- Trench
- Fossil location
- Adit
- Topographic contour (500 foot interval) — 1500
- Road: all weather, secondary
- Railway







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GEOLOGICAL SURVEY BRANCH

FIGURE 42

GEOLOGY OF THE CAROLIN MINE AREA, BRITISH COLUMBIA

GEOLOGICAL MAPPING BY G.E. RAY ASSISTED BY P. DESJARDINS

SCALE

METRES 50 0 50 100 METRES

LEGEND

UNCERTAIN AGE

COQUIHALLA SERPENTINE BELT

U — *Undifferentiated;* Us - *serpentinite;* Ug - *gabbro and micrograbbo*

LOWER TO UPPER JURASSIC

LADNER GROUP

UPPER UNIT

A — *Slaty, organic-rich argillite*

MIDDLE UNIT

MS — *Thin-bedded, turbiditic siltstone*

MWL — *Lithic wacke*

LOWER UNIT

LS — *Siltstone;* LSw - *siltstone with minor wacke;* LSa - *siltstone with minor argillite*

C — *Conglomerate;* Cm - *conglomeratic mudstone;* Cb - *green coloured sedimentary breccia and conglomerate*

LW — *Wacke;* LWl - *lithic wacke;* LWs - *wacke with minor siltstone;* LWc - *wacke with minor conglomerate*

---------- UNCOMFORMITY ----------

LOWER TRIASSIC (?)

SPIDER PEAK FORMATION

TrV — *Undifferentiated greenstone;* Vm - *massive greenstone;* Vb - *brecciated greenstone;* Vp - *greenstone with pillow structures;* Vf - *foliated greenstone.*

SYMBOLS

Strike and dip of bedding: tops known, tops unknown, overturned

Strike and dip of slaty cleavage (S_1)

Plunge of L_1 lineation

Strike and dip of primary(?)volcanic layering

Fault with dip of fault plane: observed, assumed

Geological contact: observed, assumed

D_2 fold vergence determined from bedding-cleavage intersections or small scale folds

D_2 antiform, synform

Lithogeochemical gold anomaly - gold assay in ppm Au — 2.4

Younging direction

Area of outcrop

Sulphide mineralization

Adit

Topographic contour (100-foot interval) — 2900

Line of geological cross section — 5 6

Fossil location

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TO ACCOMPANY BULLETIN 79

CARTOGRAPHY BY P. CHICORELLI

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GEOLOGICAL SURVEY BRANCH

FIGURE 44

GEOLOGY OF LEVEL 4 – THE PIPESTEM MINE, BRITISH COLUMBIA

GEOLOGICAL MAPPING BY G.E. RAY ASSISTED BY M.A. FOURNIER

SCALE 1 : 250

METRES 5 0 5 10 15 20 METRES

LEGEND

UNCERTAIN AGE

Massive quartz vein and/or quartz breccia, with sporadic sulphides and gold

Areas containing abundant thin quartz veins

Felsic sill

LOWER TO UPPER JURASSIC

LADNER GROUP

Ab — *Black, organic-rich slaty argillite; Ag - grey slaty argillite; As - argillite interbedded with minor siltstone*

W — *Massive to bedded wacke and tuffaceous wacke; Wa - interbedded with thin argillites; Wc - well-cleaved wacke and tuffaceous wacke*

Wacke containing rounded pebbles

Wacke containing angular clasts of argillite and andesite

SYMBOLS

Strike and dip of bedding: tops unknown

Strike and dip of slaty cleavage (S_1)

Plunge of L_1 lineation (bedding-cleavage intersection)

Plunge of slickenslide lineation

Plunge of strain slip cleavage or kink fold axis

Strike and dip of strain slip folds-kink fold axial plane

Fault with dip of fault plane

Width of fault in centimetres .... F (8 cm)

Geological contact

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