CAROLIN MINE - COQUIHALLA GOLD BELT PROJECT (92H/6, 11)

By G. E. Ray

INTRODUCTION

The second season of fieldwork studying the geology and mineralization of the Coquihalla gold belt was carried out by a two-man field crew. The area studied in 1982 is situated approximately 20 to 25 kilometres northeast of Hope. This work included the following:

(1) Regional geological mapping (scale 1:50 000) of the belt from Mount Snider in the south northward toward Siwash Creek. A third field season's work should complete the regional geological mapping of the gold belt northward to the vicinity of Chapmans Bar.

(2) Geological mapping, at a scale of 1:6000, of an area between Spider Peak and the Coquihalla River. This area contains most of the gold occurrences in the belt, many of the past gold producers, such as the Emancipation, Aurum, and Pipestem, as well as the presently operating Carolin mine.

(3) Detailed surface geological mapping (scale 1:500) over the former Pipestem gold mine (MI 92H/NW-11), together with underground mapping and sampling (scale 1:250) of the lower, most extensive (No. 4) level of the old Pipestem mine workings.

(4) Surface geological mapping and sampling of the 'McMaster zone' gold mineralization, situated approximately 0.5 kilometres southeast of McMaster pond.

(5) Sampling the Home X gold occurrence (MI 92H/NW-13) and the newly discovered 'Murphy occurrence.'

(6) Collection of approximately 80 silt samples from streams draining the belt. These are being assayed for gold, arsenic, chromium, copper, mercury, nickel, lead, antimony, zinc, and cobalt, and this data will be used in conjunction with the results of the 1981 Regional Geochemical Survey (RGS 7) to determine whether any regional geochemical patterns are associated with mineralization in the belt.

REGIONAL GEOLOGY

Gold occurrences in the Coquihalla gold belt are regionally clustered close to the eastern margin of the Coquihalla serpentine belt (Fig. 22). This serpentine belt forms an elongate, north-northwesterly trending, steeply dipping unit separating supracrustal rocks of the Ladner Group in the east from the Hozameen Group in the west (Fig. 22). The serpentine belt reaches its maximum development in the Carolin mine-Coquihalla River area where it exceeds 2 kilometres in width. 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. Dark, highly sheared to massive serpentinite of probable peridotite parentage (Cairnes, 1929; Table 5) characterizes the belt but it also contains substantial amounts of highly altered gabbro-diabase rocks (Table 7).

The eastern margin of the serpentine belt is sharply delineated by the Hozameen fault which, due to its close spatial association with many gold occurrences, has been mapped and studied in some detail (Cairnes, 1924, 1929; Cochrane, *et al.*, 1974; Anderson, 1976; Cardinal, 1981, 1982; Ray, 1982; Wright, *et al.*, 1982). In contrast, the western margin of the serpentine belt has previously been largely ignored. However, current mapping suggests it too represents a major fracture, which like its eastern counterpart, has had a long and complex history of both vertical and horizontal movements. The eastern boundary fracture is herein termed 'East Hozameen fault;' the hitherto unnamed western tectonic boundary is called the 'West Hozameen fault.' With the gradual disappearance of the serpentine belt both north and south, these boundary fractures merge into a single tectonic feature, the Hozameen fault (Fig. 22).

The Hozameen Group consists largely of cherts, pelites, and altered spilitic basalts (Daly, 1912; Cairnes, 1924; McTaggart and Thompson, 1967; Monger, 1970). Monger (1975) interprets this as an oceanic supracrustal sequence of Triassic or pre-Triassic age. In the map-area the Hozameen Group rocks have been subjected to lower greenschist metamorphism and strong deformation; some parts are overprinted by either a schistosity or an intense, subhorizontal mullion structure. Close to the serpentine belt, Hozameen Group rocks commonly show signs of increased deformation and crushing, minor silicification, late brittle faulting, and pronounced slickensiding. The West Hozameen fault appears to dip steeply east, and serpentinites in the immediate vicinity contain highly sheared talcose rocks and, in rare instances, poor quality nephrite.

The Ladner Group (Cairnes, 1924) comprises a sequence of fine-grained, poorly to well-bedded slaty argillites and siltstones with minor amounts of coarser grained material. These metasedimentary rocks have a weak to intense slaty cleavage and were subjected to at least three periods of regional folding (Table 1). Despite this, Ladner Group rocks give an overall impression of being less deformed than the Hozameen Group, and a wide variety of sedimentary structures are commonly preserved (Ray, 1982). Regional folding has resulted in widespread structural repetition and many sections of the Ladner Group adjacent to the Coquihalla serpentine belt, including those hosting the gold mineralization at Carolin mine (Idaho zone), are structurally inverted (Table 1). Cairnes (1924) considered the thickness of the Ladner Group in the Coquihalla

River-Ladner Creek area to be approximately 2 000 metres, but recognition of widespread structural repetition suggests its true thickness may be considerably less.

The broad stratigraphic sequence recognized within the Ladner Group in the Carolin mine-Ladner Creek area (Ray, 1982) continues further north into the vicinity of the Pipestem mine (Fig. 23). The Ladner Group rests either unconformably or disconformably upon an older volcanic greenstone; its lowermost stratigraphic portion consists of a thin, heterogeneous assortment of coarse clastic, partly volcanogenic sedimentary rocks that pass upward into a thicker sequence of well-bedded siltstones. These are overlain in turn by a thick unit of carbon and iron-rich argillites. The lower clastic unit which hosts the Carolin gold mineralization (Idaho zone) comprises discontinuous wedges of interbedded greywacke, lithic wacke, conglomerate, and possible reworked tuff with intercalated units of argillite and volcanogenic siltstone. The basal portion also includes rare, thin horizons of clastic, impure limestone. The conglomerates contain angular to well-rounded clasts; most are of volcanic origin but there are minor amounts of quartz, jasper, chert, limestone, granite, and gabbroic material. While most of the volcanic pebbles are identical to the underlying greenstone unit, clasts of recrystallized, altered porphyritic and nonporphyritic flow-layered dacites are locally common.

The economically important lower clastic unit shows great variation in thickness along the belt. In most parts it is either thin or absent; for example, near the Emancipation mine it is less than 5 metres thick, while in the vicinity of Carolin mine (Ray, 1982) it is approximately 200 metres thick.

The Ladner Group stratigraphically overlies older greenstones which are traceable discontinuously for more than 15 kilometres along the eastern side of the East Hozameen fault (Fig. 23); in many places it structurally overlies the Ladner Group. The greenstone-Ladner Group contact is commonly marked by faulting and shearing, but in places the sedimentary rocks rest directly on the volcanic rocks with either an unconformable or a disconformable relationship. A local basal conglomerate of variable thickness contains abundant clasts of material clearly derived from the underlying greenstones. Refractive index determinations on fused glass beads and chemical analyses (Table 6) indicate that the greenstones are highly altered andesitic to basaltic volcanic rocks. The greenstones are fine to medium grained and are generally characterized by their massive, homogeneous appearance; some specimens contain randomly orientated, late crystals of stilpnomelane. Many outcrops close to the Ladner Group contact display remnant vesicles, pillow structures, aquagene breccias, and weak layering, while their high sodium content (Table 6) indicates the presence of some spilitic lavas. Rare lenses of immature volcanic sandstone and conglomerate are also seen, while bodies of gabbro-diorite are present within the volcanic unit near Emancipation mine. The age of the volcanic rocks is uncertain and some rare examples of interpillow cherts in the greenstones have been examined for microfossils without

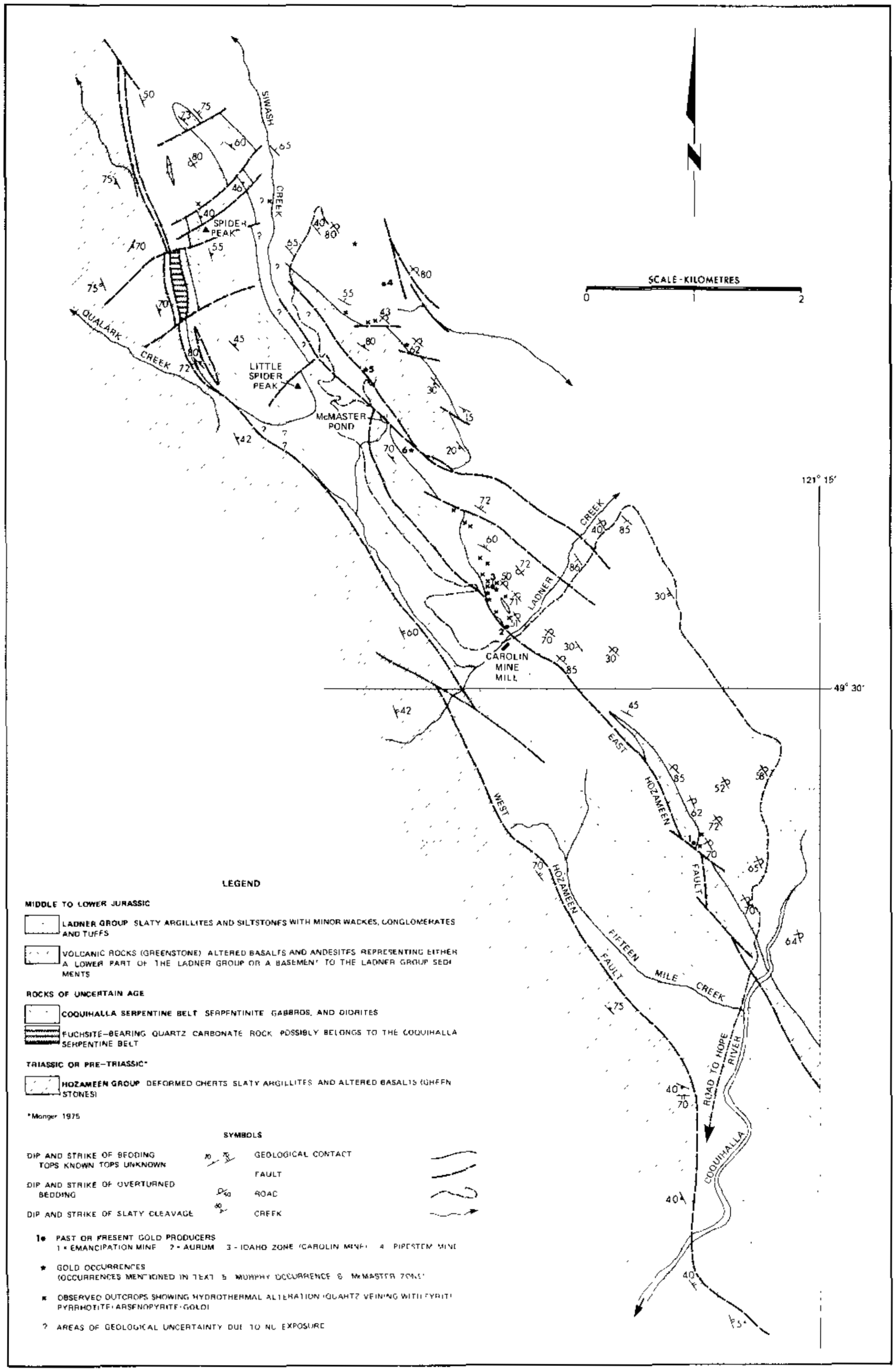


Figure 23. Regional geology of the Carolin-Pipestem-Emancipation gold mines area.

success. However, at one locality east of Serpentine Lake, a 1-metre-wide chert breccia horizon that separates pillowed greenstones from the Ladner Group contains conodonts of Early Triassic age (M. Orchard, personal communication). This horizon probably originated from pre-Ladner weathering and concentration of interpillowed chert breccia material present in the greenstones. This would strongly suggest that the volcanic rocks are Early Triassic in age.

Both the Ladner and Hozameen Groups are cut by a wide variety of intrusive rocks. A distinctive suite of leucocratic quartz porphyry sills is restricted to the Hozameen Group. These sills contain large, rounded phenocrysts of quartz and some rare flakes of biotite, set in a fine to medium-grained quartz-feldspar matrix. The quartz porphyries look fresh but their restriction to the Hozameen Group suggests that they predate the tectonic emplacement of this unit adjacent to the serpentine belt.

The Ladner Group is cut by two main intrusive suites. One forms dykes, sills, and irregular masses up to 300 metres in width that display wide variations in texture and composition. Individual bodies are zoned with gabbroic and ultrabasic cores grading out to granitic contact zones. The other suite forms narrow dykes and sills of feldspar porphyry that are locally syenitic (Bateman, 1911; Cairnes, 1924). Quartz veining with minor pyrite, arsenopyrite, and traces of gold occur in some sills and dykes. Consequently Bateman (1911) and Cairnes (1924, 1929) considered these intrusive rocks to be genetically related to some gold mineralization in the district.

GOLD MINERALIZATION IN THE BELT

GENERAL

The locations of deposits and occurrences comprising the Coquihalla gold belt are shown on Figure 22 and further details are listed in Tables 2 and 3. Most gold production has come from five deposits (Table 2); only the newly opened Carolin Mines Ltd. operation on the Idaho zone is currently being worked. Information on early gold production from the belt, particularly from the Aurum and Ward deposits, is poorly documented and unreliable. Nevertheless, until closure of the Emancipation mine in 1941, approximately 119 000 grams of gold had been won from the belt. Of this, the majority (90 104 grams) came from Emancipation mine, the most southerly deposit in the belt (Fig. 22).

Carolin Mines Ltd. is planning to mill 1 350 tonnes of ore per day, grading 4.2 grams gold per tonne (P. W. Richardson, personal communication). Shortly, one month's production from the Idaho zone is expected to exceed that from the previous 70-year history of the belt.

IDAHO ZONE (CAROLIN MINE)

No futher surface or underground mapping of the Idaho zone was undertaken by the author during the 1982 field season, although laboratory investigation of the ore geochemistry and petrology continued. Hopefully underground mapping by J. T. Shearer and R.J.E. Niels of Carolin Mines Ltd., together with a study of the sulphide distribution in the Idaho zone (Shearer, 1982), will delineate the ore controls and morphology of the deposit. Underground work on the property (R.J.E. Niels, J. T. Shearer, personal communication) indicates that the Idaho zone consists of at least two major orebodies; a lower (No. 1 orebody), and an upper (No. 2 orebody), separated by highly sheared and faulted carbonaceous argillites. The upper orebody crops out just north of the old Idaho adit (Ray, 1982) and was discovered during the initial surface exploration. A rusty-weathering, 13-metre-wide zone assaying up to 4 800 ppb gold outcropping approximately 160 metres south-southeast of the old Idaho adit, may be the surface expression of the lower orebody. Comparative analyses on mineralized and unmineralized wackes in the Idaho zone (Table 4) suggest that mineralization was accompanied by the introduction of silica, sodium and sulphur, the removal of magnesium, potassium, calcium and carbon dioxide, and the conversion of ferrous to ferric iron. Introduction of sodium resulted in the formation of abundant white albite (An_{3-5}) in the ore zone. Trace element analyses (Table 4) show that the the Idaho zone is weakly to strongly anomalous in copper, arsenic, molybdenum, antimony, and tungsten.

Shearer (1982), in a study on the sulphide distribution within the Idaho zone, made the following observations:

(1) Mineralized samples from the zone are separable into pyrite dominant and pyrrhotite dominant types. Consequently, the deposit may be zoned.

(2) Small grains of gold, up to 0.02 millimetre in size, occur either as inclusions within pyrite and arsenopyrite or as rims on pyrite and chalcopyrite.

(3) Small grains of free gold, apparently spatially independent of sulphides, are present inside some quartz, calcite, and feldspar crystals.

These observations explain how samples 25163M and 25164M (Table 4), which are arsenopyrite rich and arsenopyrite poor respectively, could both contain high gold values. They also suggest that economical gold mineralization is possible in sulphide-poor parts of the Idaho zone. Thus, while arsenic is a pathfinder for gold exploration in parts of the belt, gold could also occur without arsenic geochemical anomalies.

Examination of thin and polished sections from the Idaho zone reveals a complex history of mineralization, alteration, and structural deformation. The mineralized wackes 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 per cent 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 Idaho zone is characterized by a closely spaced, irregular network of white vein material, representing the injection of many generations of quartz, calcite, and albite. The development of sigmoidal gash fractures and the wide variation in vein deformation, from highly folded to apparently undeformed, suggests that the multistage injection occurred during a long period of recurrent structural deformation. White quartz veins, generally less than 15 centimetres wide, comprise the commonest vein material on megascopic scale. At least three generations are recognized and all appear to postdate the main period of gold-sulphide mineralization. Many veins are monomineralic but in others the quartz crystals are intergrown with variable amounts of calcite, albite, and clinozoisite; in rare instances there are small flakes of pyrobitumen. Some quartz veins that cut and postdate the main F_2 slaty cleavage (*see* Table 1) are seen under thin section to be folded and contain strained quartz crystals that are elongated parallel to both the F_2 fold axial planes and the slaty cleavage. These veins are interpreted to be of syn-F_2 age, being injected after the main cleavage development, but before that period of deformation had ceased. Larger quartz crystals in these veins display finely sutured margins suggesting crystallization during strain (Spry, 1969).

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

On the megascopic scale, albite veining is less evident than either quartz or calcite. However, in thin section the effects of sodium metasomation are reflected by at least three generations of albitization. Disseminated and partially altered albite-oligoclase (An_{3-15}) crystals make up a significant proportion of the fine-grained ore groundmass and represent 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. It consists of coarse, well-twinned albite crystals (An_{3-5})* up to 8 millimetres in length with locally deformed twin planes. Locally, small angular fragments of sulphide-rich ore are entirely engulfed in this third generation albitic material.

Pyritic argillites with abundant quartz veining occur within and adjacent to the Idaho zone but these rocks generally contain no gold (R.J.E. Niels, personal communication). Abundant minute carbonaceous lenticules

*Identified by X-ray diffraction using a method described by Bambauer, *et al.*, 1967.

are seen under thin section. They are elongated parallel to the F_2 chlorite-sericite cleavage (Table 1). These argillites have preferentially taken up strain and are cut by many fault planes that are smeared with carbonaceous material and marked by slickensiding. X-ray examination shows that the carbonaceous material in both the fault planes and argillites is amorphous; thus the regional metamorphic grade was too low to produce crystalline graphite.

In rare instances, white quartz veins contain small flakes of pyrobitumen whose optical and physical characteristics suggest it has acquired a maturation equivalent to meta-anthracite (J. Kwong, personal communication). These pyrobitumen flakes 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 degrees 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.

MURPHY GOLD OCCURRENCE

The Murphy gold occurrence is located approximately 400 metres north-northwest of McMaster pond (Fig. 23). It was discovered in 1982 by prospector D. Murphy, while investigating a soil geochemical gold anomaly outlined by Carolin Mines Ltd. The mineralization consists of fine gold with pyrite and arsenopyrite in a quartz vein between 5 and 20 centimetres in width. The vein can be traced discontinuously for 20 metres within altered greenstones immediately adjacent to their faulted contact with highly sheared talcose serpentinites. This fracture zone represents the steeply dipping East Hozameen fault; the quartz vein, however, dips very gently northeastward into the hillside. The dark brick red soil over the occurrence contains pannable gold.

The mineralized white quartz vein contains small vugs lined with clear quartz crystals, and the sulphides are visually estimated to form less than 2 per cent by volume. Gold is most commonly seen as a fine coating on chocolate brown alteration products; the latter contains a mixture of goethite, hematite, and lepidocrocite with some remnant pyrite. Elsewhere, fine gold is associated with both pyrite and arsenopyrite and, in rare instances, it is free in the quartz. Both gold and sulphides occur at the vein margins and vein centres.

SILT GEOCHEMISTRY

Approximately 80 silt samples were collected from streams within the mapped area; these have been assayed for gold, arsenic, chromium, copper, mercury, nickel, lead, antimony, zinc, and cobalt. No statistical analysis of the data has been made yet, but the following points are noted:

(1) Tangent Creek, which drains the old Emancipation mine, is the only stream with marked arsenic and mercury anomalies (152 ppm and 180 ppb respectively).

(2) Some streams draining the serpentine belt are highly anomalous in chromium and nickel (up to 0.11 per cent and 0.14 per cent respectively).

(3) Many streams draining the eastern side of Ladner Creek Valley are weakly to moderately anomalous in zinc (up to 287 ppm). These streams drain the Needle Peak pluton and its wide thermal metamorphic aureole in the Ladner Group.

(4) No anomalous cobalt or antimony values were recorded.

(5) One large stream flowing southwestward from Mount Snider into Sowaqua Creek contains anomalous lead (58 ppm) and zinc (606 ppm). This raises the possibility that the stream drainage basin is underlain by lead-zinc-silver veins, similar to those found around Treasure Mountain 10 kilometres further west.

DISCUSSION

DEPOSITIONAL ENVIRONMENT AND STRATIGRAPHY OF THE LADNER GROUP

Overall, the Ladner Group is an upward fining succession. It passes from a thin, heterogeneous, coarsely clastic unit at the base into a much thicker sequence of finely bedded siltstones and argillites. The lowermost unit includes discontinuous wedges of coarse, poorly sorted material interbedded with lesser amounts of finer sediment. This implies rapidly alternating periods of low and high energy deposition, the latter involving high density turbidites and chaotic slumping. The extreme variation in thickness and character of the lower clastic unit suggests that either rapid lateral facies changes existed or that the marine transgression took place across an irregular basement topography. Overturned flame structures in some basal beds indicate an easterly derivation, while the assorted pebble lithologies show a source underlain by greenstones, granitic and gabbroic rocks, flow-banded acid to intermediate volcanic rocks, and some limestones.

The finely bedded siltstones and argillites comprising the higher portion of the Ladner Group succession (Ray, 1982) are believed to represent DE turbidites (Bouma, 1962) deposited in a low energy, deeper water environment. In parts, this sequence contains thin, impersistent horizons of coarse wacke which reflect the periodic influx of higher energy turbidite sediments. One such wacke horizon is traceable for 900 metres and hosts the gold mineralization at Pipestem mine. It also contains belemnites and bivalves, the only Ladner Group fossils seen in the district.

GREENSTONES

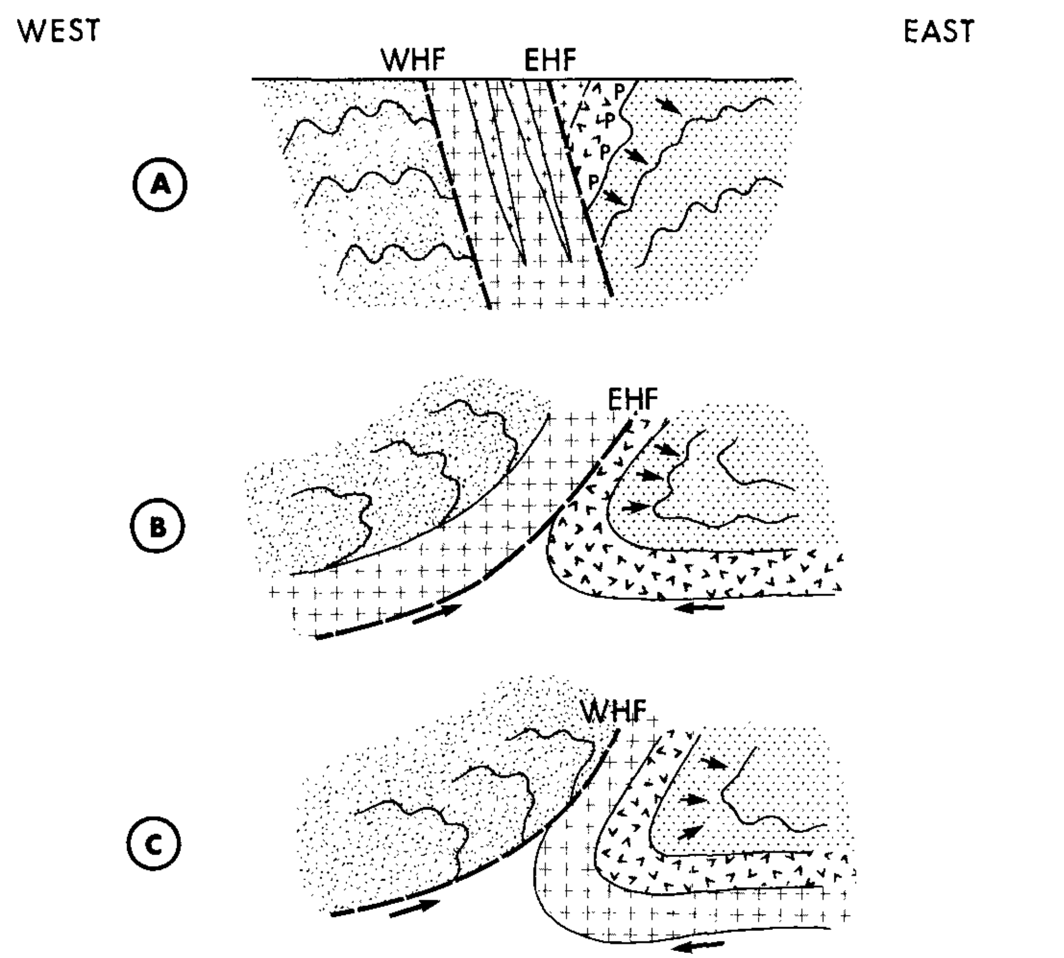
The greenstones are generally massive but adjacent to the Ladner Group contact there are aquagene breccias and vesicular pillowed basalts, while further west, adjacent to the East Hozameen fault, the unit includes bodies of gabbro-diorite (Fig. 24A). These bodies may have formed feeders to the overlying lavas and thus the present westerly progression from submarine extrusive basalts to plutonic gabbros could reflect a gradation from near surface to deeper levels.

The Ladner Group-greenstone contact is believed to represent an unconformity. This is tentatively supported by microfossil evidence and by the presence of both greenstone and gabbroic clasts in the basal Ladner Group conglomerates. These suggest that the Lower Triassic volcanic pile was deeply eroded prior to the onset of Lower Jurassic (Coates, 1974) Ladner Group sedimentation.

EVOLUTION OF THE COQUIHALLA SERPENTINE BELT

Extensive serpentine belts throughout the world are believed to represent either oceanic crust or upper mantle material that was emplaced either as low temperature, plastic intrusions along vertical fractures or as slices in allochthonous thrusts formed during major orogenic plate movements. Serpentine belts are generally associated with fundamental fractures that are believed to mark major crustal boundaries (Shackleton, 1976). The Coquihalla serpentine belt separates two important geological units, the Hozameen and Ladner Groups, that are of different age and contrasting character. It is bounded by major fractures that are interpreted to be refolded thrust faults. Field and laboratory data explaining the origin and development of the Coquihalla serpentine belt is preliminary and inconclusive; consequently two alternative models are presented (Figs. 24B and 24C). The serpentine belt may represent obducted oceanic crust (Ray, 1982; Fig. 24B) which originally underlay, and formed a basement to, the Hozameen Group. In this model both allochthonous units were emplaced by easterly directed overthrusting that caused tectonic inversion in some parts of the Ladner Group (Fig. 24B). This model suggests that the main overthrusting occurred along the East Hozameen fault, and that the serpentinites and greenstones are unrelated. However, this obduction model is difficult to reconcile with the plate tectonic models proposed by Monger, *et al.* (1972) and Monger (1977) to explain the formation of the Canadian Cordillera. Furthermore, X-ray and thin section examination of rocks immediately adjacent to the East Hozameen fault reveals no high temperature minerals like those found in the thin, basal aureoles underlying many obducted, Alpine-type ophiolite complexes (Williams and Smyth, 1973).

An alternative proposal (Fig. 24C) is that the serpentinites and greenstones are related, and represent lower and upper oceanic crustal material which originally underlay and acted as basement to the Ladner Group. Structural inversion of these units took place during easterly



LEGEND

HOZAMEEN GROUP

SERPENTINE

VOLCANIC GREENSTONES

LADNER GROUP

GABBRO

YOUNGING DIRECTION IN THE LADNER GROUP

P = PILLOWED VOLCANICS
WHF = WEST HOZAMEEN FAULT
EHF = EAST HOZAMEEN FAULT

A = PRESENT DAY DIAGRAMMATIC EAST/WEST SECTION ACROSS THE SERPENTINE BELT IN THE EMANCIPATION MINE VICINITY

B AND C = TWO ALTERNATIVE MODELS SHOWING POSSIBLE EVOLUTION OF THE COQUIHALLA SERPENTINE BELT

B = EASTWARD OVERTHRUSTING OF THE HOZAMEEN GROUP AND UNDERLYING OCEANIC CRUST ALONG THE EAST HOZAMEEN FAULT, CAUSING TECTONIC INVERSION IN THE VOLCANICS AND LADNER GROUP

C = EASTWARD OVERTHRUSTING OF THE HOZAMEEN GROUP ALONG THE WEST HOZAMEEN FAULT CAUSING TECTONIC INVERSION OF THE LADNER GROUP AND UNDERLYING OCEANIC CRUST

Figure 24. Evolution of the Coquihalla serpentine belt.

overriding of the Hozameen Group but the main movement in this model took place along the West Hozameen fault. The Ladner Group, the greenstones, and the serpentinite-gabbro belt could represent respectively the classical oceanic layers 1, 2, and 3 (Cann, 1974) although no sheeted dykes are recognized in the Coquihalla belt.

Different tectonic relationships are implied in these two models, but in both, the Ladner Group is interpreted to be deposited on oceanic crust, and the Hozameen Group is viewed as allochthonous. However, interpretation is complicated by accompanying right lateral transcurrent movements along the Hozameen fault system, similar to that described in other major strike-slip faults in the Canadian Cordillera (for example, Templeman-Kluit, 1977; Monger, 1977) and by subsequent deformation and refolding.

GOLD MINERALIZATION

An overall examination of deposits and occurrences in the Coquihalla gold belt (Fig. 22; Tables 2 and 3) reveals the following features:

(1) Coquihalla gold belt mineralization is proximal to greenstones, fault-bounded serpentinites, and small outcrops of fuchsite-bearing quartz carbonate rock. These associations are similar to that seen at the Bralorne-Pioneer mines (Cairnes, 1937; Joubin, 1948), the Cassiar gold camp (Panteleyev and Diakow, 1982), and the Mother Lode belt of California (as noted by Cairnes, 1929).

(2) The occurrences and deposits, with the possible exception of the Norm and Georgia 2 occurrences whose precise locations are uncertain, are situated east of the East Hozameen fault (Fig. 22).

(3) The gold is generally fine grained; coarse visible gold is relatively uncommon throughout the belt (a noted exception is the Aurum mineralization).

(4) All gold mineralization in the belt is in highly fractured host rocks. It was accompanied by the introduction of silica which forms either discreet, generally narrow quartz veins (Emancipation mine, Murphy occurrence, Monument vein) or wider zones of intense network veining and diffuse silicification (Idaho and McMaster zones).

(5) Gold throughout the belt is associated with varying degrees of sulphide mineralization (*see* Ray, 1981). These sulphides include pyrite, arsenopyrite, pyrrhotite, and chalcopyrite.

(6) Gold mineralization occurs in a wide variety of fractured host rock types that includes greenstone (Emancipation mine and Murphy occurrence), felsite porphyry sills (Ward and Emigrant), and metasedimentary rocks of the Ladner Group (Idaho and McMaster zones, Pipestem, Rush of the Bull, Gem, Golden Cache, Home X, and the Spuz

occurrences). However, these host rocks share a common characteristic -- they are more competent than the surrounding country rock. Consequently they were brittle and subject to open space fracturing. Gold mineralization in the belt is therefore preferentially hosted either within the wackes and felsite sills or in fault zones between competent and incompetent units, like those separating greenstones from metasedimentary rocks.

(7) Studies are incomplete, but few occurrences in the belt, including the Idaho zone, show enrichment in mercury. However, Tangent Creek, which drains the Emancipation mine, has anomalous mercury silt values (up to 180 ppb mercury) which suggests a gold-mercury association in this deposit.

(8) Gold mineralization in the Spuz occurrence and at the Idaho zone is associated with weak tungsten geochemical anomalies.

(9) The source of the Idaho zone gold mineralization is uncertain. However, the introduction of sodium, which is probably derived from the nearby spilitic volcanic rocks, suggests that the greenstones could represent the source of the gold.

Weathered, gold-bearing outcrops of the Idaho and McMaster zones are characterized by black manganese oxide and rusty staining, together with sulphide mineralization and a dense network of quartz veins. However, many other similarly mineralized quartz veined outcrops exist throughout the belt, particularly north of the Aurum deposit (Fig. 23) where the lower clastic unit of the Ladner Group is best developed. A few carry gold but most appear barren and there is no reliable field method for distinguishing these two, although outcrops with chalcopyrite tend to carry gold also. Future studies may reveal zoning patterns, raising a possibility that some of these barren sulphide-bearing, quartz veined outcrops could pass into gold-bearing ore at depth.

The temperature of mineralization in the Idaho zone is uncertain. However, the stability data for meta-anthracite from the Idaho zone quartz veins suggest temperatures of 250 degrees Celsius were attained. This lies within the temperature range established by fluid inclusion studies for many vein-type deposits (Spooner, 1981).

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TABLE 1. STRUCTURAL HISTORY OF THE CAROLIN MINE AREA

	Late faulting.
F_4	Sporadically developed, minor conjugate folds associated with kink banding and crenulation cleavage.
F_3	Major asymmetric folding of the Ladner Group. Folds have subhorizontal axes with southeast-striking axial planes that dip steeply northeast. No associated metamorphic axial planar fabric recognized.
F_2	Major disharmonic folds having subvertical, southeast-striking axial planes and gently plunging axes. It is associated with the regional axial planar slaty cleavage and mineral lineation in the Ladner Group. Major disruption and quartz veining along some fold limbs and axial planes.
F_1	Widespread structural inversion of the Ladner Group and greenstones, related to the easterly overthrusting of the allochthonous Hozameen Group. No associated axial planar fabric recognized.
Early to Middle Jurassic ? (Coates, 1974)	Deposition of the Ladner Group sedimentary rocks.
	- Unconformity -
Early Triassic ?	Submarine volcanism with extrusion of pillowed basalts (greenstones).

TABLE 2. MAJOR GOLD PRODUCERS IN THE COQUIHALLA GOLD BELT (see Fig. 22)

No. on Fig. 22	Name of Mine	Year(s) of Production	Total Production (g) Au	Ag	Sources
1	Emancipation	1916-1941	90 104	18 818	1
2	Aurum	1930-1932 1939-1942	16 578	3 017	1
3	Idaho zone (Carolin mine)	1981-1982	253 216	Not reported	2
4	Pipestem	1935-1937	8 460	1 151	1
5	Ward	1905	4 199	Not reported	1

Sources

1 B.C. Mineral Inventory File.

2 Gold shipped up to December 31, 1982; P. W. Richardson, personal communication.

TABLE 3. REPORTED GOLD OCCURRENCES IN THE COQUIHALLA GOLD BELT (see Fig. 22)

No. on Fig. 22	Name	Details	Sources
6	Broken Hill	Single quartz vein up to 3 metres wide and 60 metres long in Ladner Group slates close to their contact with greenstones. Uncertain gold values with pyrite, arsenopyrite and rare galena.	1
7	Snowstorm (Pittsburg)	Twelve-metre-long adit along mineralized zone between Ladner Group and volcanic greenstones. Quartz vein up to 3 metres wide with pyrite, arsenopyrite, pyrrhotite, and gold. Cairnes (1924) reports gold values of up to $8.00 per ton.	1, 2
8	Montana	Gold and pyrite-bearing, 5-centimetre-wide quartz veins in greenstones close to contact with Ladner Group.	1
9	Rush of the Bull	Two narrow (10-centimetre) quartz veins, mineralized with coarse arsenopyrite and free gold. Veins cut Ladner Group slates near their contact with a feldspar porphyry sill.	2
10	Golden Cache	At least six narrow quartz veins sparingly mineralized with pyrite-arsenopyrite and low gold values. Veins believed to lie close to the Ladner Group-volcanic greenstone contact.	2
11	McMaster zone	Network quartz veining with pyrite, arsenopyrite, and gold, hosted in highly fractured, Ladner Group wackes and siltstones close to their contact with greenstones. Mineralization and network veining closely resembles that in the Idaho zone.	15
12	Murphy	Visible gold with pyrite and arsenopyrite hosted in a thin, vuggy quartz vein cutting greenstone close to their faulted contact with serpentinite.	15
13	Gem	Two-metre-wide quartz vein within Ladner Group. Both vein and wallrock show sparse pyrite-arsenopyrite mineralization with pannable gold.	2
14	Star	Quartz stringers up to 15 centimetres wide cutting Ladner Group rocks, carry pyrite, arsenopyrite, and low gold values.	12
15	Home X	Numerous thin quartz stringers containing pyrite, arsenopyrite, and low gold values. Veins cut black slates of the Ladner Group close to their contact with a fossiliferous wacke horizon. A collapsed adit of unknown length is on property.	3, 15

TABLE 3. REPORTED GOLD OCCURRENCES IN THE COQUIHALLA GOLD BELT (Continued)

No. on Fig. 22	Name	Details	Sources
16	Georgia 2	Precise location uncertain. Pyrite, arsenopyrite, and gold within faulted diorites (probably part of greenstone package). Some confusion over gold values. Cairnes (1929) reports 2.5 tons of ore gave $9.00 per ton gold.	4, 15
16	Norm	Claims are in the vicinity of Georgia 2 occurrence near Spider Peak. Gold geochemical anomalies and pannable gold from quartz-veined, mariposite-fuchsite-bearing rocks.	5, 15
17	Emigrant	Minor gold in quartz veins associated with felsic porphyry sills intruding the Ladner Group slates.	6
18	Roddick	No geological description available. In 1901 adits and crosscuts 106 metres in length were driven through material valued at $15.00 to $25.00 per ton gold.	7
19	Marvel	No geological description available. In 1906 existing adits were extended and a six-stamp mill installed.	7
20	Spuz A, B, G, and Monument	Weak gold mineralization in quartz veins and silicified zones within the Ladner Group close to the Hozameen fault. One major vein, the Monument, is up to 2 metres wide and traceable for 80 meters. It carries pyrite, with rare arsenopyrite, chalcopyrite, and gold. Gold also found associated with rare scheelite in felsic porphyry sills.	9, 10, 15
21	Majestic	No geological description available.	11
22	Gold Coin	No geological description available.	13
23	Gold Cord	No geological description available.	14

Sources

1 Cairnes, 1920.
2 Cairnes, 1924.
3 Minister of Mines, B.C., Annual Report, 1933.
4 Cairnes, 1929.
5 B.C. Ministry of Energy, Mines & Pet. Res., Exploration in B.C., 1978.
6 Bateman, 1911.
7 B.C. Mineral Inventory File, MI 92H/NW-17.
8 Minister of Mines, B.C., Annual Report, 1906.
9 Cochrane and Littlejohn, 1978.
10 Cardinal, 1982.
11 B.C. Mineral Inventory File, MI 92H/NW-33.
12 B.C. Mineral Inventory File, MI 92H/NW-14.
13 B.C. Mineral Inventory File, MI 92H/NW-32.
14 B.C. Mineral Inventory File, MI 92H/NW-31.
15 Observed by author.

TABLE 4. 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.

TABLE 5. WHOLE ROCK AND TRACE ELEMENT ANALYSES OF VARIOUS SERPENTINITE SAMPLES FROM THE COQUIHALLA SERPENTINE BELT AND ELSEWHERE

	25478[1]	25479[2]	25482[3]	25486[4]	A	B
SiO_2	39.41	36.30	41.15	35.40	40.7	41.7
Al_2O_3	1.15	5.99	0.32	0.59	1.0	0.8
MgO	38.29	36.20	39.41	37.26	36.4	38.5
CaO	0.14	0.05	<0.01	0.18	0.1	0.4
Na_2O	<0.06	<0.06	<0.06	<0.06	N.D.	N.D.
K_2O	<0.01	<0.01	<0.01	<0.01	N.D.	N.D.
TiO_2	0.03	0.42	<0.01	0.04	N.D.	N.D.
MnO	0.09	0.20	0.069	0.16	N.D.	N.D.
$+H_2O$	12.0	12.2	12.3	10.5	12.4	11.0
$-H_2O$	0.79	0.60	0.57	0.62	N.D.	N.D.
CO_2	0.10	0.1	0.01	6.20	0.2	0.0
P_2O_5	0.08	0.08	0.08	0.08	N.D.	N.D.
FeO	1.08	3.00	1.03	3.49	1.2	2.1
Fe_2O_3	5.73	4.27	4.23	5.47	6.6	4.1
S	0.02	0.03	0.16	0.12		
SrO ppm	<3	<3	<3	8		
BaO ppm	3	7	6	11		
Zr ppm	7	30	5	20		
Y ppm	<3	7	<3	<3		
Co ppm	59	55	58	74		
Cr	0.15	0.24	0.18	0.10		
Cu ppm	8	100	8	16		
Mo ppm	<3	<3	<3	3		
Ni	0.24	0.14	0.27	0.24		
Pb ppm	12	12	10	12		
Au ppb	<20	<20	<20	<20		
Ag ppm	<0.5	<0.5	<0.5	<0.5		
Sb ppm	<10	<10	<10	22		
Zn ppm	50	59	28	66		
As ppm	51	45	45	75		

In per cent except as noted.

[1]Antigorite-bastite-rich serpentinite with some remnant enstatite. Coquihalla serpentine belt.
[2]Antigorite-rich serpentinite. Coquihalla serpentine belt.
[3]Antigorite-rich serpentinite. Coquihalla serpentine belt.
[4]Serpentine with antigorite pseudomorphs after olivine. Coquihalla serpentine belt.

A Serpentinite derived from dunite. Cornwall, England (Pirsson and Knopf, 1966).

B Serpentinite derived from pyroxenite. Mount Diablo, California (Pirsson and Knopf, 1966).

TABLE 6. WHOLE ROCK AND TRACE ELEMENT ANALYSES OF VARIOUS VOLCANIC GREENSTONE SAMPLES

	25465[1]	25466[2]	25470[3]	25472[4]
SiO_2	50.77	50.16	48.58	46.26
Al_2O_3	14.48	13.77	14.81	13.27
MgO	6.24	3.16	7.33	6.60
CaO	6.97	7.86	6.86	7.40
Na_2O	5.46	7.20	4.58	3.51
K_2	0.42	0.02	0.06	0.69
TiO_2	1.53	1.27	1.78	1.81
MnO	0.19	0.19	0.19	0.17
$+H_2O$	2.47	1.17	3.34	4.14
$-H_2O$	0.99	0.10	0.20	0.25
CO_2	0.85	6.90	0.01	4.90
P_2O_5	<0.08	<0.08	<0.08	<0.08
S	0.01	2.60	0.11	0.04
FeO	7.31	3.09	10.10	8.84
Fe_2O_3	1.69	2.60	1.78	0.64
SrO	0.03	0.03	0.01	0.02
BaO	0.007	0.005	0.006	0.007
Zr ppm	50	40	90	70
Y ppm	30	22	38	30
Co ppm	21	20	25	23
Cr ppm	95	14	21	59
Cu ppm	22	37	53	30
Mo ppm	<3	32	<3	<3
Ni ppm	54	26	31	39
Pb ppm	8	17	12	12
Au ppb	<20	33	<20	<20
Ag ppm	<0.5	<0.5	<0.5	<0.5
Sb ppm	<10	<10	13	10
Zn ppm	72	22	98	103
As ppm	<15	48	15	39

In per cent except as noted.

[1]Augite-bearing pillowed greenstone. East of Serpentine Lake.
[2]Sulphide-bearing, carbonate veined greenstone. Emancipation mine.
[3]Augite-bearing altered volcanic greenstone showing aquagene brecciation. Carolin mine.
[4]Altered greenstone volcanic. Drill core sample. South of Pipestem mine.

TABLE 7. WHOLE ROCK AND TRACE ELEMENT ANALYSIS OF GABBROIC ROCKS WITHIN THE COQUIHALLA SERPENTINE BELT

	25481[1]	25483[2]
SiO_2	50.19	48.73
Al_2O_3	13.15	14.44
MgO	7.16	6.92
CaO	9.66	11.09
Na_2O	4.09	3.60
K_2O	0.05	0.12
TiO_2	1.66	1.37
MnO	0.19	0.18
$+H_2O$	12.2	0.16
$-H_2O$	0.18	0.12
CO_2	0.10	0.14
P_2O_5	0.08	0.08
S	0.15	0.03
FeO	9.03	8.25
Fe_2O_3	1.31	1.21
SrO	0.05	0.06
BaO ppm	21	33
Zr ppm	80	66
Y ppm	24	24
Co ppm	26	26
Cr ppm	70	57
Cu ppm	30	71
Mo ppm	<3	<3
Ni ppm	53	56
Pb ppm	8	10
Au ppb	<20	<20
Ag ppm	<0.5	<0.5
Sb ppm	16	12
Zn ppm	102	86
As ppm	<15	15

In per cent except as noted.

[1]Altered augite-hornblende gabbro. 15 mile Creek Bridge.
[2]Altered gabbro. East of Serpentine Lake.

REFERENCES

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

Bambauer, H. U., Corlett, M., Eberhard, E., and Viswanathan, K. (1967): Diagrams for the Determination of Plagioclases Using X-ray Powder Methods, *Schweiz. Min. Pet. Mitt.*, Vol. 47, pp. 333-349.

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

Bouma, A. H. (1962): Sedimentology of some Flysch Deposits, *Elsevier Pub. Co.*, Amsterdam, 168 pp.

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

Cairnes, C. E. (1920): Coquihalla Area, British Columbia, *Geol. Surv., Canada*, Summ. Rept., 1920, Pt. A, pp. 23-42.

.... (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.

Cochrane, D. R. and Littlejohn, A. L. (1978): Spuz A, B, and G Claims, Longbar Minerals Ltd., *B.C. Ministry of Energy, Mines & Pet. Res.*, Assessment Rept. 6962.

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

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.

.... (1977): Upper Paleozoic Rocks of the Western Canadian Cordillera and Their Bearing on Cordilleran Evolution, *Cdn. Jour. Earth Sci.,* Vol. 14, pp. 1832-1859.

Monger, J.W.H., Souther, J. G., and Gabrielse, H. (1972): Evolution of the Canadian Cordillera: A Plate Tectonic Model, *Am. Jour. Sci.,* Vol. 272, pp. 577-602.

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.

Pirsson, L. V. and Knopf, A. (1966): Rocks and Rock Minerals, *John Wiley,* p. 331.

Ray, G. E. (1981): Geology and Gold Mineralization of the Coquihalla Belt, with Particular Reference to the Carolin Gold Deposit, *in* Rocks and Ores of the Middle Ages, *Geol. Assoc. Can.,* Cordilleran Section, February, 1981, Abstr., pp. 24, 25.

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

Shackleton, R. M. (1976): Shallow and Deep Level Exposures of Archean Crust in India and Africa, *in* The Early History of the Earth, B. F. Windley (editor), *Wiley,* pp. 317-321.

Shearer, J. T. (1982): Preliminary Investigation on Sulphide Distribution, Idaho Orebody, *Carolin Mines Ltd.,* unpub. Progress Rept. No. 1.

Spooner, E.T.C. (1981): Fluid Inclusion Studies of Hydrothermal Ore Deposits *in* Fluid Inclusions: Application to Petrology, L. S. Hollister and M. L. Crawford, editors, *Min. Assoc. Canada,* Short Course, Calgary, May, 1981, pp. 209-240.

Spry, A. (1969): Metamorphic Textures, *Pergamon Press,* London.

Templeman-Kluit, D. J. (1977): Stratigraphic and Structual Relations between the Selwyn Basin, Pelly-Cassiar Platform, and Yukon Crystalline Terrane, *Geol. Surv., Canada,* Paper 77-1A.

Williams, H. and Smyth, W. R. (1973): Metamorphic Aureoles beneath Ophiolite Suites and Alpine Peridotites: Tectonic Implications with West Newfoundland Examples, *Am. Jour. Sci.,* Vol. 273, pp. 594-621.

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.