PRECIOUS METAL MINERALIZATION IN SOUTHWESTERN BRITISH COLUMBIA

675774
92H/12

TRIP 9

G.E. Ray (Leader)
British Columbia Ministry of Energy, Mines and Petroleum Resources
Parliament Buildings, Victoria, British Columbia, V8V 1X4

S. Coombes
Rhyolite Resources Inc., Vancouver, British Columbia

D.R. MacQuarrie
A and M Exploration Ltd., Vancouver, British Columbia

R.J.E. Niels
Carolin Mines Ltd., Hope, British Columbia

J.T. Shearer
Trader Resources Ltd., Vancouver, British Columbia

D.G. Cardinal
Cardinal Geoconsulting Ltd., Hope, British Columbia

GENERAL INTRODUCTION
G.E. Ray

This two-day field trip should include visits to five precious metal properties in southwestern British Columbia (Fig. 1)**, and will focus on the stratigraphy, geo-chemistry and tectonic setting of the mineralization. The first day will be spent examining various precious metal-bearing veins and their host rocks along the northwest-trending Harrison Lake fracture system; this fracture is associated with regional hot spring activity and sporadic gold mineralization (Fig. 2). Visits will be made to the Rhyolite Resources Inc. gold-silver property at Doctors Point, the defunct Providence mine with its zinc-lead-silver mineralization and the Abo Oil Corporation property at the defunct RN gold mine (Fig. 1).

On the second day, two properties in the Coquihalla gold belt, which lie adjacent to the Hozameen fault and Coquihalla serpentine belt, will be visited (Fig. 1). This will include a geological examination of the Carolin Mines Ltd. gold deposit and a look at Aquarius Resources Ltd. defunct Emancipation gold mine.

The mineralization seen on this trip represents a variety of contrasting types. At the Emancipation and RN mines and at Doctors Point, the high grade precious metal mineralization is generally hosted in quartz veins, which at the latter two properties are genetically and temporally related to a c 25 Ma episode of diorite-quartz diorite plutonism. The mineralization at the Providence mine is hosted in brecciated quartz-carbonate veins that carry zinc, lead and silver, but no gold. By contrast, the Carolin mine orebody represents a replacement-type 1.5 million tonne deposit averaging 4.8 grams gold per tonne*. The complex sulphide-albite-quartz-gold mineralization is both lithologically and structurally controlled within the hinge zones of antiformal structures and forms comparatively large, irregular orebodies.

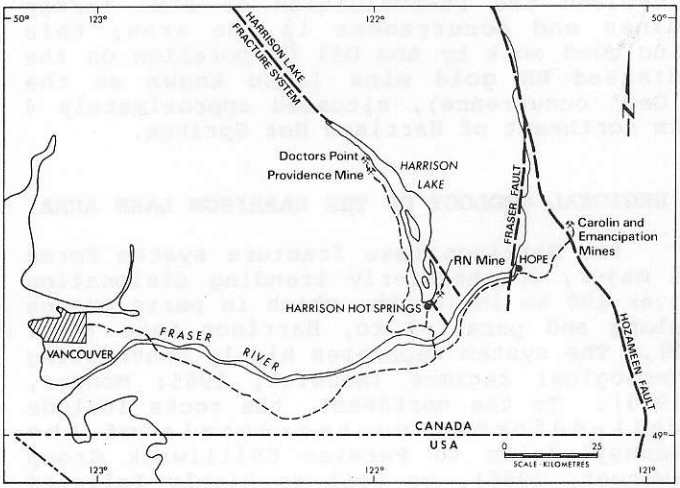


Figure 1. Field trip route and property location map.

*In this field guide, previously reported ounces per ton values were recalculated to grams per tonne using a conversion figure of 34.28. Recalculation of assays from troy onces to grams involved a conversion figure of 31.103.

**Thanks are expressed to J.L. Armitage, P. Chicorelli and M. Taylor of the B.C. Ministry of Energy, Mines and Petroleum Resources for drafting all the figures in this guide book.

DAY 1 - MORNING
DOCTORS POINT AND PROVIDENCE MINE

G.E. Ray and S. Coombes

INTRODUCTION

The northwest-trending Harrison Lake fracture system, approximately 100 km east-northeast of Vancouver, is associated with regional hot spring activity and sporadic gold mineralization (Fig. 2). Most of this gold was found before the turn of the century; it includes numerous occurrences and several small producers (Table 1) such as the Providence (Mineral Inventory 92H/NW-30) and RN (Mineral Inventory 92H/SW-92) mines. Since the 1930's, extensive parts of the Harrison Lake area have not experienced much exploration activity or regional geological mapping.

In 1981-1982 Rhyolite Resources Inc. started drilling some gold-bearing quartz-sulphide veins at Doctors Point, on the western shore of Harrison Lake. The results of this work led to a large staking rush, as some companies realized that areas adjacent to the Harrison Lake fracture system had favourable potential for either epithermal or mesothermal gold mineralization. Part of this activity involved the re-evaluation of some former mines and occurrences in the area; this included work by Abo Oil Corporation on the disused RN gold mine (also known as the 'Geo' occurrence), situated approximately 4 km northeast of Harrison Hot Springs.

REGIONAL GEOLOGY OF THE HARRISON LAKE AREA

The Harrison Lake fracture system forms a major, southeasterly trending dislocation over 100 km in length, which in parts passes along and parallel to, Harrison Lake (Fig. 2). The system separates highly contrasting geological regimes (Roddick, 1965; Monger, 1970). To the northeast, the rocks include well-deformed supracrustals of the Pennsylvanian to Permian Chilliwack Group (Monger, 1966), as well as highly foliated gneissic rocks and some younger granites. By contrast, the rocks on the southwestern side of the fracture are generally younger, are less deformed and have suffered lower metamorphic grade; they include a variety of volcanic, volcaniclastic and sedimentary rocks, as well as intrusive granitic rocks and migmatites. These supracrustals are separable into a number of different groups of Jurassic/Cretaceous age. To the northwest (Fig. 2), the Upper Jurassic to Lower Cretaceous Fire Lake Group (Roddick, 1965) comprises a 4500-m-thick sequence of largely sedimentary rocks with lesser amounts of volcanic greenstone. The group contains one jasper-bearing horizon at the interface between volcanic greenstones and an overlying sequence of aquagene breccias and tuffs; this horizon in interpreted as submarine exhalitive in origin (Ray and Coombes, 1985). The greenstones in the group host at least five fault-filled quartz veins (Table 1) that carry chalcopyrite and sporadic native gold; these are clustered in the vicinity of Fire Mountain (Fig. 2) and include the defunct Money Spinner gold workings (Ray and Coombes, 1985). Another vein, the Dandy (Table 1), which lies 10 km northwest of Fire Mountain (Fig. 2), is a lead-zinc-bearing quartz carbonate vein hosted in brecciated sedimentary rocks.

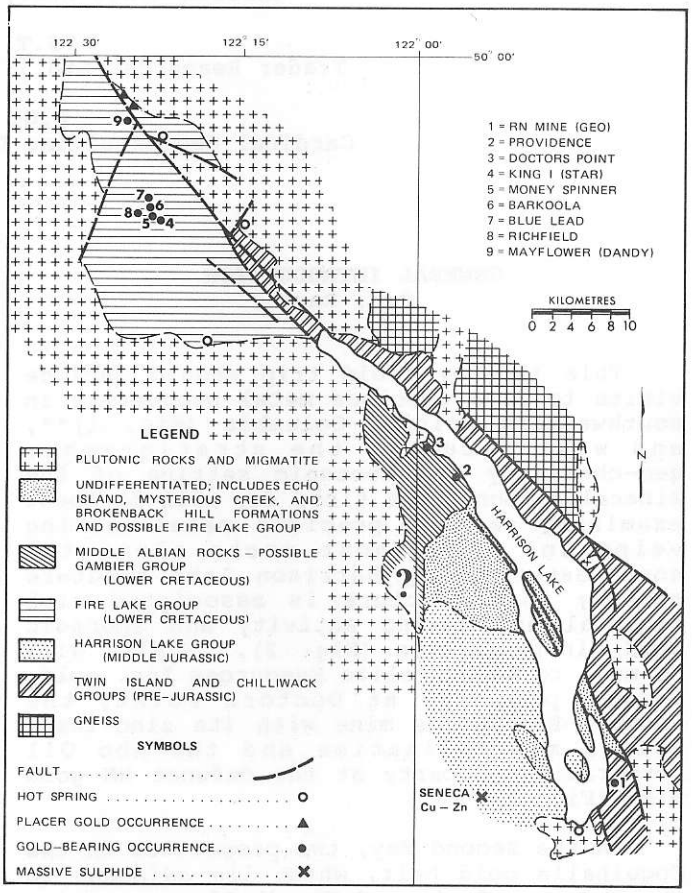


Figure 2. Regional geology of the Harrison Lake fault system (adapted after Roddick, 1965, and Monger, 1970).

The area southwest of Harrison Lake (Fig. 2) is largely underlain by the Middle Jurassic Harrison Lake Group (Crickmay, 1925; Roddick, 1965), a predominantly volcanic sequence of andesitic to dacitic composition, with lesser amounts of volcaniclastic and sedimentary rocks. The Harrison Lake Group hosts massive sulphide mineralization at the Seneca deposit (Fig. 2).

The western shore of Harrison Lake south of Doctors Point is underlain by a variety of supracrustal rocks whose age and relationship to one another is poorly understood. However, locally derived float

TABLE 1
AREAS WITH MINERALIZED VEINS ASSOCIATED WITH THE HARRISON LAKE FRACTURE SYSTEM

Name	MI No.	Host Type	Gangue	Reported Mineralization
Money Spinner	92G/NE-2	Greenstone	Quartz	Cu-Au
Barkoola	92G/NE-3	Greenstone	Quartz	Cu-Au
Blue Lead	92G/NE-4	Greenstone	Quartz	Cu-Au
King No. 1 (Star)	92G/NE-5	Greenstone	Quartz	Cu-Au
Richfield	92G/NE-6	Greenstone	Quartz	Au
Dandy (Mayflower)	92G/NE-10	Brecciated sedimentary rocks	Quartz-carbonate	Pb-Zn-Ag-Au
Doctors Point (Nagy)	92H/NW-71	Diorite and hornfelsed volcanic and sedimentary rocks	Quartz	Au-Ag-As
Providence Mine	92H/NW-30	Greenstone	Quartz-carbonate	Pb-Zn-Ag
RN Mine (Geo)	92H/SW-92	Diorite	Quartz	Au-Cu

bearing a Middle Albian ammonite fossil, Cleonicera penezianum (Dr. H. Tipper, pers. comm., 1984), was recently discovered in the Doctors Point area (Ray and Coombes, 1985). This suggests that the volcano-sedimentary sequence at Doctors Point is Early Cretaceous in age and may represent a lateral equivalent to the Gambier Group (Armstrong, 1953). Since the Gambier Group elsewhere hosts the Brittania and Northair deposits (Barr, 1980; Payne, et al., 1980), its presence at Doctors Point may have economic significance regarding exploration for massive sulphide mineralization.

The sequence at Doctors Point is intruded by several diorite-quartz diorite plutons which are surrounded by a wide thermal metamorphic aureole. The gold-bearing veins in the area exhibit a pronounced spatial relationship to the pluton margins and the mineralization is believed to be genetically and temporally related to these intrusion.

The Providence mine area, situated approximately 5 km southeast of Doctors Point (Fig. 2), is largely underlain by andesitic volcanic rocks of unknown age. It is uncertain whether these rocks form a southern extension of the Gambier Group (?) volcanics seen at Doctors Point, or whether they belong to the Harrison Lake Group, as shown by Monger (1970).

The regional geology of the RN mine area, at the southern end of Harrison Lake (Fig. 2) is poorly known. Like Doctors Point, the gold mineralization is related to diorite intrusions which cut pelitic metasediment rocks belonging either to the Pennsylvanian to Permian Chilliwack Group, or the Middle Jurassic Mysterious Creek Formation (Monger, 1970).

DOCTORS POINT AREA

INTRODUCTION

In the late 1970's, Mr. G. Nagy discovered gold-silver mineralization at Doctors Point, on the southwest shore of Harrison Lake, approximately 45 km north-northeast of Harrison Hot Springs (Fig. 2). In 1981 Rhyolite Resources Inc. purchased the Nagy claims and subsequently conducted an exploration program involving geological mapping, soil sampling, trenching and drilling. The drilling program intersected gold-silver-bismuth mineralization in sulphide-bearing quartz veins; the best holes intersected 3.2 m of 7.1 grams gold per tonne (0.21 ounce gold per ton) and 3.9 m of 4.2 grams gold per tonne (0.125 ounce gold per ton.

GEOLOGY

The simplified geology of the area is shown on Figure 3. The southern part is underlain by a variety of generally moderately dipping volcanic, volcaniclastic and sedimentary rocks that may belong to the Early Cretaceous Gambier Group. To the north these supracrustals are intruded by five diorite-quartz diorite bodies that vary in size from only 25 m in diameter to over 2 km across. The volcanic rocks are fine to

medium grained, are generally highly altered and range from andesite to dacite in composition. Both porphyritic and non-porphyritic varieties are seen and abundant disseminated pyrite is a widespread feature; the dacitic varieties are commonly devitrified and silicic. Most of the volcanic rocks are massive; flow banding is rarely seen.

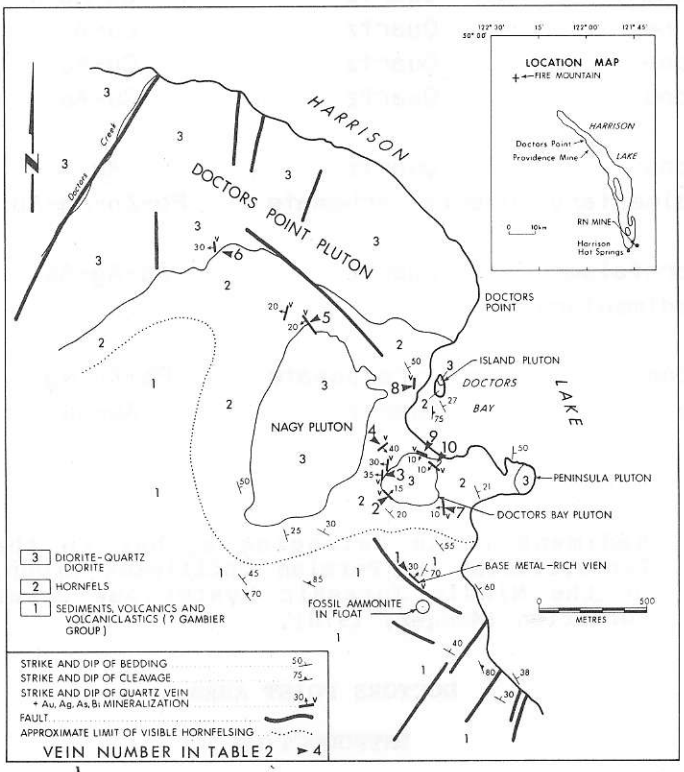


Figure 3. Geology of the Doctors Point area, Harrison Lake (after Ray et al., 1984).

The sedimentary rocks range from massive, black argillites, some of which contain rounded concretionary structures, through to finely bedded, siliceous siltstones that in places display excellent graded bedding. Most of the sedimentary rocks indicate deposition in a low-energy environment but some siltstones contain argillitic rip-up clasts and others show signs of soft sediment deformation and chaotic slumping. At one locality, a very coarse-grained conglomerate is seen; this contains angular to subrounded clasts up to 0.6 m in diameter which are composed of amygdaloidal dacitic and andesitic volcanics, bedded sedimentary rocks, massive limestone and fragments of broken quartz and feldspar crystals.

The volcaniclastic rocks vary from massive to finely bedded, often siliceous crystal-lithic tuffs through to chaotic volcanic breccias having angular to subangular clasts up to 0.15 m in diameter; most clasts are of volcanic origin. The more mafic breccias are marked by rounded clots of calcite rimmed with epidote, while some of the finely bedded tuffs display load cast structures. In parts the bedded tuffs and breccias are interlayered with volcanic flows that also sporadically contain angular, lithic clasts. Consequently, it is often difficult to distinguish between tuffaceous lavas and volcaniclastic rocks, particularly where devitrification is widespread.

The plutons intruding the supracrustals (Fig. 3) range from diorite to quartz diorite in composition. When fresh they form grey-coloured, generally massive and coarse-grained rocks. Biotite is the most widespread mafic mineral but hornblende is sporadically developed and can exceed 20 % by volume in parts. Locally these rocks contain up to 10 % disseminated pyrite, but this sulphide is not associated with gold.

Five individual plutons are seen. They range in size from the small body underlying the northern portion of the island in Doctors Bay through to the incompletely mapped large mass situated between Doctors Creek and Doctors Point (Fig. 3). The three remaining bodies form rounded to oval-shaped masses whose contacts with the country rocks are highly irregular in parts. The Doctors Point pluton (Fig. 3) represents the largest body and is notable for its higher quartz content and for the presence of rounded, mafic xenoliths; the latter are rarely seen in the other four bodies. The diorites are generally massive textured, but the western margin of the Peninsula pluton (Fig.3) exhibits a vertically inclined, rhythmic compositional layering. This consists of subtle, diffuse concentrations of light and dark minerals; no sharp boundaries exist between the individual layers which are mostly regular and vary from 1 to 2 cm in thickness.

The plutons are surrounded by a 100 to 250-m-wide hornfelsic aureole marked by intense recrystallization of the country rock; in places identification of the original rock type is impossible. Close to the pluton margins the hornfels contains fine biotite and magnetite and is characterized by weak silicification with some disseminated fine grained pyrite and pyrrhotite. The pyrite-pyrrhotite can exceed 15% by volume immediately adjacent to the plutons but these sulphides do not carry gold. In rare instances, the hornfelses close to the pluton margins also contain cordierite, andalusite and coarse garnet crystals.

Biotite and hornblende samples from the Doctors Bay pluton are currently undergoing K/Ar analysis for dating; a preliminary date of 25 Ma for the biotite has been made by J. Harakal (pers. comm., 1985). This suggests that the diorite bodies at Doctors Point

were contemporaneous with the diorite plutons and their related gold-bearing veins at the RN mine, approximately 45 km to the southeast.

GEOLOGICAL HISTORY OF THE DOCTORS POINT AREA

The Early Cretaceous sedimentation was accompanied by submarine volcanism and the possible development of an explosive, submarine caldera. Some of the massive tuffs may represent ash flows. This was followed during the Middle Cretaceous (?) by a period of uplift and folding which resulted in the consistent easterly dip of the bedding and the imposition of a subvertically inclined fracture and slaty cleavage. Bedding-cleavage intersections indicate that the entire area occupies the eastern limb of a major, northwest-trending anticline. There is no evidence of structural repetition in the sequence and the graded bedding shows tectonic inversion did not occur.

The diorite plutons and a related suite of late mafic dykes were emplaced approximately 25 Ma ago. The late hydrothermal gold-silver-arsenic mineralization was injected along gently inclined cone sheet fractures that had developed during the diorite intrusion.

This was followed by two sets of subvertically inclined faulting that trend northeast and southeast respectively. Slickensiding indicates the southeast-striking fault set, which trends parallel to Harrison Lake fracture system, suffered both vertical and subhorizontal movements.

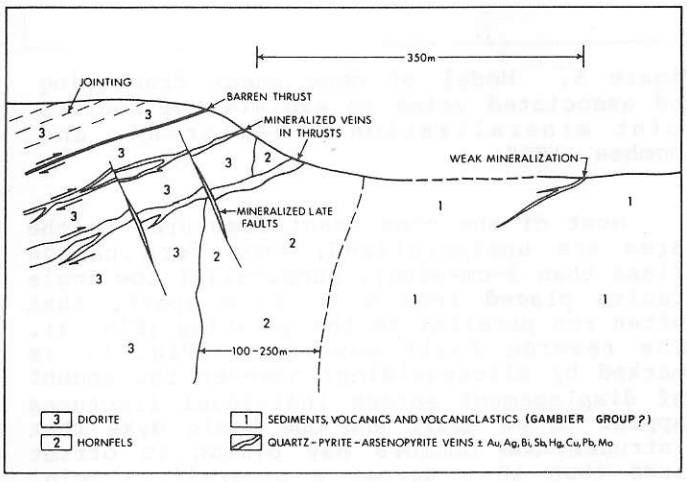


Figure 4. Schematic section showing mineralized veins following cone-sheet fractures, Doctors Point, Harrison Lake. (After Ray et al., 1984).

MINERALIZATION

The gold-silver mineralization at Doctors Point is hosted in long, narrow, gently dipping (10 to 35°) vuggy quartz-sulphide veins that show an overall spatial association to the diorite pluton margins (Fig. 3 and 4). These veins follow pre-existing low angle fractures which probably represent cone sheet-type fractures formed during the diorite intrusion. On surface the veins vary from a few cm to 0.75 m wide, but drilling has intersected veins over 3 m in width. The veins include both clear and white vuggy quartz, the vug cavities being lined with small quartz crystals. Pyrite and arsenopyrite are the commonest sulphides; in part the veins comprise coarse, massive sulphide material in which quartz is subordinate. Surface leaching results in abundant boxwork textures in the quartz veins and many mineralized outcrops are coated with green scorodite ($FeAsO_4 \cdot H_2O$), an alteration product of the arsenopyrite. In some instances the veins contain small amounts of chalcopyrite, while rare examples of molybdenum and galena also occur. Analyses (Table 2) show that the gold-silver-arsenic mineralization at Doctors Point is sporadically associated with anomalous amounts of bismuth, antimony, mercury, copper, lead and zinc. Surface veins are traceable over a 30-m distance, but drilling indicates some exceed 200 m in length. One surface mineralized zone at the northern end of the Nagy pluton (vein 5; Fig. 3) is traceable for 30 m from the diorite into the adjacent, sulphide-rich hornfels without any apparent dislocation or change in either mineralogy or vein dimension.

Veins are found in at least 12 separate locations (Fig. 3), 11 of which are under lain by either diorite or hornfelsic rocks. Analyses on veins from 10 of these areas are shown in Table 2. The veins generally contain high gold and silver values (Table 2) and are enriched in arsenopyrite and pyrite, with only trace amounts of galena, copper and sphalerite. However, the southernmost mineralized fracture (vein 1; Fig. 3), which lies outside the hornfelsic aureole, is enriched in gold, silver, lead and zinc (vein 1, Table 2) and contains abundant galena and tetrahedrite. Thus a temperature-related mineral and element zoning probably exists in the area, with gold predominating closer to the pluton margins and base metals predominating outside the hornfelsic envelope (Fig. 5).

The mineralized veins are usually bounded by a 'bleached zone' in which the nature and texture of the original rock type is unrecognizable. These bleached zones comprise a very fine mixture of quartz, sericite and kaolin, with some disseminated pyrite; in places it carries trace amounts of gold. The bleached zone varies from a

TABLE 2
TRACE ELEMENT ANALYTICAL RESULTS OF THE MINERALIZED VEINS AT DOCTORS POINT, HARRISON LAKE
(for location see Fig. 3)

Vein No.	1	1	2	3	4	4	5	6	7	8	9	10
Sample No.	28924	27851	28925	28927	28928	27855	28929	28931	28932	28933	28934	28935
Au	29	NA	8.9	7.2	34.6	NA	9.6	<0.3	12.7	26	NA	NA
Ag	953	NA	10	16	37	NA	90	35	3	140	1	110
Cu	0.28%	0.21	0.0004%	0.02%	0.01%	0.36%	1.24%	0.07%	0.004%	0.06%	0.01%	0.17%
Pb	2.95%	5.5%	0.014%	0.04%	0.01%	48	0.04%	0.03%	0.003%	0.07%	0.001%	0.04%
Zn	374	712	25	33	30	44	211	74	18	71	42	115
Co	<2	<2	13	7	<2	5	182	8	5	13	29	6
Mo	<6	8	8	<6	<6	7	<6	<6	<6	<6	<6	<6
Ni	<2	NA	9	<2	<2	NA	29	13	<2	15	18	NA
Sb	0.99%	3.3%	186	300	112	580	58	36	325	72	<3	0.11%
Bi	NA	5	NA	NA	NA	55	NA	NA	NA	NA	NA	NA
As	19.1%	8.0%	26.4%	29.6%	16.8%	5.7%	0.34%	3.16%	25.4%	0.41	0.007%	14.0%
Hg	NA	534 ppb	NA	NA	NA	710 ppb	NA	NA	NA	280 ppb	NA	NA

NA - Not assayed
All values in ppm except where stated as per cent or ppb

Vein 1 - Stop A
Vein 2 - Stop B
Vein 3 - Stop C
Vein 5 - Stop D

few cm to 3 m in width; generally the wider zones are associated with the thicker veins and commonly the hangingwalls contain the widest zones of alteration. The bleached alteration passes gradually out to a wider 'rotted zone' which is characterized by its friable, weathered and rusty appearance. In this zone the feldspars are extensively kaolinitized, but the textures of the original rocks are clearly visible. This alteration zone can exceed a total of 8 m in width and generally carries weakly disseminated pyrite but no gold.

The mineralization is genetically and temporally related to the diorite plutons and probably represents a late hydrothermal phase of this magmatic event. The postulated sequence is: (1) emplacement of the diorite plutons with some barren sulphide mineralization, accompanied by the development of low angle cone sheet fractures (Fig. 5); (2) intrusion of some rare, mafic dykes; (3) minor reverse fault movement along the fractures; (4) gold-silver-arsenic mineralization along some of the cone sheet fractures; and (5) late subvertical faulting. Most veins are associated with the Doctors Bay pluton (Fig. 3) and they generally dip toward the pluton core; a few veins also lie within or adjacent to the Doctors Point and Nagy plutons (Fig. 3). This suggests that the dioritic bodies in the area are related and probably represent apophyses of a single, major body.

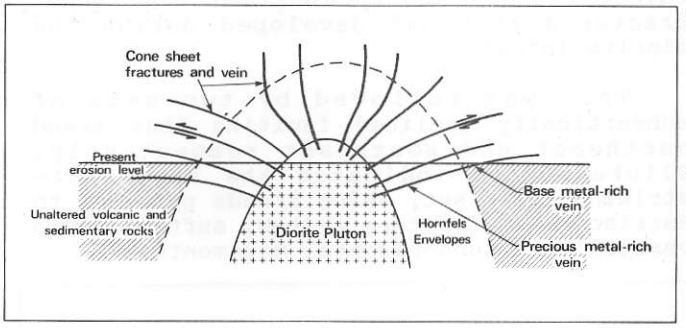


Figure 5. Model of cone sheet fracturing and associated veins to explain the Doctors Point mineralization. (After Ray and Coombes, 1985).

Most of the cone sheet fractures in the area are unmineralized; they form narrow (less than 3-cm-wide), subparallel low angle faults placed from 5 to 20 m apart, that often run parallel to the jointing (Fig. 4). The reverse fault movements (Fig. 5) is marked by slickensiding; however the amount of displacement across individual fractures appear to be small and one basic dyke that intrudes the Doctors Bay pluton is offset less than 10 m across a mineralized vein. Drilling reveals that some mineralized veins bifurcate and rejoin one another in a complex manner, similar to that shown on Figure 4. Some late, subvertical normal fractures crosscut and cause minor displacement of the main veins. These later faults can also carry 1 to 3-cm-wide gold-bearing quartz-sulphide veins suggesting that some later remobilization occurred.

A petrographic and scanning electron microscope (SEM) study on the Doctors Point mineralization was completed by Littlejohn (1983). He noted that the native gold is associated mainly with the pyrite and only to a lesser extent with the arsenopyrite. The gold occurs as small inclusions, mostly less than 0.01 mm in diameter and is generally concentrated close to the edges of the sulphide crystals. Some pyrite and arsenopyrite crystals contain abundant, minute vesicles, which Littlejohn (1983) interprets to result from boiling. The numerous microfractures cutting the sulphides are filled with calcite, together with small amounts of gel pyrite, clay and native bismuth and lead-bismuth sulphosalts. Argentite, associated with the bismuth minerals, is also present; some native bismuth contains minute specks of chalco-pyrite. Traces of galena are intergrown with and rim the arsenopyrite.

Littlejohn (1983) concludes that the veins experienced two distinct episodes of precious metal mineralization. The first involved the introduction of gold with the sulphides and quartz, followed by a period of microbrecciation. The second resulted in injection of the silver-bismuth minerals into the microfractures. A period of calcite injection postdates the early quartz -sulphide-gold episode, but its precise relationship to the later silver-bismuth phase is unknown.

DETAILS OF INDIVIDUAL STOPS TO BE VISITS IN THE DOCTORS POINT AREA

STOP A (Vein 1: see Figure 3 and Table 2). This small, mineralized outcrop is the only one in the district that occurs outside the hornfelsic envelope surrounding the diorite plutons (Fig. 3). The vein is hosted in a highly fractured, steeply dipping sequence of acid volcanics, volcanic breccias and cherty sedimentary rocks. Mineralization follows a southeasterly striking fracture that dips 35° northeast. The 3 to 6-cm-wide vein contains massive pyrite, arsenopyrite, tetrahedrite and galena, but quartz is generally absent. Assays for this vein are shown in column 1 of Table 2. The vein is enveloped by a 15 to 30-cm-wide bleached alteration zone that mainly comprises fine-grained quartz, sericite and sulphides with some thin quartz veins. The alteration zone assays Au 3.4 ppm, Ag 27 ppm, Cu 0.02%, Pb 0.2% , Zn 93 ppm, Mo 6, As 7.09% and Sb 493 ppm. Alteration minerals on the outcrop include scorodite ($FeAsO_4.H_2O$), anglesite ($PbSO_4$), schultenite ($PbHAsO_4$), jarosite and malachite.

STOP B (Vein 2: see Figure 3 and Table 2). This mineralized vein is localized along the faulted contact between quartz diorite rocks of the Doctors Bay pluton and some structurally underlying hornfelsic rocks (Fig. 3). The vein is up to 0.7 m wide, trends southeasterly and dips gently at between 15 and 25° to the northeast. The mineralization appears to follow a cone sheet fracture which had previously suffered minor, westerly directed reverse fault movement; this movement caused the dioritic rocks to structurally override the hornfelses.

Mineralization consists mainly of coarse arsenopyrite and pyrite, with crystalline quartz stringers up to 9 cm wide. In addition, the zone carries abundant light green scorodite ($FeAsO_4.H_2O$) with limonite, sericite and feldspar. Locally the mineralization is rhythmically zoned and vuggy, while elsewhere the sulphides have been extensively leached, producing pronounced boxwork textures. Assays from this vein give maximum values of 34 ppm Au, 112 ppm Ag, 0.004% Cu, 0.02% Pb, 136 ppm Zn, 8 ppm Mo, 710 ppb Hg, 55 ppm Bi, 26.4% As and 204 ppm Sb.

The vein is cut and displaced by minor, normal faults that trend south-southeast and dip steeply east; locally these younger fractures contain thin mineralized quartz veins.

In thin section the footwall hornfelsic rocks have a marked decussate texture; the original coarse feldspar and quartz crystals are recrystallized into a polygonal mosaic of fine, fresh crystals up to 0.3 mm in diameter. Biotite forms minute (less than 0.1-mm), randomly orientated, subhedral laths and makes up to 10% of the rock. Other minerals include abundant magnetite, with accessory sericite, epidote, clinozoisite, chlorite and minor sulphides.

The hangingwall quartz diorite adjacent to the vein is altered, fractured and leached. Unaltered samples of this massive, coarse-grained rock comprises 10 to 15% hornblende which forms subeuhedral prisms and commonly encloses remnant, corroded augitic cores. Biotite forms 1 to 5% of the rock; some is intergrown with the hornblende and is partially altered to chlorite. The plagioclase (An_{30-47}) forms well-twinned, zoned crystals with clouded cores and clear margins; many are partially saussuritized. Quartz makes up 1 to 3% of the rock and subeuhedral pyrite crystals are recognizable in hand specimen.

STOP C (Vein 3: see Figure 3 and Table 2). This vicinity has been extensively drilled by Rhyolite Resources Inc. The steeply dipping, intrusive contact between the Doctors Bay pluton to the east and hornfelsed, siliceous, pyritic metavolcanic (?) rocks to the west is seen (Fig. 3). Immediately adjacent to the pluton margin the hornfels contains abundant pyrite and

pyrrhotite, while the hornblende-biotite diorite also locally carries some rare sulphide-rich pockets. However, the sulphides in the hornfels and diorite do not carry any gold.

The hornfels at this locality is cut by several unmineralized and weakly mineralized fractures that are 1 to 5 cm wide and spaced between 5 to 10 m apart. These fractures strike north-south and dip between 18 and 35° west; some carry minor amounts of pyrite, arsenopyrite, quartz and scorodite. A few of the unmineralized fractures are marked by slickensiding.

STOP D (Vein 5: see Figure 3 and Table 2). This stop is made at the northern extremity of the Nagy pluton (Fig. 3) where the steeply dipping, intrusive contact between the diorite (to the south) and siliceous, pyritic hornfelsed (?) meta-volcanic rocks (to the north) is seen. Barren sulphides in the hornfels are particularly abundant immediately adjacent to the pluton margin.

A narrow, northerly trending, gold-bearing mineralized zone passes beneath the road and is traceable from the diorite into the hornfels. The zone in parts comprises two to three mineralized veins that follow fractures spaced between 2 to 8 cm apart. The veins bifurcate and rejoin one another and dip westward at approximately 30°. They carry vuggy, crystalline quartz together with stringers and masses of pyrite and arsenopyrite. Scorodite is also present. The veins are bordered by bleached and rusted alteration zones up to 1.5 m wide, but some weak kaolinization and alteration in the diorite is evident up to 3 m from the veins.

Assay results from mineralized material taken at the southern end of the vein are shown in Table 2 (vein 5). Mineralization hosted in the hornfels at the northern end of the vein assays Au 7.5 ppm, Ag 4 ppm, Cu 0.01%, Pb 0.005%, Zn 19 ppm, Mo <6 ppm, As 8.0% and Sb 217 ppm.

PROVIDENCE MINE

INTRODUCTION

The Providence mine property (Mineral Inventory 92H/NW-30) is situated close to the shore of Harrison Lake, approximately 5 km southeast of Doctors Point (Fig. 2). It was worked at the turn of the century but precise details concerning the early work, the number and orientation of the veins and the tonnage mined, as reported in the Annual Reports of the B.C. Ministry of Mines for 1897, 1901 and 1929 are confusing and contradictory. The early literature describes pyritic mineralization containing 40% free gold hosted in a northerly trending, 0.3 to 1.3-m-wide quartz vein. A shaft and 175-m-long adit were driven and in 1896, a 91-tonne shipment, which was presumably derived from this vein, reportedly yielded 4665 grams of gold (B.C. Mineral Inventory File 92H/NW-30); this indicates an average grade of 51 grams gold per tonne! The present location of this mineralized vein on the property is uncertain and no geochemical or mineralogical data concerning this gold mineralization is available.

The mineralization we will examine on the property was not mentioned in the early literature and is situated approximately 100 m north of where Davidson Creek enters Harrison Lake (Fig. 6). The veins are not gold bearing, but carry Zn-Pb-Ag mineralization within a quartz-carbonate gange. One shaft and four adits of various lengths (Fig. 6) were driven through the veins and examples of the mineralization and vein breccia textures can be seen on the tailings dump.

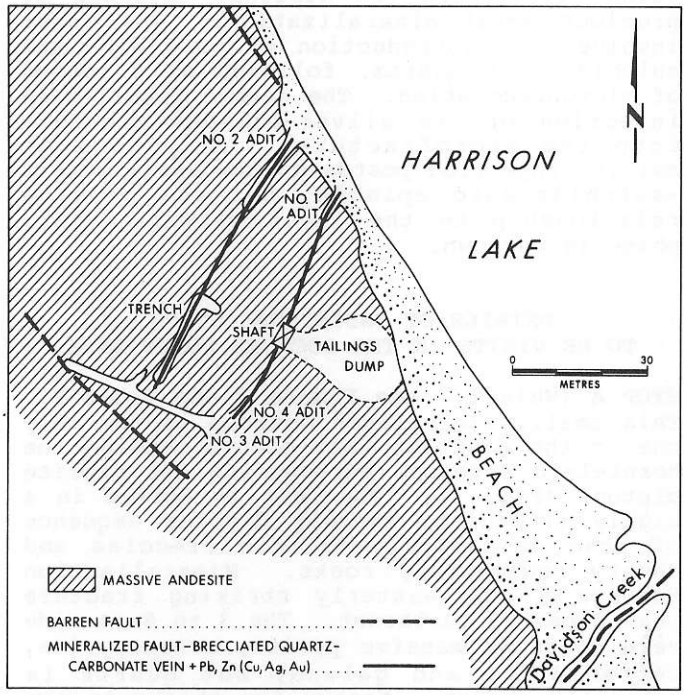


Figure 6. Geology and plan of the Providence Zn-Pb mine, Harrison Lake. (After Ray et al., 1984)

GEOLOGY AND Zn-Pb-Ag MINERALIZATION

The regional geology around the Providence mine property consists primarily of massive, dark volcanic rocks of presumed andesitic and/or basaltic composition, with lesser amounts of volcanic breccia. A major, north-northeast-trending fault passes along Davidson Creek and the Zn-Pb-Ag-bearing veins are controlled by several fractures which are either subparallel to, or represent splays from, the Davidson Creek

fault. The geology and location of the two mineralized veins and the adits and shaft are shown on Figure 6. Two adits (Nos. 1 and 2) were driven in from the lake shore and follow the veins for short distances. Immediately north of the No. 2 adit (Fig. 6) pillowed volcanics and aquagene breccias are seen. A 4-m-long adit (No. 4) was driven along the southern end of the eastern vein, while the 34-m-long No. 3 adit was driven close by in a westerly direction (Fig. 6). The No. 3 adit intersects a southern extension of the two veins; however the veins are poorly developed in the adit and contain only minor pyrite. On surface the western vein was deeply trenched and the shaft was driven down the central portion of the eastern vein (Fig. 6). The veins are steeply dipping and have a maximum width of approximately 0.7 m; they largely comprise a complex quartz-carbonate breccia that has sharp, often fractured contacts with the surrounding andesites. However, the wallrocks up to 3 m from the veins carry irregular, subparallel veinlets of quartz and calcite, while the andesites immediately adjacent to the main veins contain disseminated pyrite. Sulphides are sporadically developed in the veins; in the No. 3 and No. 4 adits (Fig. 6) only weak pyrite is seen, while the trench overlying the western vein carries pyrite with weak chalcopyrite and rare bornite. On the tailings dump, however, numerous large specimens containing abundant sulphides are seen. In hand specimen the brecciated and mineralized vein material consists of angular to rounded clasts of rhythmically layered, crystalline and vuggy quartz up to 8 cm in diameter, embedded in a carbonate matrix. These quartz fragments tend to be matrix supported and do not appear to carry any sulphides. The carbonate cement is often rhythmically banded and associated with colliform layered, dark-coloured sphalerite, together with fine galena, chalcopyrite and pyrite. In parts the carbonate material is also extensively brecciated and recemented, indicating the vein suffered repeated fault movements. Trace element analyses on samples collected from the tailings dump are shown in Table 3; these show the zinc-lead-copper mineralization is associated with anomalous amounts of antimony, bismuth, silver and mercury; the latter reaching concentrations of up to 17 ppm.

The complex brecciated textures in the veins suggest that the following sequence of deformation and mineralization occurred:

(1) Early northeast-trending, brittle faulting in the andesites produced subvertical, open fractures.

(2) Deposition of banded, crustiform, vuggy, possibly epithermal quartz, which was possibly associated with the mercury, bismuth and antimony.

(3) A second period of faulting causing brecciation of quartz vein.

(4) The introduction of the carbonate matrix, together with the lead, zinc, silver and copper mineralization.

(5) A third period of faulting causing rebrecciation of the quartz and fracturing of the carbonate matrix.

TABLE 3
TRACE ELEMENT ANALYTICAL RESULTS OF MINERALIZED GRAB SAMPLES, PROVIDENCE MINE TAILINGS DUMP, HARRISON LAKE

Sample No.	28084	28085	28086	28087
Au	0.7	<0.3	<0.3	<0.7
Ag	30	<10	86	23
Cu	0.1%	115	0.55%	160
Pb	0.36%	255	0.7%	590
Zn	2.04%	910	2.6%	0.37%
Co	6	16	5	7
Mo	<3	3	<3	4
NI	6	16	10	12
Sb	38	23	43	95
BI	15	<5	7	7
As	570	740	320	300
Hg	17	2	13	9

All values (including Hg) in ppm except where recorded in per cent

DAY 1 - AFTERNOON
RN MINE (GEO)

G.E. Ray and D.R. MacQuarrie

INTRODUCTION

The RN mine property is situated approximately 4 km northeast of Harrison Hot Springs (Fig. 2). The gold is hosted in quartz veins and stringers that cut two small diorite-quartz diorite plutons; the plutons intrude hornfelsed, deformed slaty pelitic metasedimentary rocks (Fig. 7). In the late 1970's, a 50-m adit was driven and a 37-tonne bulk sample averaged 31 grams gold per tonne (B.C. Mineral Inventory File 92H/SW-92). In 1983 the property was re-evaluated by Abo Oil Corporation who reported a 1100-tonne test bulk sample averaging 45 grams gold per tonne (Huber, 1983). A drilling program was completed in 1983 and 1984 with encouraging results; for example, hole 83-23 (Fig. 7) intersected a 22-m section averaging 4.7 grams gold per tonne, while hole 84-29 intersected 40 m averaging 4.6 grams gold per tonne. An option agreement to work the property has recently been signed with Kerr Addison Mines Ltd.

GEOLOGY

The geology of the RN mine area is shown on Figure 7; the area is largely underlain by deformed metapelites that belong to

either the Pennsylvanian to Permian Chilliwack Group, or to the Middle Jurassic Mysterious Creek Formation. These rocks are intruded by several small plutons ranging from gabbro to quartz diorite in composition and the gold is hosted in quartz veins and stringers that are developed within the diorite-quartz diorite bodies; the veins rapidly die out in the metapelites. The quartz veins form two differently orientated sets, one being subvertically inclined, while the other is gently dipping to sub-horizontal. The veins, which reach a maximum width of 0.3 m, generally have sharp contacts with the quartz-diorites and can exhibit weakly sheared margins with slickensiding. They contain both masses and disseminations of pyrrhotite with lesser amounts of pyrite; the latter locally forms coarse cubes. The pyrite distribution is patchy; it appears to be a late mineral as it is associated with late crystalline quartz. Rare chalcopyrite and molybdenite are present and some veins contain traces of scheelite and bismuth telluride. Visible free gold is best seen in the drill core.

Sericite is also commonly found in the veins, mostly being concentrated toward the margins and occasionally forming thin seams that separate the veins from the diorite. Some quartz crystals in the veins also include small blebs of calcite, while the biotite-hornblende quartz diorite is altered and contains finely disseminated pyrrhotite and pyrite some considerable distance from the vein contacts. Analyses (Table 4) indicate that some of the sulphide-rich, gold-bearing quartz veins contain weakly anomalous amounts of copper and molybdenum. However, in contrast to the mineralization at Providence mine and Doctors Point, there is no enrichment in mercury and only sporadic and weak enrichment in antimony and bismuth.

The sericite in the veins gives a K/Ar age of 24.5±1 Ma which is accepted as the age of the gold mineralization. This date coincides with a preliminary K/Ar age of 25 Ma (J. Harakal, pers. comm., 1984) obtained from a diorite pluton at Doctors Point. Thus, a synchronous plutonic and gold mineralizing event probably took place along the Harrison Lake fracture system in Late Oligocene-Early Miocene times. This event is coeval with some ages obtained from both the Mount Barr and Chilliwack batholiths (Richards and White, 1970), which lie along a projected southeasterly extension of the Harrison Lake fracture system.

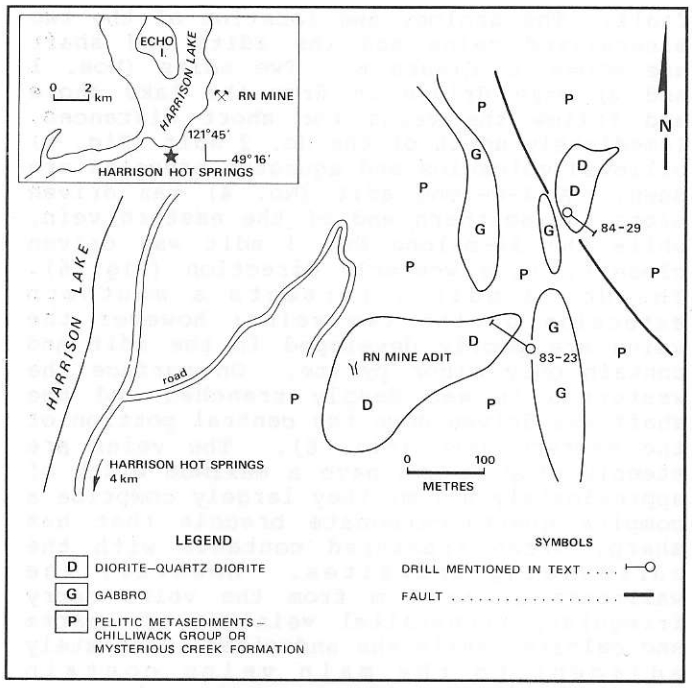


Figure 7. Geology of the RN mine vicinity, Harrison Lake.

GENERAL CONCLUSIONS ON THE HARRISON LAKE MINERALIZATION

(1) Gold mineralization along the Harrison Lake fracture system (Fig. 2) is hosted in rocks of various ages and lithologies, but all precious metal occurrences discovered to date represent vein-type mineralization.

(2) Gold throughout the region is always associated with varying amounts of sulphides, of which pyrite and chalcopyrite are the most widespread. Sphalerite and galena are found at the Providence mine; arsenopyrite is abundant at Doctors Point, rare at the RN property, and absent at the Providence mine.

(3) Mercury, antimony and bismuth are associated with the Providence mine and Doctors Point mineralization, but are generally absent at the RN mine.

(4) At two widely separated properties (Doctors Point and the RN mine) the gold mineralization is associated with a 25 Ma episode of diorite-quartz diorite plutonism.

(5) The Harrison Lake fracture system is associated with many favourable geological and geochemical factors indicating it represents a good regional exploration target for both vein-type and Carlin-type epithermal gold mineralization.

(6) There are some geological indications (Ray and Coombes, 1985) that the Gambier Group (?) rocks at Doctors Point and the Fire Lake Group at Fire Mountain warrant exploration for massive sulphide mineralization.

TABLE 4
TRACE ELEMENT ANALYTICAL RESULTS OF MINERALIZED QUARTZ VEINS, RN MINE, HARRISON LAKE

Sample No.	28088	28089	28436	28439
Au	1.4	4.3	4.8	190
Ag	<10	<10	5	68
Cu	690	240	44	185
Pb	10	3	4	59
Zn	21	16	13	7
Co	19	31	39	89
Mo	<3	6	<3	<3
Ni	15	8	<1	1
Sb	<3	<3	<10	23
Bi	NA	NA	4	91
As	<5	<5	61	5
Hg	<15 ppb	<15 ppb	NA	NA

BIBLIOGRAPHY OF HARRISON LAKE AREA

Anderson, E.M. and Jeffreys, H. (1936): The Dynamics of the Formation of Cone-sheets, Ring-dykes and Caldron-subsidence, Roy. Soc. Edinburgh, Proc., Vol. 56, No. 2, pp. 128-163.

Armstrong, J.E. (1953): Vancouver North Map-area, British Columbia, Geol. Surv., Canada, Paper 53-28

Barr, D.A. (1980): Gold in the Canadian Cordillera, C.I.M., Bull., Vol. 73, No. 818, pp. 59-76

Crickmay, C.H. (1925): The Geology of the Harrison Lake District, unpub. Ph.D. thesis, Standford Univ., Ohio, California.

Ditson, G.M. (1978): Metallogeny of the Vancouver-Hope Area, British columbia, unpub. M.Sc. thesis, Univ. of British Columbia.

Huber, D. (1983): Prosperity Looming for ABO with Alberta Oil and Gold at Harrison, British Columbia, Prospector, May-June, 1983, pp. 13-15.

Littlejohn, A.L. (1983): Report on Petrography and Mineralogy at Harrison Lake Property, unpub. rept. for Rhyolite Resources Inc., by Vancouver Petrographics Ltd.

Monger, J.W.H. (1966): The Stratigraphy and Structure of the Type Area of the Chilliwack Group, Southwestern British Columbia, unpub. Ph.D. thesis, Univ. of British Columbia.

.....(1970): Hope Map-area, West Half (92H W1/2), British Columbia, Geol. Surv., Canada, Paper 69-47, 75 pp.

Payne, J.G., Bratt, J.A. and Stone, B.G. (1980): Deformed Mesozoic Volcanogenic Cu-Zn Sulphide Deposits in the Britannia District, British Columbia, Econ. Geol., vol. 75, pp. 700-721.

Ray, G.E. (1983): The Nagy Gold Occurrences, Doctors Point, Harrison Lake (92H/12W), B.C. Ministry of Energy, Mines & Pet. Res., Geological Fieldwork, 1982, Paper 1983-1, pp. 55-61.

Ray, G.E., Coombes, S. and White, G. (1984): Harrison Lake Project (92H/5, 12; 92G/9), B.C. Ministry of Energy, Mines & Pet. Res., Geological Fieldwork, 1983, Paper 1984-1, pp. 42-53.

Ray, G.E. and Coombes, S. (1985): Harrison Lake Project (92H/5, 12; 92G/9, 16), B.C. Ministry of Energy, Mines & Pet. Res., Geological Fieldwork and Current Research, 1985, Paper 1985-1.

Richards, T.A. and White, W.H. (1970): K/Ar Ages of Plutonic Rocks between Hope, British Columbia and the 49th Parallel, Cdn. Jour. Earth Sci., Vol. 7, pp. 1203-1207.

Roddick, J.A. (1965): Vancouver North, Coquitlam, and Pitt Lake Map-areas, British Columbia, Geol. Surv., Canada, Mem. 335.

DAY 2 - MORNING
CAROLIN GOLD MINE

G.E. Ray, R.J.E. Niels and J.T. Shearer

INTRODUCTION

Carolin gold mine lies approximately 20 km northeast of Hope, British Columbia (Fig. 1), being situated in the headwater valley of Ladner Creek, a tributary of the Coquihalla River. Access from Hope is via a 23-km-long gravel road passing northeastward along the disused Coquihalla Railway route and then a northerly turnoff up a steep, 6-km-long gravel road to the mine. The road journey from Hope to the mine takes approximately 45 minutes.

The mine started regular production in 1982 and comprised a 1.5 million-tonne ore zone grading 4.8 grams gold per tonne (at a cutoff grade of 2.7 grams gold per tonne). The mineralization is hosted in Jurassic metasediments of the Ladner Group, close to both their unconformable contact with older greenstones of the Spider Peak Formation and their faulted contact with ultramafic rocks of the Coquihalla serpentine belt (Fig. 8). This trip should include an examination of the varied surface geology. We will also look at the mineralized surface exposure of the Carolin mine deposit (Idaho zone) whose original discovery resulted in the current mine development.

MINING HISTORY IN THE COQUIHALLA BELT

By the early part of this century, numerous gold-bearing quartz veins had been discovered in rocks adjacent to the eastern edge of the Coquihalla serpentine belt. The location of these occurrences and deposits comprising the Coquihalla gold belt are shown on Figure 9. The early discoveries led to erratic production from four deposits: the Ward, Pipestem, Emancipation and Aurum. All four properties are now closed and the mineralization and geology at these sites have been described by Cairnes (1924, 1929). The reported production from these four properties and Carolin mine are shown in Table 5.

The Ward, situated on Siwash Creek approximately 10 km north-northwest of Carolin mine (Fig. 9), was worked in 1905 and 1911 (Table 5). The mineralized quartz veins were hosted in felsic sills that intrude the Ladner Group; the gold is associated with pyrite, chalcopyrite, traces of galena and rare globules of mercury (Bateman, 1911).

The Emancipation mine, located 2.5 km southeast of Carolin mine (Figs. 9 and 10), was originally staked in 1913, with production occurring from 1916 to 1941 (Table 5). Mineralization at Emancipation was in quartz veins cutting sheared and altered volcanic greenstones close to their faulted contact with serpentinites. The gold-bearing quartz veins contained silver, pyrite, arsenopyrite, pyrrhotite, chalcopyrite and calcite.

In 1926-1927, the Aurum deposit was discovered approximately 450 m south of the present Carolin mine orebody (Fig. 10). Spectacular values of free gold, hosted in a talcose shear, were found within the East Hozameen fault, which is a major fracture marking the eastern margin of the Coquihalla serpentine belt (Figs. 10 and 11). At Aurum, gold was associated with pyrrhotite, pyrite, chalcopyrite, arsenopyrite and possibly millerite (Cairnes, 1929).

The Pipestem deposit, situated 3 km northwest of Carolin mine (Fig. 9 and 10), was staked in 1922, but was mainly explored and worked in the mid to late 1930's. Extensive underground workings were driven on four levels and a mill was constructed*. Only 8.4 kg of gold were reportedly produced (Table 5); however, the size and grade of some stopes at Pipestem mine suggests that the statistics in the B.C. Mineral Inventory file are incorrect and that considerably more gold was produced. Mineralization is hosted in veins of quartz breccia that cut fractured sedimentary wackes belonging to the Late Jurassic Dewdney Creek Group (Ray, 1984). The gold and silver is associated with pyrite and arsenopyrite.

The Carolin mine claims (originally called the 'Idaho claims') were first staked in 1915 and the surface exposures of the Idaho zone, the gold deposit which comprises the current Carolin mine operation, were initially described by Cairnes (1929). In 1945 and 1946, nine shallow diamond-drill holes were collared in the Idaho zone resulting in mineralized intersections averaging 5.4 m width grading 5.8 grams gold per tonne. In 1966, 2400 m of trenching was completed by Summit Mining Ltd.; this work extended the mineralized zone for a strike length of 75 m. Following an increase in gold prices, Carolin Mines Ltd. conducted a major exploration and drilling program on the property in 1973. By the end of 1974, the mining potential of the Idaho zone was realized and in 1975 a similar gold-bearing zone of considerable economic potential, the McMaster zone (Fig. 10), was discovered 2 km north-northwest of the Idaho zone. A bulk sampling decline into the Idaho zone was

* Due to the initiative of J.W.T. Shearer, assisted by Carolin Mines Ltd., the original Pipestem mine mill has been moved to Hope and renovated; it can now be seen at the Hope Mining Museum.

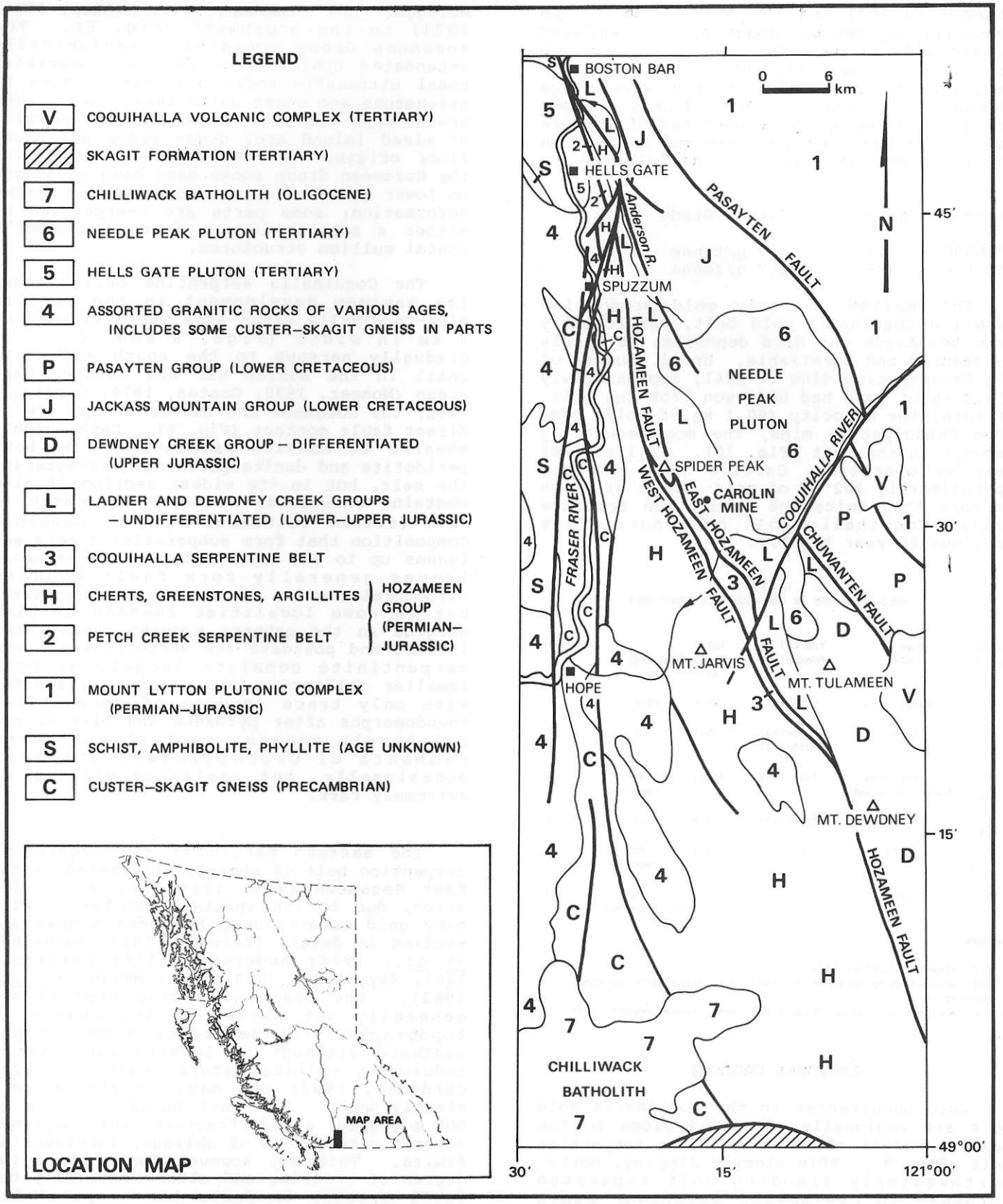


Figure 8. Regional geology of the Hope-Boston Bar-Coquihalla River area. (Adapted after Monger, 1970 and Ray, 1983, 1984)

started in 1977 and the mill, with a 1360 tonne-per-day design capacity, was completed by the end of 1981; the first dory bar was poured on February 11, 1982. The mining is generally by long-hole stoping with rings placed 1.5 m apart. Other mining methods are used in the narrower portions of the ore zone. The outlined ore reserves in 1982 on the Idaho zone were reported as follows:

Tonnes	g/tonne	Cutoff Grade
2000000	4.3	1.7 g/tonne
1500000	4.8	2.7 g/tonne

Information on early gold production from the Coquihalla gold belt, particularly from the Aurum and Ward deposits, is poorly documented and unreliable. Until closure of the Emancipation mine in 1941, approximately 119.0 kg of gold had been won from the belt. Of this, the majority (90.1 kg of gold) came from Emancipation mine, the most southerly deposit in the belt (Fig. 10). In its first year of operation, Carolin mine produced approximately 262 kg of gold (Table 5) which is more than twice the amount won from the entire Coquihalla gold belt during its previous 80-year history.

TABLE 5
GOLD PRODUCERS IN THE COQUIHALLA GOLD BELT

No. on Fig. 1	Name of Mine	Year(s) of Production	Total Production (kg) Au	Ag	Sources
1	Emancipation	1916-1941	90.1	18.8	1
2	Aurum	1930-1932, 1939-1942	16.5	3.0	1
3	Idaho zone (Carolin mine)	1981-1982	253.2	Not reported	2
4	Pipestem	1935-1937	8.4	1.1	1
5	Ward	1905	4.2	Not reported	1
5	Ward	1911	Not reported	Not reported	3

Sources

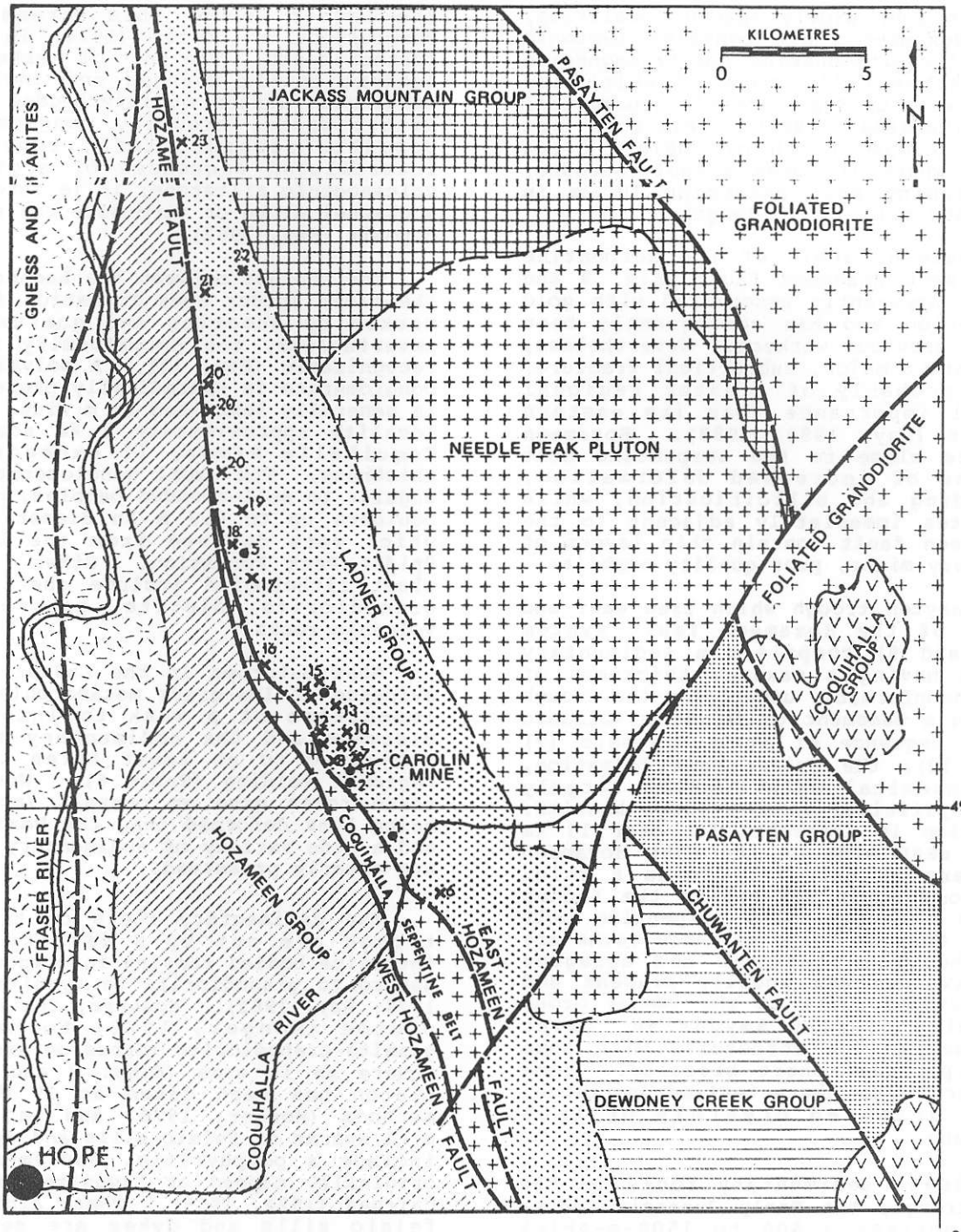
1 B.C. Mineral Inventory File
2 Gold shipped up to December 31, 1982; P.W. Richardson, personal communication
3 B.C. Ministry of Energy, Mines & Pet. Res., Annual Report, 1917

REGIONAL GEOLOGY

Gold occurrences in the Coquihalla gold belt are regionally clustered close to the eastern margin of the Coquihalla serpentine belt (Fig. 9). This steeply dipping, north-northwesterly trending unit separates Jurassic to Cretaceous successor basin deposits of the Pasayten trough (Coates, 1970, 1974) to the northeast, from Permian to Jurassic oceanic supracrustals of the Hozameen Group (Daly, 1912; Cairnes, 1924; McTaggart and Thompson, 1967; Monger, 1970, 1975) to the southwest (Fig. 8). The Hozameen Group contains a tectonically attenuated ophiolite succession comprising basal ultramafic rocks overlain in turn by greenstone and chert units (Ray, 1984). The greenstones represent calc-alkaline basalts of mixed island arc, ocean ridge and ocean floor origin. In the Carolin mine region the Hozameen Group rocks have been subjected to lower greenschist metamorphism and strong deformation; some parts are overprinted by either a schistosity or intense, subhorizontal mullion structures.

The Coquihalla serpentine belt reaches its maximum development in the Carolin mine-Coquihalla River area where it exceeds 2 km in width (Figs. 8 and 10). It gradually narrows to the south and north until in the Boston Bar and Manning Park areas (Monger, 1970; Coates, 1974; Cardinal, 1982) the Hozameen and Ladner Groups are in direct fault contact (Fig. 8). Dark, highly sheared to massive serpentinite of both peridotite and dunite parentage characterize the belt, but in its widest section it also contains substantial amounts of coarse to fine-grained intrusive rock of gabbroic composition that form subparallel sheets and lenses up to 250 m in width. The gabbroic lenses generally form fault-bounded structural boudins within the serpentinite, but in some localities remnant chilled margins in the gabbros suggest these rocks intrude and postdate the serpentinite. The serpentinite consists largely of both lamellar antigorite and massive lizardite, with only trace amounts of chrysotile. Pseudomorphs after pyroxene and olivine are relatively common; partially altered remnants of orthopyroxene are seen occasionally, but unaltered olivine is extremely rare.

The eastern margin of the Coquihalla serpentine belt is sharply delineated by the East Hozameen fault (Figs. 8, 9 and 10) which, due to its spatial association with 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 generally not marked by any change in topography. It generally dips steeply eastward although it locally exhibits an undulating rolling nature (Cairnes, 1929; Cardinal, 1982) and may, in places, dip steeply west. The East Hozameen fault is not a single, simple fracture, but comprises several generations of oblique, intersecting faults. This may account for the varying degree of shearing and alteration along the fault system; in parts the serpentinite contact is sharp and fresh, whilst elsewhere a different fault generation is occupied by a zone of highly sheared talc several metres in width (Cairnes, 1929; Cardinal, 1982).



PAST OR PRESENT GOLD PRODUCER . . . . . ● REPORTED GOLD OCCURRENCE X

1 = EMANCIPATION
2 = AURUM
3 = IDAHO ZONE (CAROLIN MINE)
4 = PIPESTEM
5 = WARD
6 = BROKEN HILL
7 = SNOWSTORM
8 = MONTANA
9 = RUSH OF THE BULL
10 = GOLDEN CACHE
11 = McMASTER ZONE
12 = MURPHY
13 = GEM
14 = STAR
15 = HOME X
16 = NORM AND GEORGIA 2
17 = EMIGRANT
18 = RODDICK
19 = MARVEL
20 = SPUZ A, B, G AND MONUMENT
21 = MAJESTIC
22 = GOLD COIN
23 = GOLD CORD

Figure 9. Regional setting of the Coquihalla gold belt. (Geology adapted after Monger, 1970).

In at least four widely spaced localities, the East Hozameen fault contains tectonic slices of fuchsite-bearing quartz-magnesite rock ('listwanite'), some of which are associated with gold and arsenic geochemical anomalies (Cardinal, 1982). This rock type is well developed north of Qualark Creek (Fig. 10), where it forms a fault-bounded, steeply dipping unit exceeding 100 m in width and 600 m in strike length.

The western margin of the serpentine belt, the West Hozameen fault (Fig. 9 and 10) is not apparently associated with gold mineralization and has consequently been ignored by previous workers. Nevertheless, it represents a major, subvertical fracture, which is probably of greater regional structural importance than its eastern counterpart (Ray, 1982, 1983). Hozameen Group rocks close to the serpentine belt show signs of increased deformation, slickensiding and silicification, while serpentinites immediately adjacent to the West Hozameen fault contain thin layers of talc and very minor, poor quality nephrite.

The Pasayten trough which lies east and northeast of the Hozameen fault system (Figs. 8 and 9) comprises a sedimentary succession having a maximum thickness of 9000 m. Unconformably underlying the trough and forming a basement to it, is a volcanic greenstone sequence of Early Triassic (?) age (Fig. 10), the Spider Peak Formation, which geochemical data suggest largely represent spilitized oceanic ridge basalts. The formation is traceable for over 15 km along the east side of the East Hozameen fault, where it generally forms a thin, discontinuous strip separating the Ladner Group from the Coquihalla serpentine belt (Fig 10). Most of these volcanic rocks are massive, but both tectonic and aquagene breccia textures are locally present and some greenstones close to the Ladner Group unconformity display amygdales, faint layering and pillow structures with some rare interpillowed chert breccias. Some outcrops are also characterized by large, randomly oriented crystals of late stilpnomelane.

The oldest sedimentary rocks in the Pasayten trough, the Early Jurassic Ladner Group, comprises a 600 to 1500-m-thick succession of slaty argillites and siltstones, with lesser amounts of wacke, lithic wacke and conglomerate (Fig. 13). The Ladner Group contains a locally developed coarsely clastic lower unit that hosts many of the gold occurrences in the Coquihalla gold belt, including the Carolin mine orebody. This lower unit is best developed in the Carolin mine vicinity where it exceeds 200 m in thickness, but to the north and south it rapidly thins and dies out. Overturned flame structures in some basal wackes near Carolin mine indicate an easterly derivation for the lower unit of the Ladner Group; this agrees with the conclusions of Coates (1974) in his study further south. The unit is marked by rapid lateral facies changes and includes discontinuous wedges of interbedded greywacke, lithic wacke, breccia, conglomerate and possible reworked tuff, together with intercalated sequences of argillite and volcanogenic siltstone; it is interpreted as a channel slope or turbidite fan sedimentary deposit (Ray, 1982).

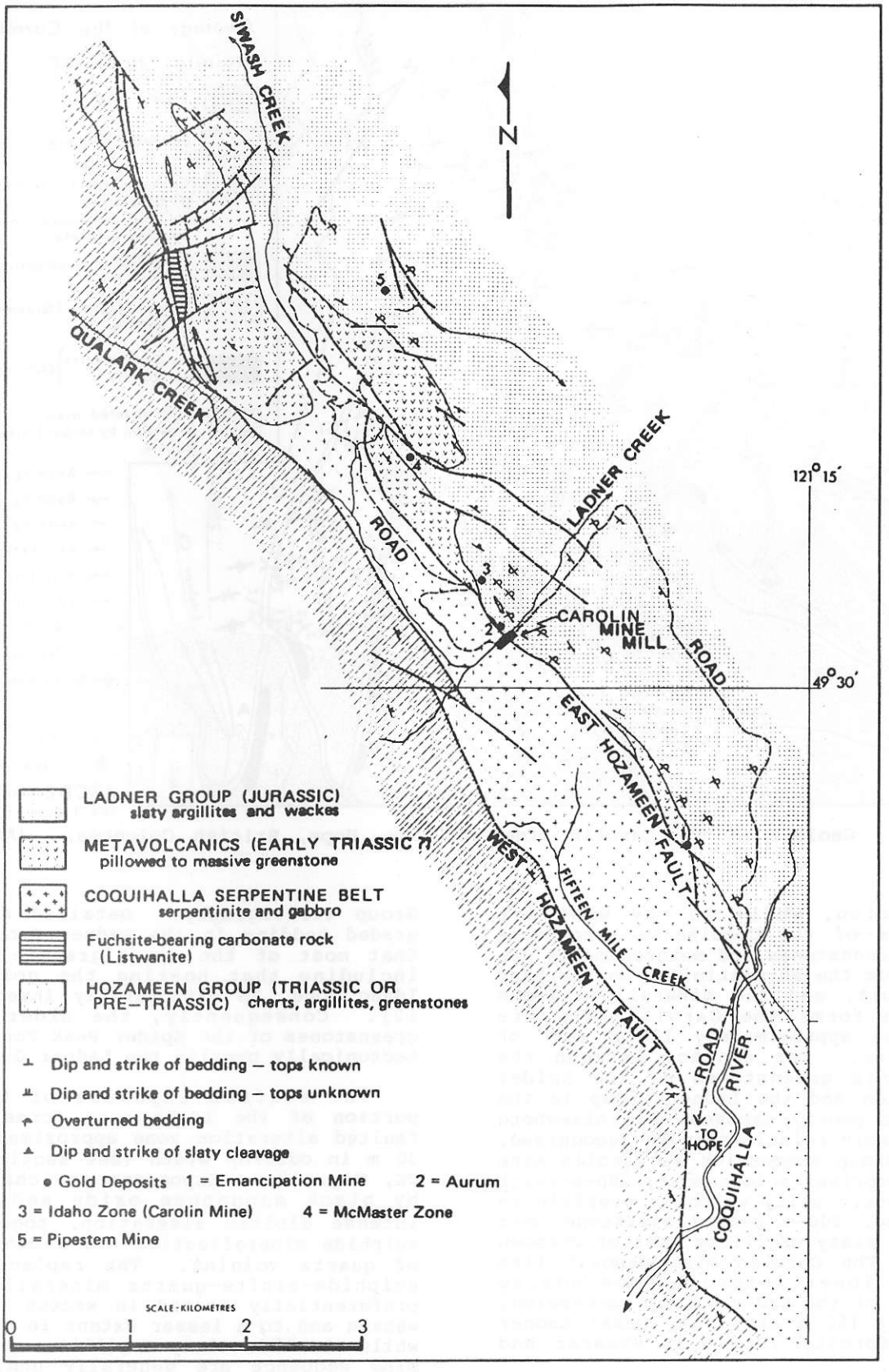
The contact between the Ladner Group and the older Spider Peak Formation is commonly marked by shearing and quartz veining; nevertheless, the unconformity is locally recognizable (Fig. 13). A polymictic basal conglomerate is sporadically preserved; this is generally less than 10 m wide, but at one locality approximately 3 km south of the Coquihalla River, it exceeds 70 m in thickness. The basal conglomerate contains angular to well-rounded pebbles, cobbles and boulders up to 0.3 m in diameter, most of which were derived from the underlying Spider Peak Formation. Other less common clast lithologies include chert, granite, granodiorite, diorite, gabbro and acid volcanic rocks.

Most outcrops in the Ladner Group show evidence of low-grade metamorphism with the imposition of a weak to intense slaty cleavage and the sedimentary rocks were subjected to at least three periods of regional folding (Table 6). Nevertheless, these rocks give an overall impression of being less deformed than the Hozameen Group and a wide variety of sedimentary structures are clearly preserved.

The sedimentary rocks of the Pasayten trough are cut by a variety of small intrusive bodies ranging in composition from gabbro to granodiorite to syenite (Cairnes, 1924; Ray, 1982). However, the Needle Peak pluton (Monger, 1970) forms a major granite-granodiorite intrusion exceeding 200 square km in area (Figs. 8 and 9). This pluton has been dated at 39 Ma by K/Ar methods (Monger, 1970) and is associated with swarms of felsic sills and dykes; these include a porphyritic, sodium-rich phase originally mapped as 'syenite porphyry' by Cairnes (1924, 1929). These albite-bearing felsic sills and dykes are seen in the Carolin mine vicinity and are common within the Ladner Group, but are not present in rocks west of the Hozameen fault.

GEOLOGY OF THE CAROLIN MINE AREA

The surface geology around Carolin mine is shown on Figure 11 and detailed surface cross-sections over the orebody are seen on Figure 12. To the east, the area includes Lower Jurassic metasediments of the Ladner Group and massive to pillowed volcanic greenstones of the Early Triassic (?) Spider



10. Regional geology of the Carolin-Emancipation mines area. (After Ray, 1983).

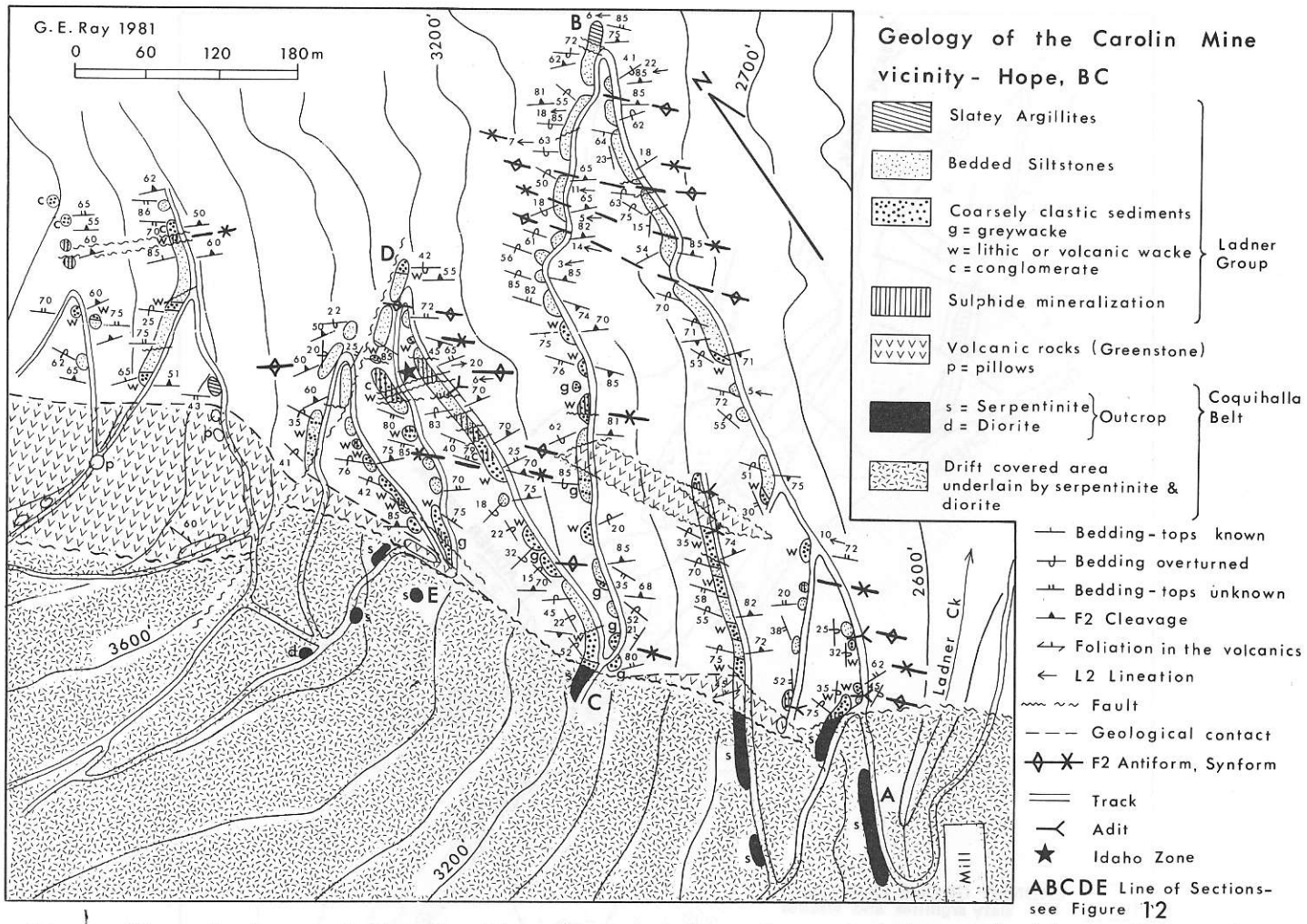


Figure 11. Geology of the Carolin mine vicinity, Hope, British Columbia. (After Ray, 1982).

Peak Formation, while to the west are serpentinites of the Coquihalla serpentine belt. The greenstones and metasediments are separated from the serpentinites by the East Hozameen fault, and the mineralized Idaho zone, which forms the Carolin mine ore deposit, lies approximately 150 m east of this fracture. The contact between the older volcanic greenstones of the Spider Peak Formation and the Ladner Group in the mine area is poorly exposed, but elsewhere an unconformable relationship is recognized. The Ladner Group succession at Carolin mine (Fig. 13) comprises a lowermost, 200-m-thick coarsely clastic unit, which is overlain in turn by a ca. 200-m bedded siltstone unit and an upper slaty argillite unit of unknown thickness. The Carolin mine deposit lies within the lower heterogeneous coarse clastic unit of the Ladner Group succession, approximately 150 m above the basal Ladner Group unconformity (Fig. 13; Shearer and Niels, 1983).

The East Hozameen fault dips steeply northeast and sharply crosscuts the Ladner Group stratigraphy. Detailed mapping of graded bedding in the Ladner Group reveals that most of the stratigraphic sequence, including that hosting the gold-bearing Idaho zone, is structurally inverted (Fig. 12). Consequently, the older volcanic greenstones of the Spider Peak Formation now tectonically overlie the Ladner Group.

The surface exposure of the upper portion of the Idaho zone forms a highly faulted alteration zone approximately 25 to 30 m in outcrop width (see sections CD and DE, Fig. 12). Exposures are characterized by black manganese oxide and rusting, intense albitic alteration, together with sulphide mineralization and a dense network of quartz veining. The replacement-type sulphide-albite-quartz mineralization is preferentially hosted in wackes and lithic wackes and to a lesser extent in siltstones, while the thin slaty argillite units in the mine sequence are generally unmineralized (Ray et al., 1983).

While the Idaho zone forms the largest

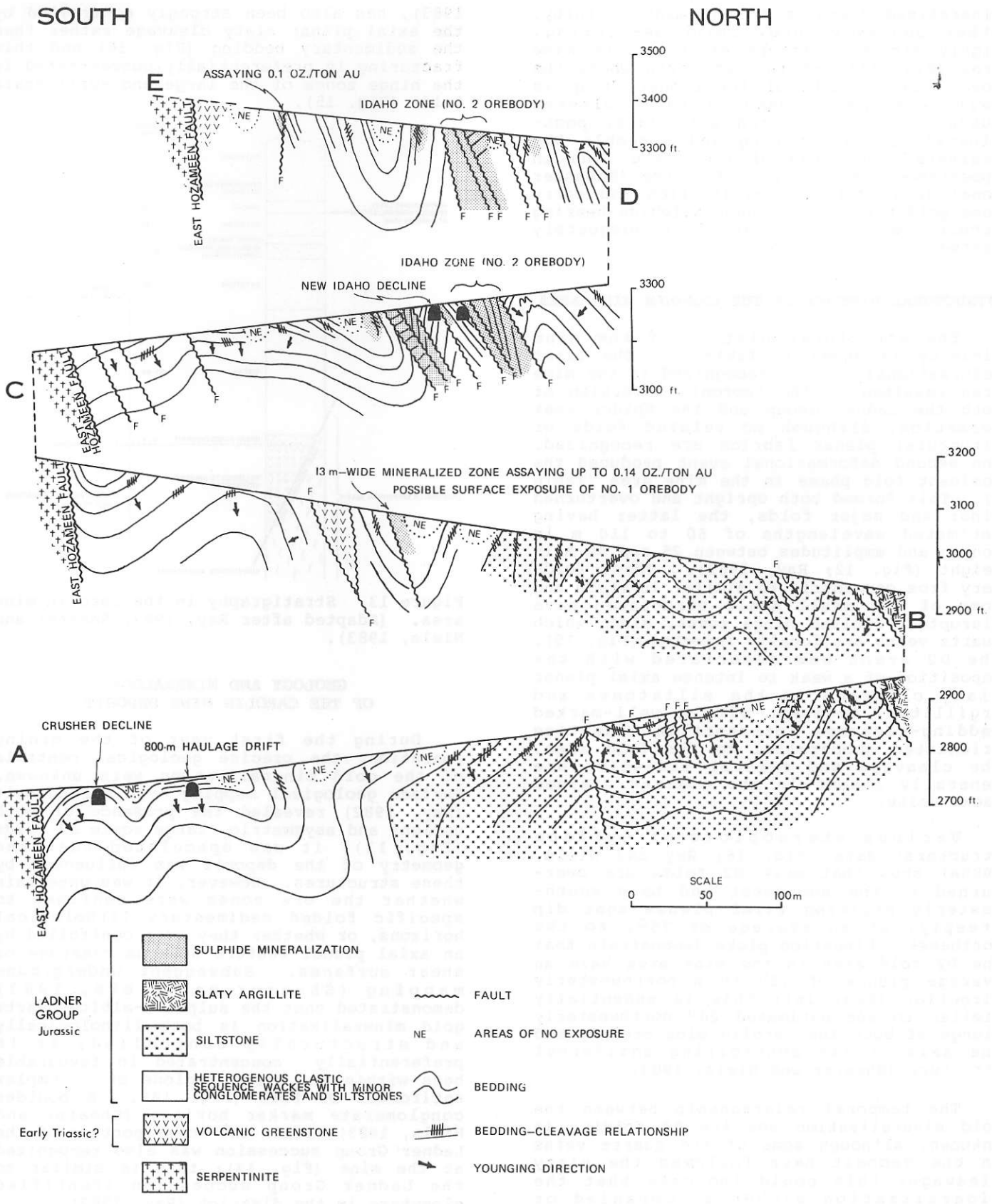


Figure 12. Geological sections across the Carolin mine area. (After Ray 1982).

mineralized exposure in the mine vicinity, other quartz-veined, sulphide-bearing, highly altered outcrops exist in the mine area (Fig. 11) and further north where the lower clastic unit of the Ladner Group is well developed. Many of these altered outcrops are associated with late, post-mineralization faulting and resemble the weathered exposures of the Idaho zone in appearance. A few, including the 'McMaster zone' (Fig. 10), are albite-rich and carry some gold but many of these sulphide-bearing occurrences have not yet been adequately tested.

STRUCTURAL HISTORY OF THE CAROLIN MINE AREA

The structural history of the mine vicinity is shown in Table 6. The first deformational episode recognized in the mine area resulted in the tectonic inversion of both the Ladner Group and the Spider Peak Formation, although no related folds or structural planar fabrics are recognized. The second deformational event produced the dominant fold phase in the mine area (Table 6). This formed both upright and overturned minor and major folds, the latter having estimated wavelengths of 60 to 110 m in length and amplitudes between 25 and 50 m in height (Fig. 12; Ray, 1982). These folds vary from concentric to similar in style and some of the small scale structures have disrupted, faulted hinge zones, along which quartz veins are locally injected (Fig. 15). The D2 event was associated with the imposition of a weak to intense axial planar slaty cleavage in the siltstones and argillites, together with a well-marked bedding-cleavage intersection lineation orientated subparallel to the fold axes. The cleavage and mineral lineation are generally absent in the coarser grained wacke units.

Various stereoplots of surface structural data (Fig. 16; Ray and Niels, 1985a) show that most D2 folds are overturned to the southwest and have south-easterly striking axial planes that dip steeply, at an average of 75°, to the northeast. Lineation plots demonstrate that the D2 fold axes in the mine area have an average plunge of 12° in a northwesterly direction (Fig. 16); this is essentially similar to the estimated 20° northwesterly plunge of both the Carolin mine orebody and the axis of its controlling antiformal structure (Shearer and Niels, 1983).

The temporal relationship between the gold mineralization and the D2 folding is unknown, although some of the quartz veins in the deposit have followed the slaty cleavage; this could indicate that the mineralization either accompanied or succeeded the D2 structural episode. The orientation of the later faulting, which displaces the ore zones (Shearer and Niels, 1983), has also been strongly controlled by the axial planar slaty cleavage rather than the sedimentary bedding (Fig. 16) and this fracturing is preferentially concentrated in the hinge zones of the large and small scale folds (Fig. 15).

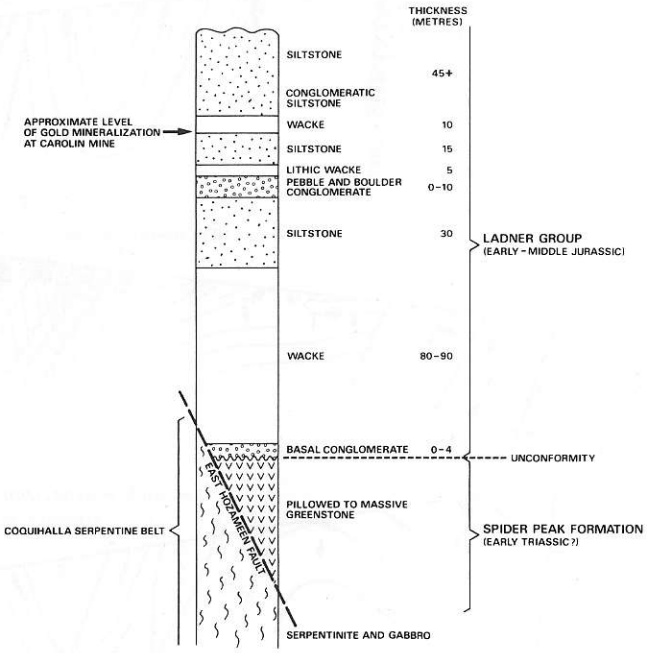


Figure 13. Stratigraphy in the Carolin mine area. (Adapted after Ray, 1982; Shearer and Niels, 1983).

GEOLOGY AND MINERALOGY OF THE CAROLIN MINE DEPOSIT

During the first year of the mining operation, the precise geological controls of the gold mineralization were unknown. Surface geological mapping over the deposit (Ray, 1982) revealed the presence of both upright and asymmetric, large scale D2 folds (Fig. 12); it was speculated that the geometry of the deposit was influenced by these structures. However, it was uncertain whether the ore zones were confined to specific folded sedimentary lithological horizons, or whether they were controlled by an axial planal feature such as cleavage or shear surfaces. Subsequent underground mapping (Shearer and Niels, 1983) demonstrated that the sulphide-albite-quartz gold mineralization is both lithologically and structurally controlled; it is preferentially concentrated in favourable beds within the hinge regions of a complex antiformal D2 fold (Fig. 14). A boulder conglomerate marker horizon (Shearer and Niels, 1983) within the lower portion of the Ladner Group succession was also recognized at the mine (Fig. 13); this is similar to the Ladner Group succession identified elsewhere in the district (Ray, 1982).

A longitudinal geological cross-section across the Carolin mine deposit at 766 North

is shown on Figure 14. The deposit plunges gently northwest, subparallel to the plunge of the D2 fold axes in the area (Fig. 16). The ore most amenable to open long hole stoping is located in the thickened regions of the fold hinge. Two well-developed ore bodies have been delineated (Shearer and Niels, 1983), an upper (No. 2) and a lower (No. 1) zones; these are separated from each other by the 'Mine fault' (Fig. 14). A third, partially outlined mineralized lens has been outlined below the lower, No. 1 zone.

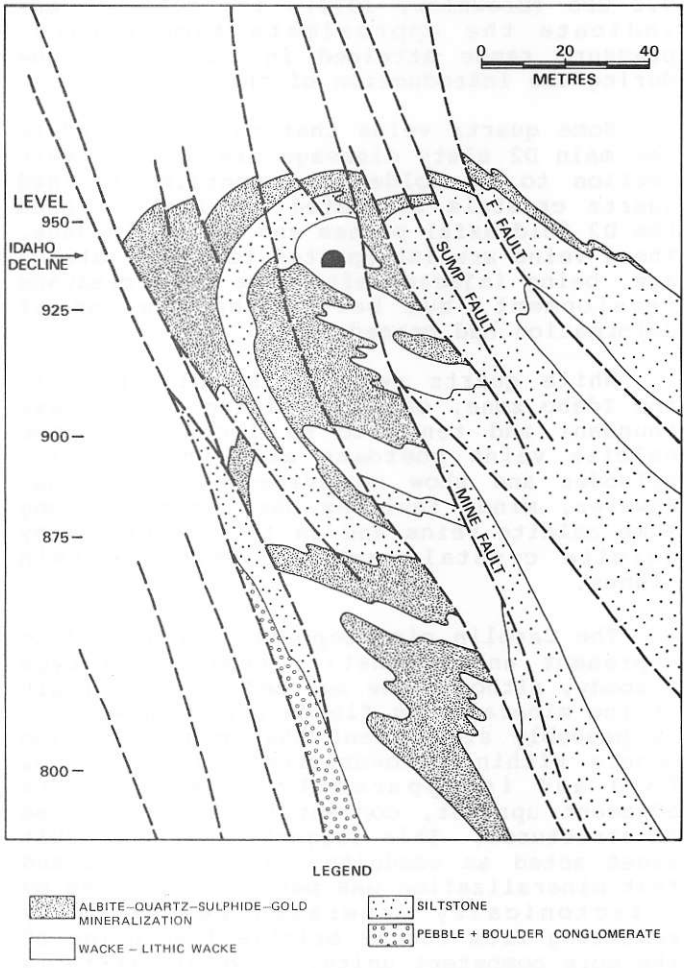


Figure 14. Carolin mine - vertical cross section at 766 North (looking north). (Adapted after Shearer and Niels 1983).

Favourable metasedimentary lithologies for gold-sulphide mineralization include wackes, lithic wackes, pebble conglomerates and siltstones, while slaty argillites are generally barren. The Mine fault, which tends to follow an incompetent unit of carbonaceous argillites, crosscuts the stratigraphy and is the most intense zone of shearing seen underground; subparallel, but less intense fractures, the 'Sump' and 'F faults' (Fig. 14) are also present. Preliminary data suggests the lower (No. 1) orebody is wider and has more ore tonnage than the upper (No. 2) orebody, but that the latter has higher grade mineralization in parts. Limited polished section studies (Shearer, 1982) indicate that the upper orebody is pyrite dominant, while the lower is pyrrhotite rich; consequently the deposit as a whole may be mineralogically zoned.

The mineralized wackes in the Idaho zone consist largely of quartz, albite-oligoclase and calcite with lesser amounts of chlorite, sericite and opaque minerals. These opaques, which make up between 1 and 15% of the rock by volume, are mainly pyrrhotite, arsenopyrite, pyrite and magnetite. Less common opaques, in decreasing abundance, include chalcopyrite, bornite and gold (Kayira, 1975). Ore specimens are characterized by coarse, subhedral crystals of pyrite and arsenopyrite with finer grained disseminations and clusters of pyrrhotite, magnetite and pyrite. The magnetite shows no spatial association with sulphides and is the oldest opaque mineral present in the ore. Arsenopyrite also appears to have been introduced early because some crystals are partly rimmed with small blebs of pyrite and pyrrhotite. The pyrrhotite in the pyrrhotite dominant sections often contain exsolution rods of pyrite; trace amounts of sphalerite are present in the ore. Small grains of gold, up to 0.02 mm in size, occur either as inclusions within pyrite and arsenopyrite or as rims on pyrite and chalcopyrite. Gold is also seen within some quartz, calcite and feldspar crystals where it forms minute grains that are apparently spatially independent of the sulphides. Visible gold, however, is generally rare throughout the Idaho zone; it is best seen as flat, thin plates and smears along fault surfaces. Rarer forms of visible gold include spongy or leaf-like masses, small scales and small rods.

Although the Idaho zone is characterized by an increase in sulphides, quartz veining and albitic alteration, not all areas containing these features are necessarily enriched in gold. For example, pyritic argillites with abundant quartz veining occur within and adjacent to the Idaho zone but these rocks contain no gold. Generally, however, the auriferous horizons are intimately and spatially associated with sulphides and quartz veining; by contrast albitization is widespread throughout the mine and produces a sodium-rich halo that extends at least 60 m from the orebody (Ray and Niels, 1985b). In thin section three generations of albitization are recognized. Disseminated and partially altered albite-oligoclase (An_{3-15}) crystals make up a significant proportion of the fine-grained ore groundmass and represents the oldest generation of albitic material. This disseminated albitic groundmass is cut by numerous thin, folded veins of poorly

twinned second generation albite. The youngest material generally forms veinlets and disseminated masses throughout the ore zone, comprising coarse, well-twinned albite crystals (An_{3-5}) up to 8 mm in length with locally deformed twin planes. In parts, small angular fragments of sulphide-rich ore are entirely engulfed in this third generation albitic material.

The complex, network quartz veining in the deposit represents many phases of quartz injection. Sigmoidal gash fracturing and the wide variation in vein deformation, from highly folded to apparently undeformed, suggests the multistage injection occurred during a period of recurrent structural deformation. The white quartz veins are generally less than 15 cm wide and at least three phases are recognized; all appear to postdate the gold-sulphide mineralization. Many veins are monomineralic but in others the quartz crystals are intergrown with

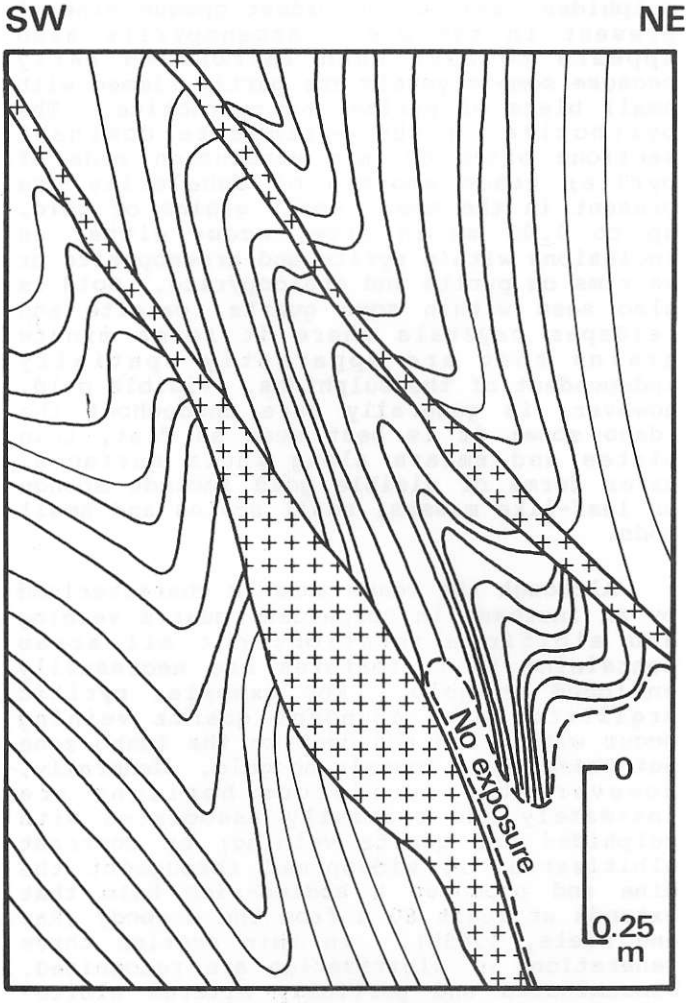


Figure 15. D2 folds in Ladner Group siltstones. Note quartz veins (cross pattern) and disrupted hinge zones. (Taken from a photograph of road outcrop 290 m ENE of old Idaho adit, Carolin mine).

variable amounts of calcite, albite and clinozoisite. In rare instances, some white quartz veins contain small flakes of pyrobitumen whose optical and physical characteristics suggest it has acquired a maturation equivalent to meta-anthracite. These pyrobitumen flakes in the quartz veins are believed to represent original amorphous carbonaceous material derived from the wallrocks, and metamorphosed during the quartz vein injection. Since meta-anthracite forms between 238° and 266° Celsius at an equivalent pressure of about 0.2 GPa (Brownlow, 1979), its presence may indicate the approximate temperature-pressure range attained in the Idaho zone during the introduction of the gold.

Some quartz veins that cut and postdate the main D2 slaty cleavage are seen in thin section to be folded and contain strained quartz crystals elongated parallel to both the D2 fold axial planes and slaty cleavage. These veins are interpreted to be of late D2 age, being injected after the main cleavage development, but before that period of deformation had ceased.

While quartz veining is ubiquitous in the Idaho zone, calcite veining is far less abundant and tends to be localized. The calcite veins postdate all other veining episodes and show no evidence of folding. However, minor faulting has occurred along some calcite veins and in thin section many calcite crystals exhibit deformed twin planes.

The Carolin mine deposit is believed to represent an epigenetic, replacement-type orebody, although the age and precise origin of the mineralizing fluids are unknown. It is probably significant that mineralization occurs within an overturned, disrupted D2 fold and is apparently absent within adjacent upright, concentric, non-disrupted D2 structures. This suggests that the fault zones acted as conduits for the fluids and that mineralization was partly controlled by a tectonically generated permeability resulting from the D2 brittle fracturing of the more competent units. However, there is conflicting evidence on whether the mineralization accompanied or postdates the D2 deformation. Some structural evidence determined from the complex quartz veining suggests that the mineralization was contemporaneous with the D2 deformation; thus the deposit would be Middle to Late Cretaceous in age. Alternatively, the mineralization at Carolin mine could be genetically and temporally related to a sodium-rich magmatic event that occurred in the district during the Tertiary. Swarms of albitic felsic sills, containing up to 8.5% Na_2O intrude the Ladner Group north and east of Carolin mine; these are probably related to the 39 Ma Needle Peak pluton (Monger, 1970) which outcrops 6 km east of the deposit (Fig. 8). Sills of this type

probably hosted the gold at the defunct Ward mine (Table 5) and if a genetic relationship between the Carolin mine mineralization and the albitic sills could be proved, it would suggest the deposit is Late Eocene in age.

TABLE 6
HISTORY OF EVENTS IN CAROLIN MINE AREA

Age	Event
	Late faulting - southeast-trending set followed by a northeast to east-northeastly striking set.
	Large scale dextral strike-slip movement along the Hozameen fault.
39 Ma	Intrusion of the Needle Peak pluton and related felsic dyke swarm.
Middle to Late Cretaceous	D3 - Asymmetric folding. Local kink folding and strain slip cleavage development.
Middle to Late Cretaceous	D2 - Major concentric to similar-type, open to tight asymmetric folding with southeast-striking axial planes and gently inclined, northwest-plunging axes. Development of regional slaty cleavage and mineral lineation.
Middle to Late Cretaceous	D1 - Easterly directed thrusting along the Hozameen fault causing local structural inversion of the Ladner Group and older volcanic greenstones.
Early Jurassic to Early Cretaceous	Deposition of the Ladner Group and other younger sedimentary rocks of the Pasayten trough.
	UUUUUU Unconformity
Early Triassic (?)	Greenstone volcanic eruption.

GEOCHEMISTRY OF THE IDAHO ZONE

Some whole rock and trace element results from mineralized and unmineralized wackes at Carolin mine are shown in Table 7. A recent geochemical study (Ray and Niels, 1985b) indicates that specific auriferous horizons at Carolin mine have complex and variable major and trace element zoning patterns in which gold is sometimes, but not always, associated with anomalous amounts of either Ag, Mo, As, or Sb. This study involved the collection of 50 core samples from two drill holes totalling 130 m in length which crosscut a portion of the deposit (Fig. 17). Four sulphide-rich, auriferous horizons are intersected in the two holes; a single 9-m-wide zone in IU-49, while IU-53 intersected a narrow upper horizon, and 11-m-thick middle unit and a narrow lower zone. These are designated auriferous zones A, B, C and D respectively (Figs. 18 to 21). Hole IU-49 passes through zone A (Fig. 17), but IU-53 only partially intersects the hinge portion of a folded orebody (zone C); thus it lies entirely within a repeated hangingwall sequence (Fig. 17). Consequently, the narrow mineralized units B and D may represent the same folded auriferous horizon, although their dissimilar geochemistry makes this unlikely.

Trace and major element geochemical plots for the two drill holes are shown on Figures 18 to 21. It must be noted that these are quantitative values and no allowance has been made for any volume changes, as described by Gresens (1967). In addition to the elements shown, analyses also were completed for Cu, Hg, P_2O_5 and SrO. While Cu was very weakly, but sporadically anomalous (up to 310 ppm Cu) in some mineralized horizons, the other three elements showed no anomalous values throughout the drill holes.

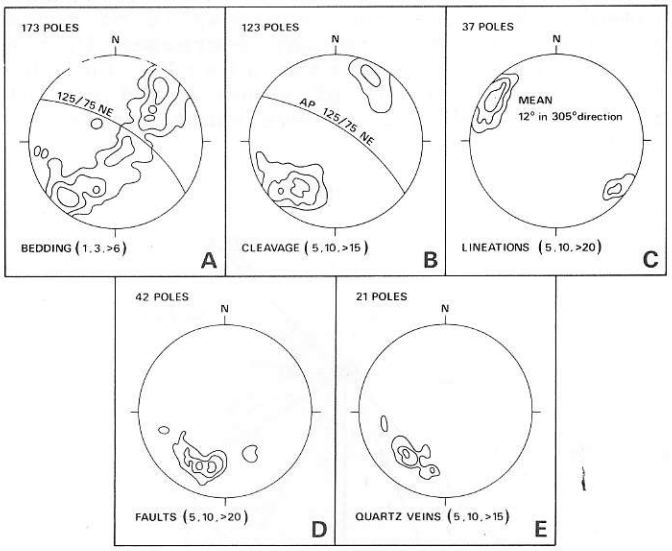


Figure 16. Ladner Group - Carolin mine (surface). Lower area equal area projection. A - poles to bedding; B - poles to slaty cleavage; C - mineral lineations; D - faults; E - quartz veins. Numbers in brackets are contour intervals in per cent.

Ore zone A contains markedly higher gold values adjacent to its footwall and hangingwall sections and a clear correlation between gold and silver is apparent (Fig. 18). Mineralization in this horizon is also associated with anomalous values of Mo, Sb and As - the latter reflecting the presence of arsenopyrite. However, these three elements are concentrated preferentially in the hangingwall of zone A, while Mo, for example, is absent in the footwall. By contrast, none of the three auriferous zones intersected in IU-53 contain anomalous quantities of Ag or Mo.

Auriferous horizons A, B and C are associated with wide barium depletion zones (Fig. 18 and 20). The barium is presumably associated with potassium feldspar, since depletion coincides with a drop in the potassium content (Fig. 19 and 21). As expected, the sulphide-rich zones in both holes are associated with a decrease in water content (H_2O+) and an increase in sulphur. Surprisingly, the total iron and titanium values drop in parts of zones A, B and C. This is particularly noticeable

adjacent to the hangingwalls of zones A and C where it reflects both the presence of arsenopyrite and the effects of dilution caused by an increase in silica and quartz veining. Silica and CaO generally correlate negatively throughout both holes; SiO_2 values increase sharply in the hangingwall portions of zones A and C, where quartz veining is abundant, but drops off in the footwall sections. These SiO_2-enriched areas lie adjacent to narrow SiO_2 depletion zones situated in the country rock immediately above the hangingwalls of zones A and C. The MgO content decreases in the ore horizons, particularly in the hangingwall sections of zones A and C, but increases immediately above these auriferous horizons.

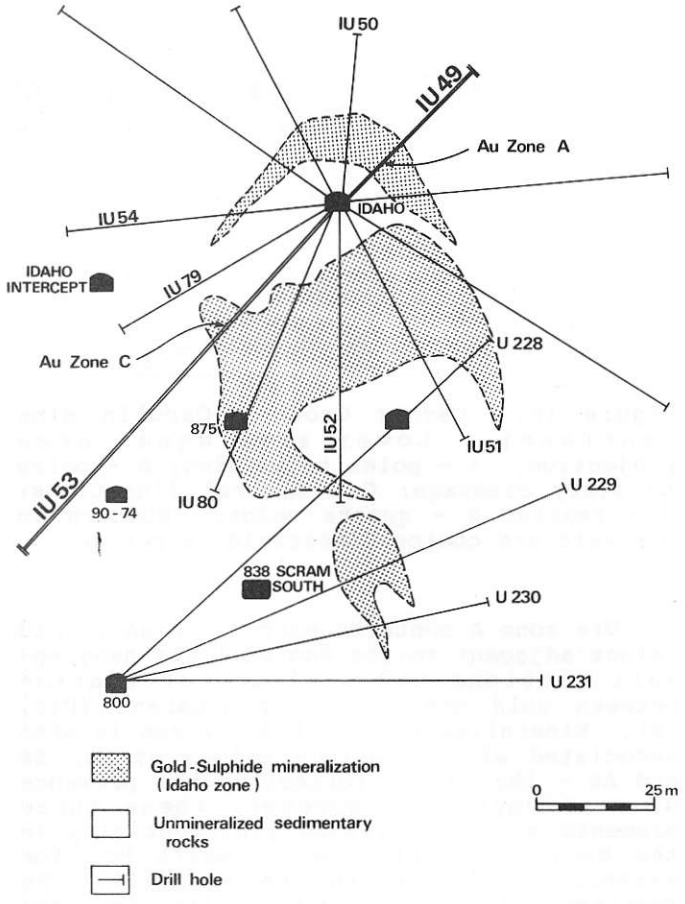


Figure 17. Longitudinal cross-section through the Idaho zone - 837 North - showing location of drill holes IU-49 and IU-53.

Compared to unmineralized Ladner Group siltstones and wackes outside the mine area, which average less than 4% Na_2O, the entire 130-m-long section of both IU-49 and IU-53 is anomalously enriched in sodium. Despite this, the relationship between mineralization and the sodium content is variable. Sodium levels rise moderately in parts of auriferous zones A and C, but drop in zones B and D. A narrow sodium depletion halo exists within and immediately above, the hangingwall portion of zones A, C and D (Figs. 19 and 21).

TABLE 7
WHOLE ROCK AND TRACE ELEMENT ANALYSES. A COMPARISON BETWEEN MINERALIZED AND UNMINERALIZED WACKES FROM THE IDAHO ZONE (CAROLIN MINE)

	25163M[1]	25164M[1]	25167M[1]	25168M[2]
SiO_2	55.20	60.62	53.11	48.92
Al_2O_3	12.64	15.42	14.51	14.05
Fe_2O_3	7.11	0.45	1.20	0.22
FeO	2.39	3.89	7.94	6.26
MgO	0.82	0.68	1.16	3.30
CaO	2.66	2.37	4.49	9.07
Na_2O	7.49	9.09	7.81	2.45
K_2O	0.05	0.09	0.30	2.84
TiO_2	0.33	1.00	1.22	0.83
MnO	0.06	0.07	0.11	0.13
CO_2	2.08	2.78	3.46	6.85
S	3.84	1.91	3.41	0.12
Au ppm	17.5	16.0	3.5	<1
Ag ppm	<10	<10	<10	<10
As	6.23	0.46	1.18	0.007
Cu ppm	89	81	161	49
Hg ppb	72	112	78	76
Sb ppm	185	13	<10	<10
Mo ppm	75	20	<2	<2
W ppm	8	19	13	<2
Cr ppm	16	24	29	22
Ba ppm	<100	<100	155	1 184
Ni ppm	14	12	18	8
Pb ppm	21	15	15	16
Sn ppm	<1	<1	<1	<1
Co ppm	19	13	20	15

In per cent except as noted

[1]Sulphide-rich wackes in Idaho zone showing albite metasomatism and abundant quartz veining

[2]Unmineralized wackes adjacent to the Idaho zone. Some quartz veining but no sulphides or albitic alteration

The relationship and distribution of elements within and adjacent to the gold-bearing zones A, B and C show many common characteristics. By contrast, the lowermost auriferous zone D is geochemically unique; it is associated with a sharp drop in SiO_2 values, despite visible quartz veining and with increases in CaO, total Fe and TiO_2 (Fig. 21). Also, this zone is not associated with either barium or potassium depletion; instead the gold mineralization is marked by an increase in these two elements (Figs. 20 and 21).

In conclusion, this geochemical study shows that the gold mineralization at Carolin mine is associated with complex element zoning and that the most dramatic element changes generally occur within and immediately above the hangingwall sections of the ore horizons. The unique geochemical character of auriferous zone D, compared to zones A, B and C, suggests that the Carolin

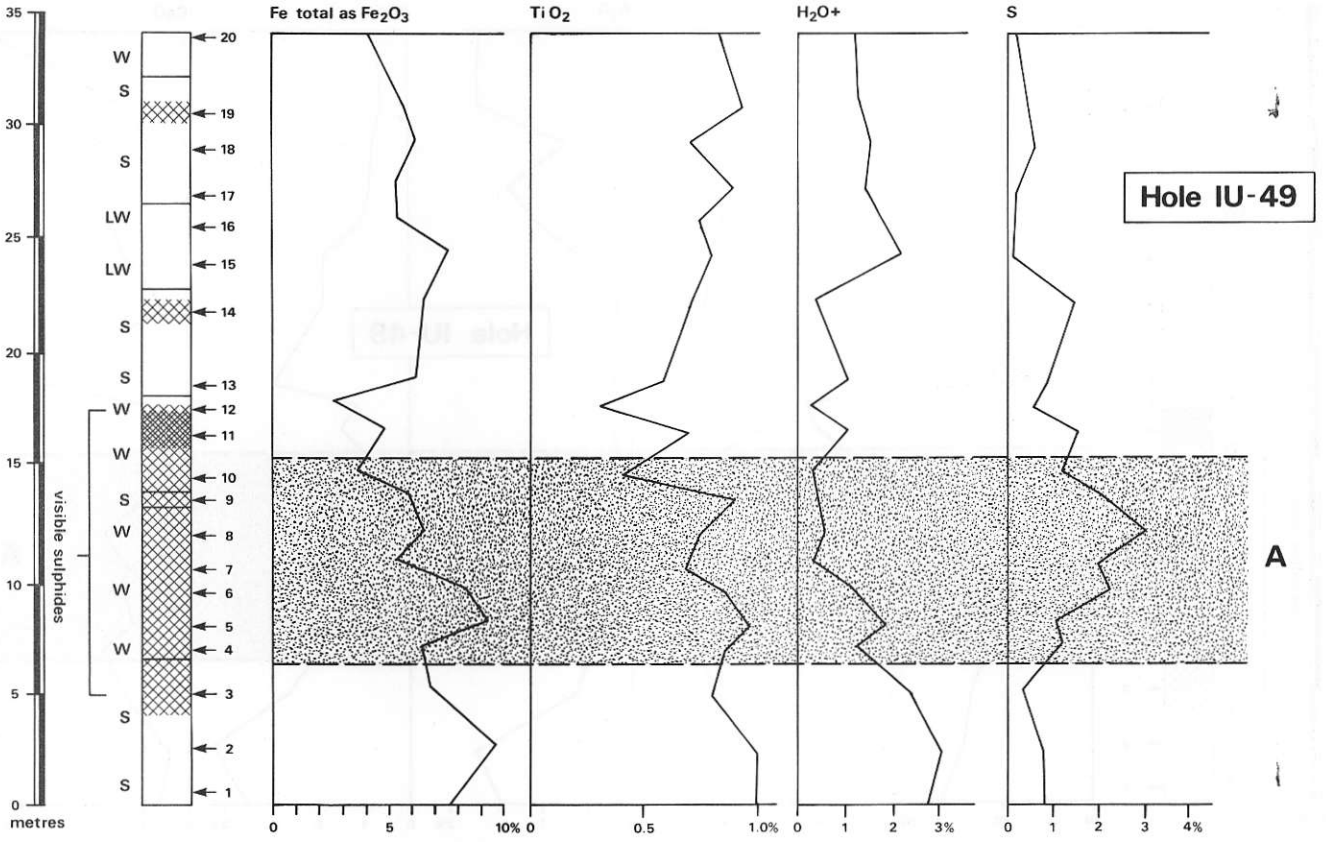


Figure 18. Geology and trace element geochemistry of hole IU-49, Carolin mine. (After Ray and Niels, 1985).

mine orebody contains two mineralogically distinct ore suites. The deposit is surrounded by a wide, sodium-enriched envelope that extends at least 60 m beyond the mineralization. The lateral extent of this envelope is unknown and a program will shortly be undertaken to establish its true dimensions. Lithogeochemical sampling to outline other areas of sodium enrichment probably represents a viable exploration tool for locating similar gold deposits in the district. Likewise, the barium and potassium depletion zones form valuable exploration drill targets since they are generally twice as wide as their associated gold-bearing horizons. Consequently, future underground drilling programs to locate extensions of the ore zones at Carolin mine will probably include routine barium or potassium analysis to test for any depletion in these elements.

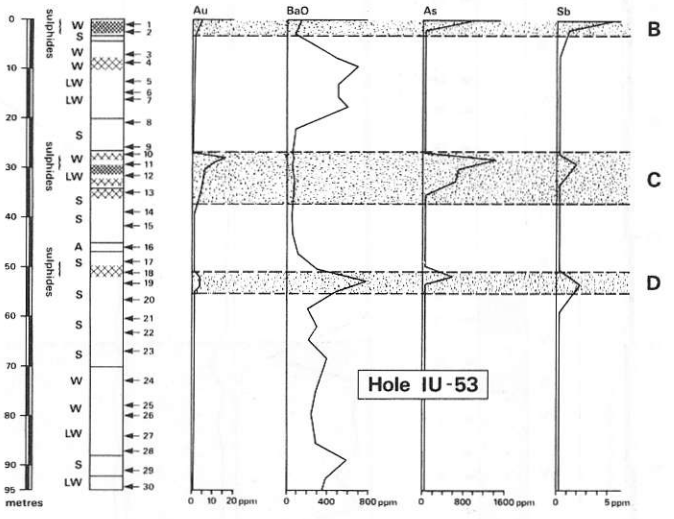


Figure 20. Geology and trace element geochemistry of hole IU-53, Carolin mine. (After Ray and Niels, 1985).

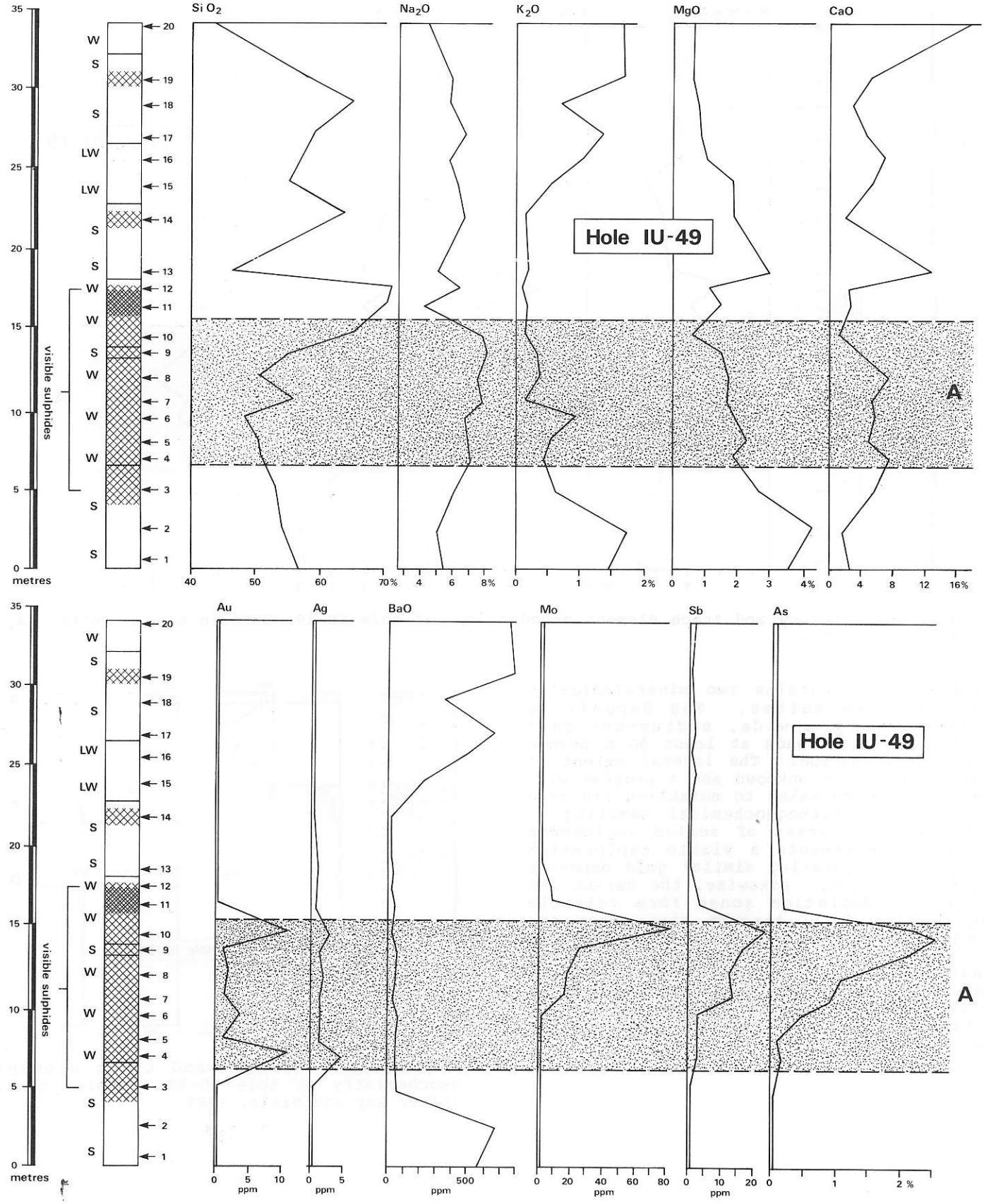


Figure 19. Geology and major element geochemistry of hole IU-49, Carolin mine. (After Ray and Niels, 1985).

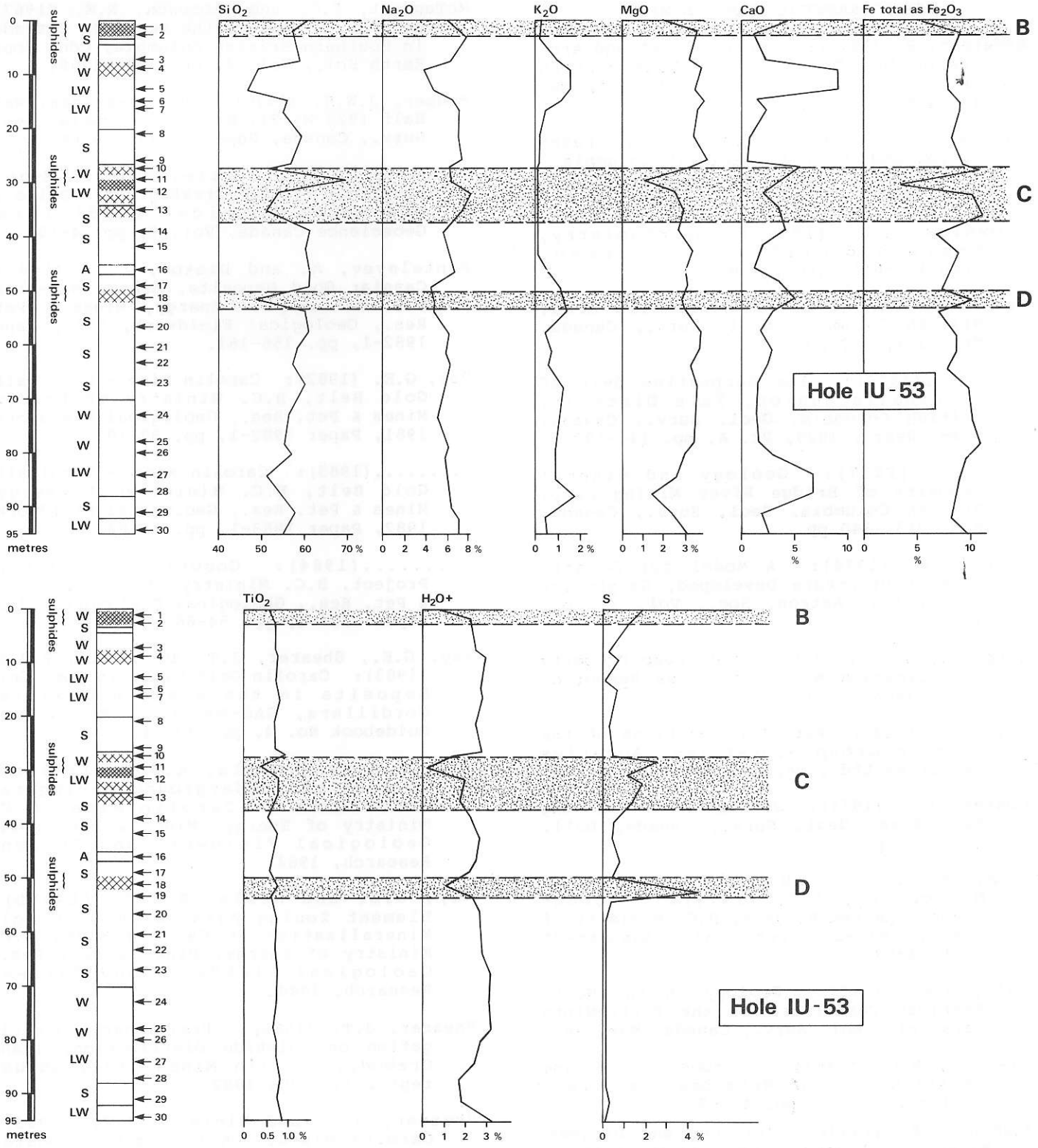


Figure 21. Geology and major element geochemistry of hole IU-53, Carolin mine. (After Ray and Niels, 1985).

BIBLIOGRAPHY OF CAROLIN MINE

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

Bateman, A.M. (1911): Geology of Fraser Canyon and Vicinity, British Columbia - Siwash Creek Area, Geol. Surv., Canada, Summ. Rept., 1911, pp. 125-129.

Brownlow, A.H. (1979): Geochemistry, Englewood Cliffs, New Jersey, Prentice-Hall Inc., 498 pp.

Cairnes, C.E. (1924): Coquihalla Area, British Columbia, Geol. Surv., Canada, Mem. 139, 187 pp.

.....(1929): The Serpentine Belt of Coquihalla Region, Yale District, British Columbia, Geol. Surv., Canada, Summ. Rept., 1929, Pt. A, pp. 144-197.

.....(1937): Geology and Mineral Deposits of Bridge River Mining Camp, British Columbia, Geol. Surv., Canada, Mem. 213, 140 pp.

Cann, J.R. (1974): A Model for Oceanic Crustal Structure Developed, Geophysics Jour., Roy. Astron. Soc., Vol. 39, pp. 169-187.

Cardinal, D.G. (1981): Hope Group Property (Emancipation Mine), Aquarius Resources Ltd., unpub. rept.

.....(1982): Report on Portions of the Spuzzum Group Properties, Aquarius Resources Ltd., unpub. rept.

Coates, J.A. (1974): Geology of the Manning Park Area, Geol. Surv., Canada, Bull. 238, 177 pp.

Cochrane, D.R., Griffiths, D. and Montgomery, J.T. (1974): Aurum-Idaho-Pipestem Project, B.C. Ministry of Energy, Mines & Pet. Res., Assessment Rept. 4852.

Daly, R.A. (1912): Geology on the North American Cordillera at the Forty-Ninth Parallel, Geol. Surv., Canada, Mem. 38.

Gresens, R.L. (1967): Composition-volume Relationships of Metasomatism, Chem. Geology, Vol. 2, pp. 47-65.

Joubin, F.R. (1948): Bralorne and Pioneer Mines, in Structural Geology of Canadian Ore Deposits, C.I.M., Jubilee Vol., pp. 168-177.

Kayira, G.K. (1975): A Mineralographic and Petrographic Study of the Gold Deposit of the Upper Idaho Zone, Hope, British Columbia, unpub. B.Sc. thesis, University of British Columbia.

McTaggart, K.C. and Thompson, R.M. (1967): Geology of Part of the Northern Cascades in Southern British Columbia, Cdn. Jour. Earth Sci., Vol. 4, pp. 1199-1228.

Monger, J.W.H. (1970): Hope Map-area, West Half (92H W1/2), British Columbia, Geol. Surv., Canada, Paper 69-47, 75 pp.

.....(1975): Correlation of Eugeosynclinal Tectono-stratigraphic Belts in the North American Cordillera, Geoscience Canada, Vol. 2, pp. 4-10.

Panteleyev, A. and Diakow, L.J. (1982): Cassiar Gold Deposits, McDame Map-area, B.C. Ministry of Energy, Mines & Pet. Res., Geological Fieldwork, 1981, Paper 1982-1, pp. 156-161.

Ray, G.E. (1982): Carolin Mine - Coquihalla Gold Belt, B.C. Ministry of Energy, Mines & Pet. Res., Geological Fieldwork, 1981, Paper 1982-1, pp. 87-101.

.....(1983): Carolin Mine - Coquihalla Gold Belt, B.C. Ministry of Energy, Mines & Pet. Res., Geological Fieldwork, 1982, Paper 1983-1, pp. 62-84.

.....(1984): Coquihalla Gold Belt Project, B.C. Ministry of Energy, Mines & Pet. Res., Geological Fieldwork, 1983, Paper 1984-1, pp. 54-66.

Ray, G.E., Shearer, J.T. and Neils, R.J.E. (1983): Carolin Gold Mine, in Some Gold Deposits in the Western Canadian Cordillera, GAC-MAC-CGU, Field Trip Guidebook No. 4, pp. 40-64.

Ray, G.E. and Niels, R.J.E. (1985a): Surface and Underground Geological Structures at Carolin Mine, B.C. Ministry of Energy, Mines & Pet. Res., Geological Fieldwork and Current Research, 1984.

Ray, G.E. and Niels, R.J.E. (1985b): Element Zoning Associated with Gold Mineralization at Carolin Mine, B.C. Ministry of Energy, Mines & Pet. Res., Geological Fieldwork and Current Research, 1984.

Shearer, J.T. (1982): Preliminary Investigation on Sulphide Distribution, Idaho Orebody, Carolin Mines Ltd., unpub. rept., June 30, 1982.

Shearer, J.T. and Niels, R.J.E. (1983): Carolin Mines: A Geological Update, Western Miner, November 1983, pp. 21-24.

Wright, R.L., Nagel, J. and McTaggart, K.C. (1982): Alpine Ultramafic Rocks of Southwestern British Columbia, Cdn. Jour. Earth Sci., Vol. 19, pp. 1156-1173.

DAY 2 - AFTERNOON

EMANCIPATION GOLD MINE

G.E. Ray and D.G. Cardinal

INTRODUCTION

The defunct Emancipation gold mine is situated approximately 2.5 km southeast of Carolin mine (Fig. 10), close to Tangent Creek, a small tributary of the Coquihalla River. The mine originally comprised five adits, the most extensive of which was 180 m long and had several crosscuts. Ore was transported via an overhead bucket and cable system down to a mill located just above the abandoned Canadian Pacific Kettle Valley railway line (Fig. 22). The mill used a petroleum fueled engine and handled approximately 6 tons of ore per shift. The mill foundations are still discernible, but the bucket and cable system is no longer in existence.

Between 1916 and 1941, Emancipation mine reportedly produced 90 kg of gold, which makes it the second largest producer in the Coquihalla gold belt after Carolin mine (Table 5). The original reserves, overall grade and production statistics are unknown; a partial list of ore shipments during the initial years of mining are as follows:

Year	Tons Shipped	Value in Dollars
1916	3	'About $ 1500'
1917	61	$21000
1918	19	$ 9250

In the early years of production the ore was hand sorted and as gold was priced at $20 per ounce, it suggests the grade of this material varied from 17 to 24 ounces Au per ton! (580 to 822 grams Au per tonne).

For several decades following World II the mine area was ignored, but in 1980 and 1981, Aquarius Resources Ltd. carried out an exploration and diamond drilling program; the most extensive adit at the mine was reopened and sampled. The surface geology at the newly opened adit entrance will be examined during this field trip.

Literature relevant to the Emancipation mine include that by Cairnes (1920, 1924, 1929), Bullis (1971), Cardinal (1981) and Ray (1984).

GEOLOGY AND MINERALIZATION

The geology of the mine area and a diagrammatic geological section through the deposit are shown on Figures 22 and 23 respectively. The gold-bearing veins are hosted within a wedge-shaped, fault-bounded slice of altered greenstones belonging to the Early Triassic (?) Spider Peak Formation. These greenstones are mostly

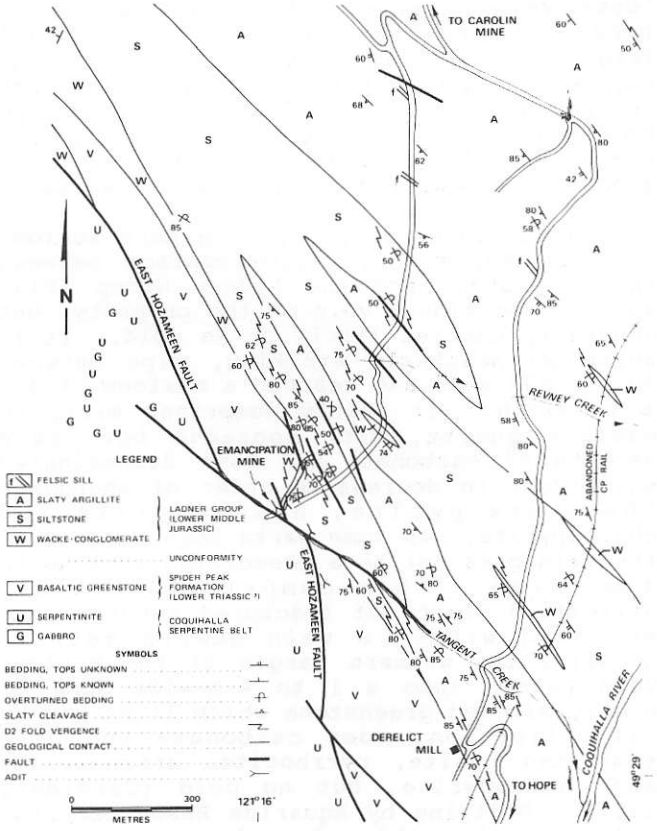


Figure 22. Geology of the Emancipation mine area (Geological mapping by G.E. Ray, 1982).

massive, but the eastern portion of the fault wedge contains some elongated sheared clasts that probably represent aquagene breccias. Immediately to the west (Fig. 23), the greenstones are in fault contact with serpentinites of the Coquihalla serpentine belt. Sheared talc within the East Hozameen fault is seen in Tangent Creek.

To the east, the unconformable contact between the greenstones and the Lower to Middle Jurassic Ladner Group is occupied by a high angle reverse fault (Fig. 23). The Ladner Group youngs eastward away from the older greenstone unit (Fig. 22) and mostly comprises slaty argillites and siltstones. Immediately adjacent to the greenstones there is a 1 to 2-m-wide unit of lithic wacke and siltstone containing chert and volcanic clasts; this is interpreted as a faulted remnant of the coarse clastic lower portion of the Ladner Group succession which further north, around Carolin mine exceeds 200 m in thickness.

There are three principal sets of quartz veins at the mine, all of which are controlled by a related, complimentary fracture system that developed during reverse movements along the East Hozameen fault (Fig. 23). The three sets are the footwall 'Boulder vein', the hangingwall

'Dyke vein', between which are a set of irregular, reverse dipping 'Flat veins' (Fig. 23). Both the Dyke and Boulder veins follow, in part, reverse fractures; the Flat veins occupy second order, sigmoidal-type tension fractures formed during the northeasterly directed thrust movements along the footwall and hangingwall faults.

The Boulder vein, which in part follows the faulted, unconformable contact between the greenstone and the Ladner Group (Fig. 23), is the widest vein on the property, but generally carries little or no gold. It is north-northeasterly striking, dips between 50 and 60° west and reaches a maximum of 4.6 m in width. It mainly comprises milky to massive quartz, with sporadic but trace amounts of carbonate and some disseminated sulphides; in decreasing order of abundance these are pyrite, arsenopyrite and chalcopyrite. In some parts both margins of the vein pass out to a brecciated zone up to 3 m thick. This comprises angular, silicified clasts of fractured country rock enclosed within a vein quartz matrix. Locally, the western margin of the Boulder vein passes into a 1 to 4-m-wide zone of highly altered greenstone which is marked by silicification, some carbonate and disseminated pyrite, pyrrhotite, arsenopyrite and chalcopyrite, but no gold (Cardinal, 1981). Drilling by Aquarius Resources Ltd. indicates that this altered zone continues with depth, but the Boulder vein quickly pinches out down dip (Fig. 23).

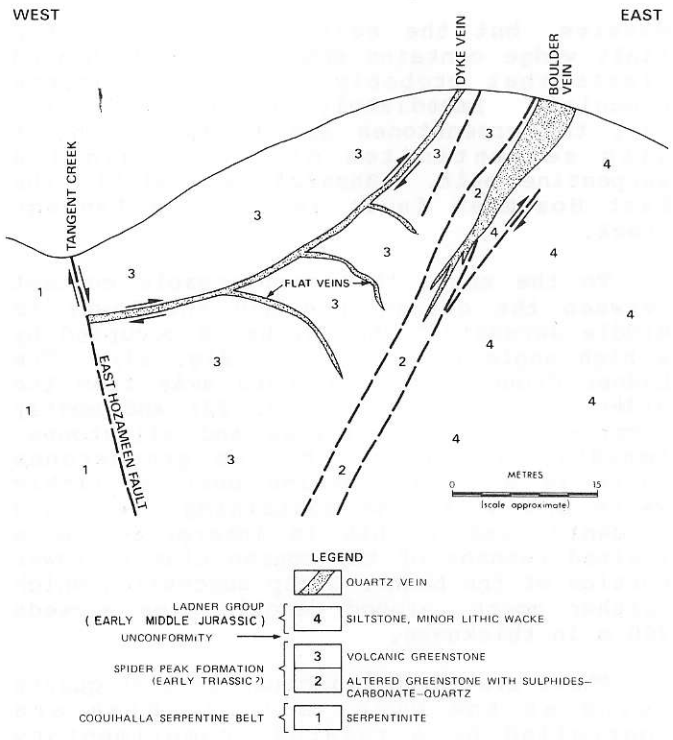


Figure 23. Diagrammatic vertical cross section through the Emancipation gold mine, Hope, British Columbia. (Adapted after Cardinal 1981).

The hangingwall Dyke vein was probably the most important regarding ore tonnage as it was stoped for 85 m along strike and over 40 m down dip (Bullis, 1971). Like the Boulder vein, it too is northerly striking, but differs in that it is thinner (between a few centimetres and 0.6 m in thickness) and its dip varies with depth. In the higher parts of the mine workings the Dyke vein dips 40° westward, but with depth the vein gets shallower until it eventually forms a gently undulating, subhorizontal structure (Fig. 23). The Dyke vein mainly comprises turbid, ribbon-textured quartz. Locally it contains altered thin slices of country rock, some sheared sheets of chlorite, together with carbonate, gypsum and nodules of pink albite. The principal sulphides in decreasing order of abundance are pyrrhotite, arsenopyrite, pyrite, chalcopyrite and marcasite. Cairnes (1929) concluded that 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 (1929) also reports the local presence of enargite (Cu_3AsS_4) and spectacular amounts of free gold in the Dyke vein; the gold-silver ratio in the vein was 6 to 1. The quartz, sulphide and gold contents apparently decreased in the vein both down dip and along strike to the northwest.

Between the Boulder and Dyke veins are the Flat veins, which comprise numerous veinlets and quartz lenses, together with at least three more prominent quartz veins. These strike northwest and dip between 30 to 45° northeast; however, even the largest Flat vein does not exceed 7 cm wide and soon pinches out with depth (Fig. 23). They are related to and splay out from, the Dyke vein and comprise quartz with minor calcite, plagioclase and gypsum, together with free gold and sulphides. These veins are noteworthy in carrying some of the highest gold values in the mine, particularly where they intersect the Dyke vein (Cairnes, 1929; Bullis, 1971).

To summarize, the mineralization at the Emancipation mine includes two types that are possibly genetically and temporally related. One of these is barren siliceous-carbonate-sulphide replacement alteration of the greenstones which is associated with the Boulder vein and its hosting fracture. The second type is represented by the gold-sulphide-bearing quartz veins which are hosted in the greenstones and which are controlled by a complimentary set of reverse movement induced fractures.

BIBLIOGRAPHY FOR EMANCIPATION MINE

Bullis, A.R. (1971): Geological Study of the Emancipation Mine, B.C. Ministry of Energy, Mines & Pet. Res., unpub. Assessment Rept. 3015.

Cairnes, C.E. (1920): Coquihalla Area, British Columbia, Geol. Surv., Canada, Summ. Rept., 1920, Pt. A, pp. 24-42.

.....(1924): Coquihalla Area, British Columbia, Geol. Surv., Canada, Mem. 139, 187 p.

.....(1929): The Serpentine Belt of Coquihalla Region, Yale District, British Columbia, Geol. Surv., Summ. Rept., 1929, Pt. A, pp. 158A-162A.

Cardinal, D.G. (1981): Hope Group Property (Emancipation Mine), Aquarius Resources Ltd., unpub. rept.

Ray, G.E. (1984): Coquihalla Gold Belt Project, B.C. Ministry of Energy, Mines & Pet. Res., Geological Fieldwork, 1983, Paper 1984-1, pp. 54-66.