



British Columbia Geological Survey  
Geological Fieldwork 1987

# Mineral Deposit Studies

# GOLD-ENRICHED SKARN DEPOSITS OF BRITISH COLUMBIA\*

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**KEYWORDS:** Economic geology, gold, skarn, Texada Island, Banks Island, Nanaimo Lakes, Zeballos, Benson Lake, OKA, Dividend-Lakeview, Greenwood, Hedley, Teepee Peak.

## INTRODUCTION

This report summarizes field studies of selected gold-bearing skarns in British Columbia (Figure 2-1-1). A com-

prehensive study of the petrology, geochemistry and distribution of gold skarn mineralization in the province is now in progress. The distribution and description of these deposits will be presented as an Open File report in early 1988.

Thirty-six per cent of the approximately 340 known skarn occurrences in British Columbia reportedly contain anomalous gold values. As gold production from 50 skarn deposits worldwide exceeds 1000 tonnes (Meinert, 1987), the poten-

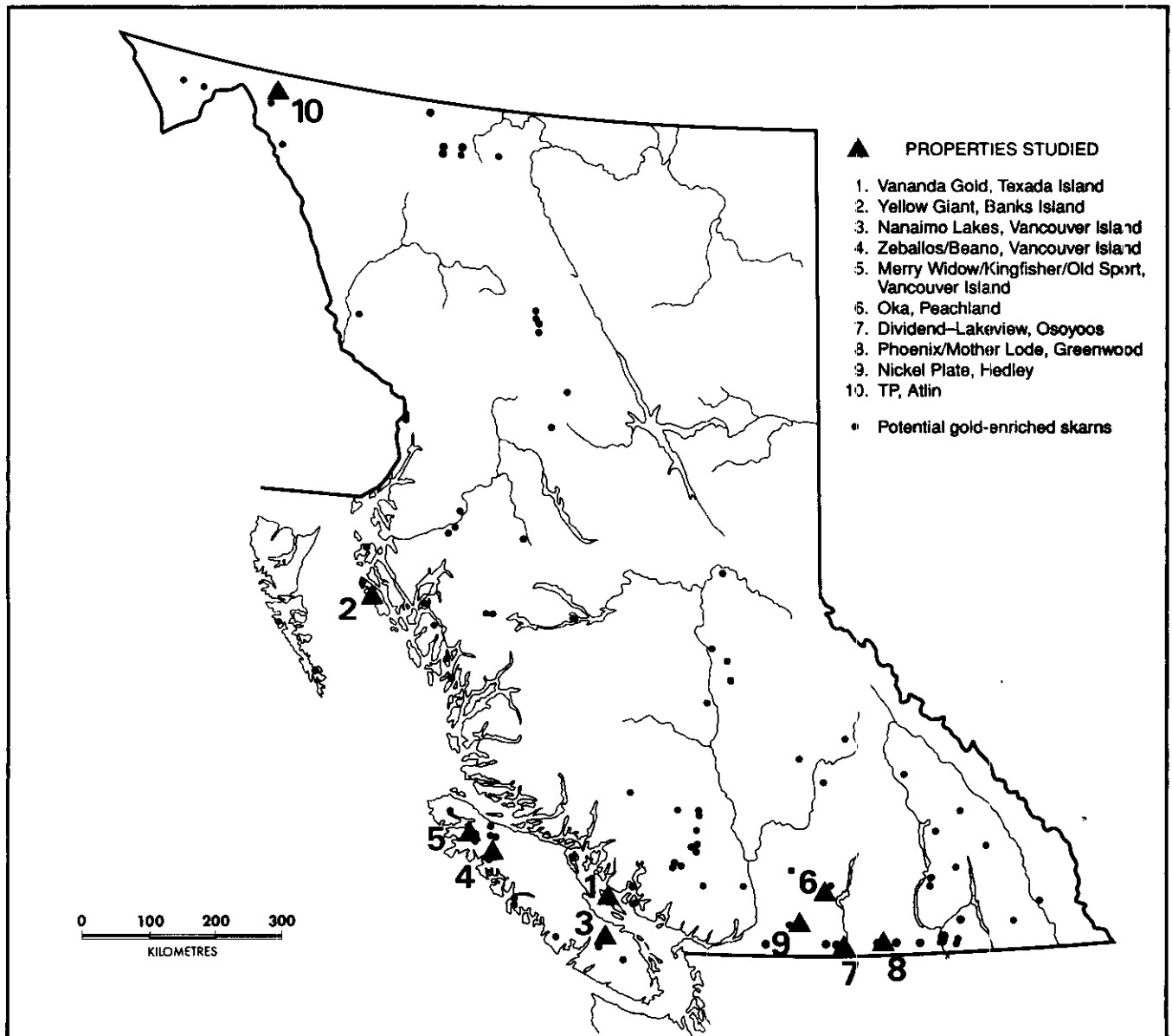


Figure 2-1-1. Location map of deposits studied.

\* This project is a contribution to the Canada/British Columbia Mineral Development Agreement. British Columbia Ministry of Energy, Mines and Petroleum Resources, Geological Fieldwork, 1987, Paper 1988-1.

tial economic importance of skarns as a source of gold in British Columbia is clear.

The following property descriptions are from skarns visited during the 1985, 1986 and 1987 field seasons. These occurrences were selected for on-site study based on the following criteria: style of skarn mineralization present (that is, copper, iron, gold skarn); gold content; current exploration interest; exposure and access. British Columbia Mineral Inventory Numbers (MINFILE) are given for each property visited.

## GEOLOGY OF SELECTED DEPOSITS

### TEXADA ISLAND SKARNS

(MINFILE 092F-105 to 107, 110, 112, 113, 257 to 259, 269 to 271, 295; 92F/10E, 15E)

Iron and copper-gold skarn mineralization occurs along a continuous belt between the villages of Vananda and Gillies Bay on northern Texada Island (Figure 2-1-2). During the

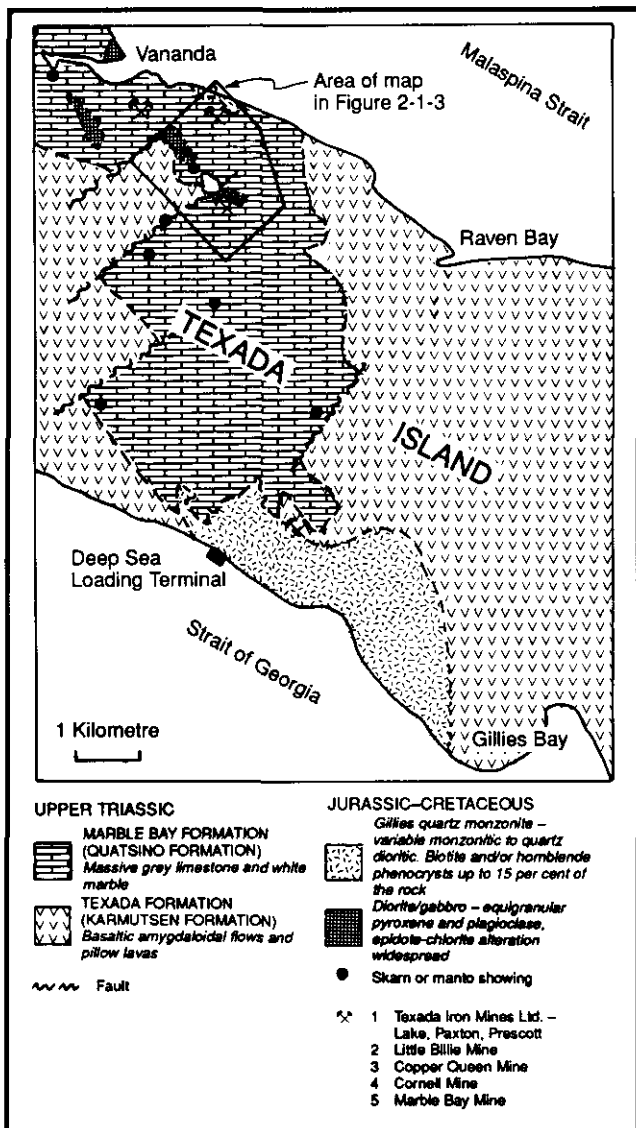


Figure 2-1-2. Location map of Texada Island skarns.

TABLE 2-1-1  
PRODUCTION FIGURES FOR TEXADA ISLAND  
SKARN DEPOSITS  
(Modified from Peatfield, 1987)

Mine	Period	Ore (t)	Au (g)	Ag (g)	Cu (kg)
<b>Copper-gold Skarns</b>					
Copper Queen	1903-1917	4 075	47 066	354 618	180 747
Cornell	1897-1919	40 687	471 085	2 194 471	1 368 513
Little Billie	1896-1952	63 711	363 168	1 198 304	819 098
Marble Bay	1899-1929	199 210	1 544 100	12 620 500	6 788 900
Total		307 683	2 425 419	16 367 893	9 157 257
<b>Iron Skarns</b>					
Texada Iron Mines Ltd. (Prescott, Lake, Paxton and Yellow Kid mines)					
	1885-1976	20 880 900	887 560	23 644 310	26 740 300

period 1896 to 1976 this area produced 21 million tonnes of ore (Peatfield, 1987). Copper-gold skarns were worked in the Little Billie, Marble Bay, Copper Queen and Cornell mines (Table 2-1-1), while magnetite skarn was exploited in the Prescott, Paxton, Lake and Yellow Kid mines. The copper-gold skarns occupy the northern part of the belt near Vananda and contain mineralogies similar to other copper skarns described by Einaudi *et al.* (1981) and Meinert (1983). The magnetite skarns, which were described by Meinert (1984), are situated in the southern part of the belt, near Gillies Bay, approximately 6 kilometres south of the Vananda camp. Between these two centres of mining activity there are numerous showings of manto-type massive sulphide replacement of limestone, sulphide-rich skarn and mineralized shear zones.

### HOST ROCK LITHOLOGY

The host rocks are Triassic Marble Bay limestones which are stratigraphically equivalent to the Quatsino limestone on Vancouver Island. This unit comprises bedded, grey, fine-grained limestone and coarsely crystalline, white to light grey marble, extending southwards, in a belt 3 kilometres wide, from the village of Vananda to the Texada Iron Mines Ltd. property. Lower greenschist metamorphosed basalts outcrop either side of the carbonate belt. These amygdaloidal and pillow lavas are probably correlative with the Karmutsen Formation which underlies the Quatsino limestone on Vancouver Island. At the Lake magnetite mine, bedded limestone conformably overlies the basalt which has been replaced by skarn. Bedding strikes northwest and dips 30 degrees southwest.

The volcanics and limestones are intruded by Mesozoic (?) felsic granodiorites and quartz monzonites which are spatially associated with skarn at the Texada Iron and Little Billie mines, and by a gabbroic suite associated with skarn mineralization at the Cornell mine and in the Florence-Security area (Figure 2-1-3). Major element oxide analyses for these two intrusive suites are presented in Table 2-1-2. Sample 800N960E is similar to the granodiorite described by Le Maitre (1976) but sample 275N37E is silica undersaturated and lies between a gabbro and a nephelinite.

## SKARN MINERALIZATION

Gold-silver-copper mineralization occurs in irregular pipe-like bodies along a granodiorite-marble contact at the Little Billie mine. The ore zones plunge 45 degrees south along the contact and are open to depth. Coarse-bladed wollastonite and garnet-diopside skarns contain bornite, chalcopyrite, pyrite, molybdenite, magnetite, sphalerite, galena, scheelite, gold and silver. Reflected light microscopy shows native gold is associated with blebs of bornite. Wollastonite-garnet textures exhibiting flow banding indicate that these two phases probably crystallized simultaneously and are of metasomatic origin. Early tan-coloured garnet is cut by later dark brown garnet veinlets. Electron microprobe analyses at Washington State University show the composition of the early garnet phase as  $Ad_{17}$  (andradite) to  $Ad_{66}$  while the later garnet is more iron rich. Only one diopside replacement event has been identified, with compositions ranging from  $Hd_2$  (hedenbergite) to  $Hd_{58}$ .

Skarn associated with the Gillies quartz monzonite at the Texada Iron Mines property is distinctively more iron rich and contains lower gold grades. Endoskarn in the quartz

TABLE 2-1-2  
MAJOR OXIDE COMPOSITIONS OF  
TEXADA ISLAND GABBRO AND GRANODIORITE<sup>1</sup>

Oxide	Gabbro 275N37E	Granodiorite 800N960E
SiO <sub>2</sub> .....	46.38	66.76
Al <sub>2</sub> O <sub>3</sub> .....	17.07	16.18
TiO <sub>2</sub> .....	1.045	0.498
Fe <sub>2</sub> O <sub>3</sub> .....	11.93	4.91
MnO .....	0.182	0.096
MgO .....	5.64	1.62
CaO .....	11.13	4.32
K <sub>2</sub> O .....	1.32	1.58
Na <sub>2</sub> O .....	2.78	3.74
P <sub>2</sub> O <sub>5</sub> .....	0.367	0.120
Total .....	97.844	99.824

<sup>1</sup> Analyses performed at Washington State University, Basalt Research Laboratory.

monzonite occurs as a widely spaced epidote stockwork with white albitic(?) envelopes. The stockwork becomes denser and garnet-amphibole skarn also replaces quartz monzonite toward the intrusive contacts. Magnetite occurs in all three hosts (limestone, volcanics and quartz monzonite), however, sulphide mineralization is best developed in skarn replacing limestone. Skarn minerals include garnet, diopside, epidote, amphibole, albite, magnetite, pyrite, chalcopyrite and erythrite.

In summary, there are at least two distinctly different types of skarn deposits on the northern end of Texada Island. Iron skarns with low gold-copper values to the south near Gillies Bay, and copper skarns with higher gold and low iron to the north near Vananda, may represent the end-members of a metallogenically zoned suite of Texada Island skarns.

## BANKS ISLAND

(MINFILE 103G-024 to 026; 103G/8E)

Gold mineralization was first discovered on Banks Island in 1960 by Ventures Ltd. at the Discovery deposit along the southern end of Hepler Lake (Figure 2-1-4). Additional gold mineralization was identified at the Bob zone in 1964. Surface trenching during 1987 has exposed mineralization at the Tel deposit. Drill-indicated probable reserves at the Tel are reported by M. Vulimiri of Trader Resource Corporation as 97 500 tonnes grading 16.2 grams per tonne gold and at the Discovery as 38 200 tonnes averaging 17.1 grams per tonne gold.

## HOST ROCK LITHOLOGY

Banks Island is mainly underlain by plutonic rocks of the Coast complex and less extensive metasedimentary rocks (Figure 2-1-4). Intrusive rocks are compositionally zoned from a monzonitic to granodioritic core surrounded by a quartz dioritic phase which in turn grades to a gneissic dioritic-gabbroic migmatite margin. Late alaskitic dykes crosscut these rocks. Surface mapping and detailed petrographic work by Trader Resource Corporation indicates that the intrusive rocks are inter-related and part of the same zoned pluton (Shearer, unpublished report, 1987).

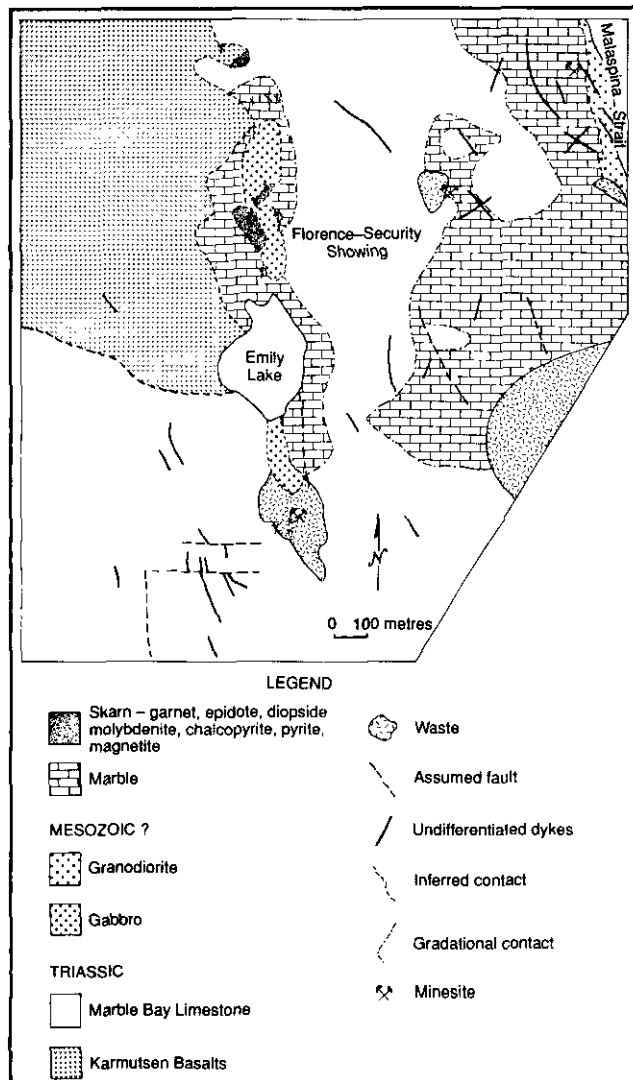


Figure 2-1-3. Surface geology of Vananda gold-copper skarns.

Pendants of metasedimentary rocks, comprising coarse-banded light grey to green marble, gneiss and migmatite, form long lenticular northwest-striking bodies along the margins of the intrusions. These Paleozoic(?) sediments are the host to skarn mineralization at the Bob zone and Discovery deposit.

## STRUCTURE

Subvertical, northwest-striking right-lateral faults bound Banks Island. Subparallel with these are near-vertical faults bordering the metasedimentary packages. These structures are cut by westerly trending lineaments defining subsidiary shears and tensional fractures. The intersections of these discordant structural features were the original exploration targets for early prospectors.

## SKARN MINERALIZATION

Skarn at the Discovery deposit occurs along a northwest-striking fracture zone at the contact between biotite quartz monzonite and marble (Figure 2-1-5). Alteration in intrusive rock (*endoskarn*) consists of subequal amounts of dark green, fine to medium-grained amphibole and dark green euhedral zoisite with minor amounts of garnet and diopside. This skarn grades into *exoskarn* replacing the marble. The *exoskarn* contains dark brown medium-grained garnet as the primary calc-silicate phase, with lesser diopside, amphibole

and epidote. Remnant patches of marble are observed within the skarn zones. Sulphide minerals present in skarn are pyrite, pyrrhotite, arsenopyrite, sphalerite and chalcocopyrite.

Two types of gold mineralization are identified in diamond-drill core (Figure 2-1-5). The first type is associated with massive pyrrhotite that replaces marble. The pyrrhotite contains up to 1 per cent pyrite with trace amounts of chalcocopyrite. The gold appears to be directly associated with the pyrrhotite which yielded assays exceeding 100 grams per tonne over a 2-metre intercept.

The second type is hosted by a brecciated quartz-pyrite vein. It appears to be filling a fracture zone which crosscuts both garnet skarn and marble. Massive white to medium-

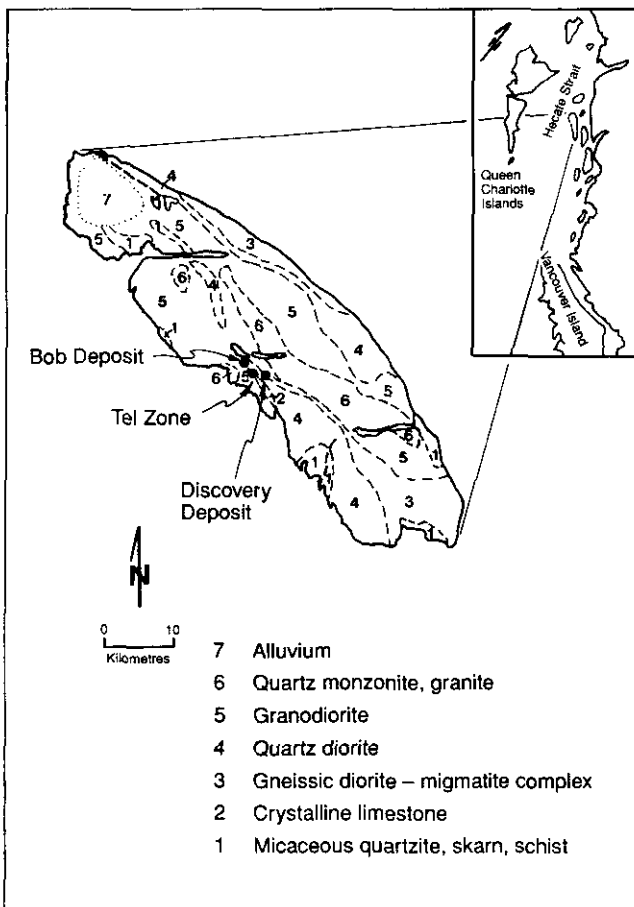


Figure 2-1-4. Location map of Banks Island deposits.

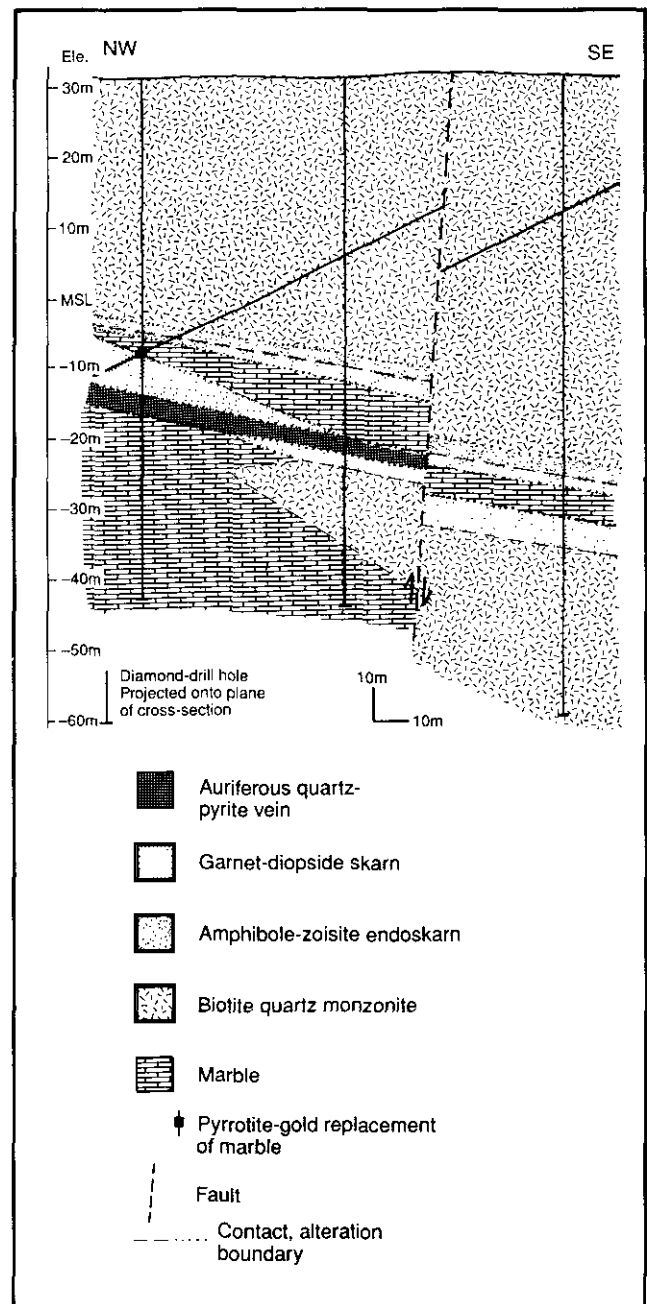


Figure 2-1-5. Cross-section of Discovery deposit, Banks Island.

grey quartz with coarse pyrite is fragmented and sometimes healed by a quartz-carbonate stockwork. Vuggy quartz commonly fills voids left by the oxidation and removal of pyrite. The possibility of a genetic link between skarn and quartz-pyrite vein mineralization is suggested. Both contain anomalous gold values and the healing of breccia textures by the quartz-carbonate stockwork indicates a complex hydrothermal history.

The recently discovered, previously undescribed mineralization of the Tel deposit is not directly related to skarn alteration but will nevertheless be briefly described. An anastomosing quartz-sulphide vein occurs within northwest-striking banded marbles and metapelites dipping approximately 60 degrees northeast. Mineralization is controlled by a westerly striking fracture zone near its intersection with a major northwest-striking lineament. The steeply dipping vein outcrops discontinuously for approximately 200 metres and varies in thickness from 1 centimetre to 3 metres. Drilling in 1987 indicates that the vein persists at depth and along strike, with the mineralization pinching and swelling in both directions.

The Tel vein is asymmetrically zoned. A breccia zone, approximately 20 to 30 centimetres wide and containing marble and quartz-calcite fragments, forms the northern margin of the vein. The breccia contains significant chlorite and a soft, light green mineral thought to be talc. Minor galena, sphalerite and pyrite occur within the matrix. This zone is not always present but is typically developed near northwest-striking crossfaults.

The inner edge of the breccia zone is marked by a 5 to 10-centimetre hematitic gouge consisting of fine sand and silt-sized material. Any original sulphides in this zone have been completely oxidized.

The primary sulphide-bearing part of the vein is approximately 40 to 50 centimetres wide and consists of massive pyrite with sporadic amounts of blackjack sphalerite, arsenopyrite, galena, chalcopyrite and tetrahedrite in dark grey quartz. This sulphide-rich zone is bounded to the south by a 20-centimetre bull-quartz zone with variable amounts of disseminated pyrite.

Fine-grained quartz + chlorite + pyrite with stringers of a very fine-grained sulphide, tentatively identified as galena, form the southern wall of the vein. This zone may be totally absent and is thought to represent a sheared mafic dyke.

Country rocks surrounding the vein are finely interbedded metapelites and marbles intruded by a quartz diorite of uncertain origin. Alteration of the host rocks is limited to hornfelsing of the pelitic layers and development of epidote-chlorite bands in the silty lenses. The marble is bleached and has limonitic staining adjacent to the vein. A brown phlogopitic alteration, differing slightly from biotite hornfelsing typically observed in pelitic sediments adjacent to hot plutons, replaces the sediments at depth. This alteration may be fracture controlled and hence metasomatic rather than contact metamorphic in origin. Only minor quantities of pink to reddish brown garnet and green diopside occur at the margins of alaskite dykes.

The limited development of garnet-diopside skarn at depth, and minor epidote alteration of the sediments on the surface, probably reflects the low permeability and porosity

of the host rocks. This may be due to total recrystallization of the host during regional metamorphism prior to pluton emplacement. Metasomatism is limited to early potassium alteration, incipient garnet-diopside formation along contacts, and minor epidote veining in the upper levels of the system.

## NANAIMO LAKES

(MINFILE 092F-182, 384; 92F/1W, 2E)

Byproduct-gold skarn mineralization is seen on the Jane, Toni, Kathy and Larry (JTKL) claims held by Goldbrae Developments Ltd., and the adjacent Villalta deposit held under option by Southern Gold Ltd., along the Nanaimo River approximately 40 kilometres west of Nanaimo. Gold mineralization occurs in a hematite-altered breccia of uncertain origin on the Villalta claims, and in massive garnet-diopside-amphibole skarn on the JTKL claims. While the Villalta mineralization is not skarn hosted, a genetic link between the two deposits is possible.

## HOST ROCK LITHOLOGY

Paleozoic Sicker Group volcanic and sedimentary rocks underlie most of the study area which is within the northwest half of the Cowichan - Horne Lake uplift described by Muller (1980). The Myra and overlying Buttle Lake formations, which form the upper two-thirds of the Sicker Group, outcrop on both claim groups and are host to the skarn mineralization on the JTKL property. The Myra Formation comprises medium to dark green siliceous tuff and black argillite which are locally altered to a brown biotite or pale green diopside hornfels. The Buttle Lake Formation comprises a massive crinoidal limestone which has been recrystallized to a white marble. Minor siltstone and chert form interbeds within the limestone.

The stratigraphic relationships above the Buttle Lake Formation become less clear. On the Villalta claims, a brecciated potassium-feldspar rhyolite porphyry up to 2.5 metres thick lies between the limestone and an unconformably overlying heterolithic breccia. The breccia has been variously described as Cretaceous Nanaimo Group conglomerate (Chandler and Runkle, 1985), or Paleozoic volcanic agglomerate (S. Quin, personal communication, 1987). The breccia consists of angular clasts of fine-grained dark green volcanic rock and lesser amounts of subrounded granitic and cherty fragments. The volcanic fragments are similar to lithologies observed on the JTKL claims. The matrix is generally dark green to brown and composed of fine to medium-grained particles of probable volcanic origin. The large volcanic component to this breccia, and the lack of marine or fluvial features commonly seen in Nanaimo Group sediments, suggest it is part of the Sicker Group.

Plutonism in this area is represented first by early to middle Jurassic Island Intrusions of granodioritic to dioritic composition. Skarns are developed where these diorites have intruded near limestone-volcanic contacts. Tertiary Catface intrusions are sparsely represented by small outcrops and short drill-hole intersections of hornblende feldspar porphyry sills and dykes.

## SKARN MINERALIZATION

Skarn mineralization on the JTKL claims occurs both in the lower Buttle Lake limestone and upper Myra volcanoclastic rocks. Jurassic quartz diorite contains epidote-amphibole endoskarn at surface and is associated with massive garnet-wollastonite skarn replacing limestone at depth. The latter consists of coarse-grained euhedral garnet varying from a massive yellow grossularite(?) to a later, fracture-controlled, brown andradite. The wollastonite is fine grained and forms the matrix surrounding garnet. The calc-silicate mineralogy seen on these claims is unique in that massive garnet outcrops exhibit crustiform banding, bladed and cockscomb crystal clusters, and a euhedral megacrystal habit possibly indicative of a low pressure (that is, near surface) environment of formation.

Where skarn replaces Myra volcanoclastic rocks, the garnet-diopside ratio decreases. Dark green amphibole increases and, together with epidote, replaces the earlier garnet; wollastonite is absent. Veinlets of earthy hematite crosscut the skarn and bright red hematite completely replaces zoned garnet. Coarse specular hematite and a fibrous form of magnetite, also observed at the Little Billie mine on Texada Island, occur in minor amounts.

Sulphide content of the skarn is generally low. Pyrite occurs in minor amounts as fine-grained clots and irregular disseminations throughout the skarn and scattered through the underlying volcanoclastic rocks. Chalcopyrite is present in trace amounts, associated with disseminated magnetite. Arsenopyrite was noted in one drill-hole intercept.

## ZEBALLOS

(MINFILE 092E-002, 092L-027, 068; 92E/15W, 92L/2W)

Amphibole-rich gold-bearing skarn mineralization occurs near the village of Zeballos on the northwest coast of Vancouver Island. Limited placer activity began along the Zeballos River in 1907 and lode gold was discovered in 1924. Zeballos Iron Mines Ltd. produced magnetite from skarn on the FL property in the early 1960s. Current activity is focused at the Privateer gold mine, a quartz vein deposit, in Spud Valley.

## HOST ROCK LITHOLOGY AND MINERALIZATION

The Hiller (Artlish, MINFILE 092L-027, 068) showing outcrops along Toray Creek approximately 15 kilometres northwest of Zeballos (Figure 2-1-6). Potential gold-skarn mineralization is hosted by volcanoclastic and marine sediments originally assigned to the lower Bonanza Formation by Hoadley (1953) and subsequently described as Parson Bay Formation by Muller (1977). Lithologies observed are intercalated aquagene tuffs, argillites, impure limestones and volcanic breccias which dip 20 to 30 degrees to the west, toward the Zeballos batholith. This sequence is underlain by the Quatsino limestone.

Skarn and unaltered host rock are complexly inter-fingered, reflecting both the original variability of the protolith and pre-skarn and post-skarn structural features. A simplified cross-section, based on 1984-1985 diamond drilling through the A-25 showing, is presented in Figure 2-1-7.

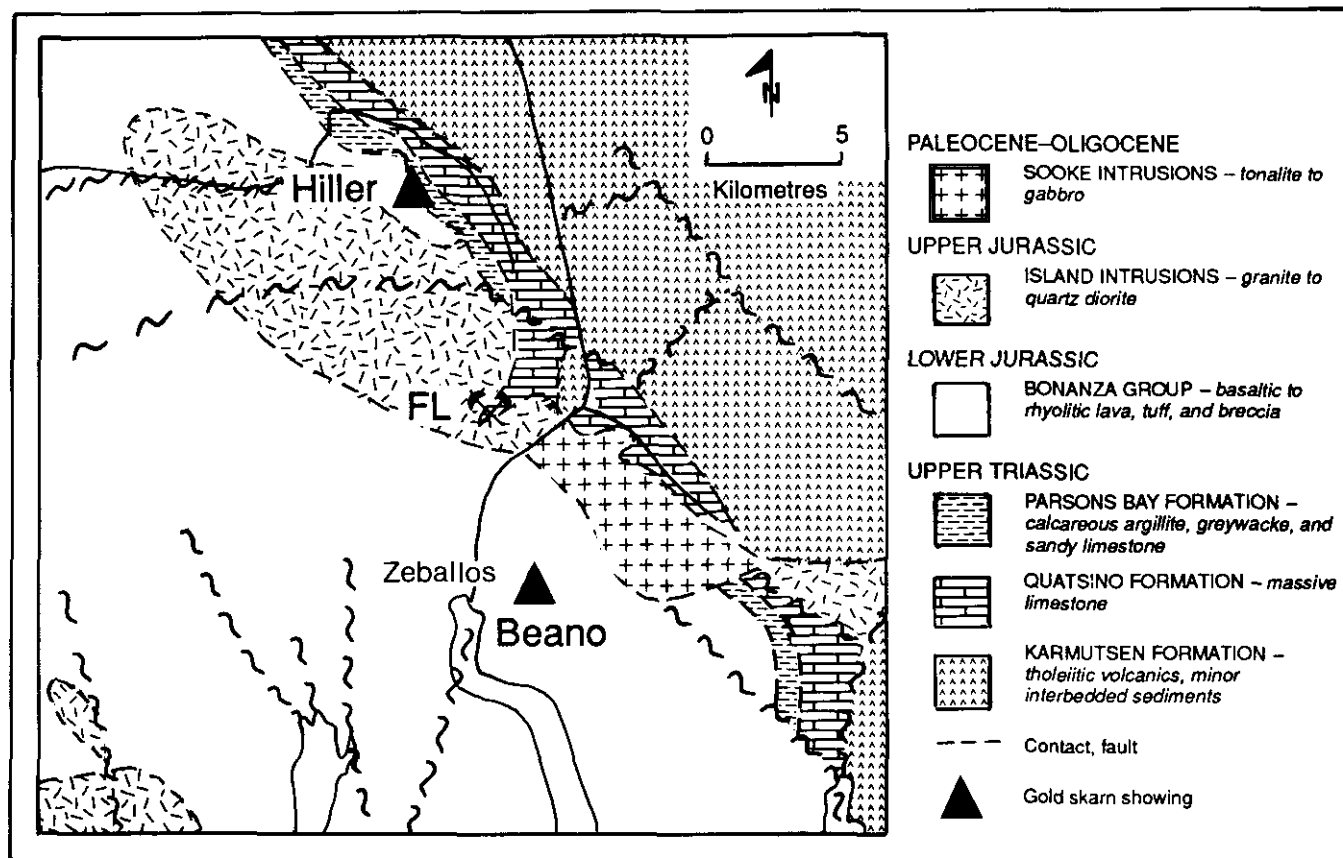


Figure 2-1-6. Location map of gold skarns near Zeballos.

Six separate units are identified in this section. Skarn occurs in a zone with an apparent thickness of 60 to 90 metres. Above and below this zone are unaltered calcareous Bonanza volcanoclastics, argillite and siltstone. Two different skarn types are present. One type, which is hosted by the Bonanza sequence, comprises dark green, fine to medium-grained felted masses of euhedral amphibole, and lesser light green euhedral pyroxene, calcite, quartz, chlorite, pyrrhotite, magnetite, pyrite and chalcopryrite. In this section, the amphibole is zoned with strong pleochroic light to dark green cores and clear to pale green rims. Chemical analyses by electron microprobe indicate the cores are probably hastingsitic hornblende while the rims are ferroactinolite.

The second skarn type replaces an intermixed sequence of limestone and volcanoclastic/argillite hosts. It contains abundant pyroxene, carbonate and sulphides, with lesser amphibole compared to the previously described skarn. It is commonly brecciated and contains rare pods of unreplaced marble and blocks of amphibole-rich skarn.

Gold mineralization favours this mixed protolith skarn. An analysis of the aggregate length of intercepts of each lithology in 2450 metres of drill core, and the distribution of gold assays greater than 1 gram per tonne in each of these lithologies, is presented in Table 2-1-3. These data show that

**TABLE 2-1-3**  
**AGGREGATE LENGTH OF INTERCEPTS OF EACH LITHOLOGY IN 2450 METRES OF DRILL CORE, AND DISTRIBUTION OF GOLD ASSAYS GREATER THAN 1 GRAM PER TONNE**

Lithology	% of Total Core Recovered	# Assays >1 g/t Au
Skarn; volcanic protolith .....	26	7
Volcanics/argillites .....	20	2
Dykes and sills .....	18	1
Skarn; volcanic/limestone mixed protolith .....	13	20
Skarn; limestone protolith <sup>1</sup> .....	12	6
Limestone and marble .....	9	3
Hornfels .....	2	

<sup>1</sup> This skarn consists of light green granular pyroxene, carbonate and minor amphibole. It is not exposed in the section presented in Figure 2-1-7.

although the second skarn-type only comprises 13 per cent of the lithology drilled, more than half of the assays greater than 1.0 gram per tonne gold are from this zone.

A similar amphibole-rich gold-bearing skarn outcrops on the Beano claims, approximately 3 kilometres east of Zeballos (Figure 2-1-6). The main Beano showing lies at the

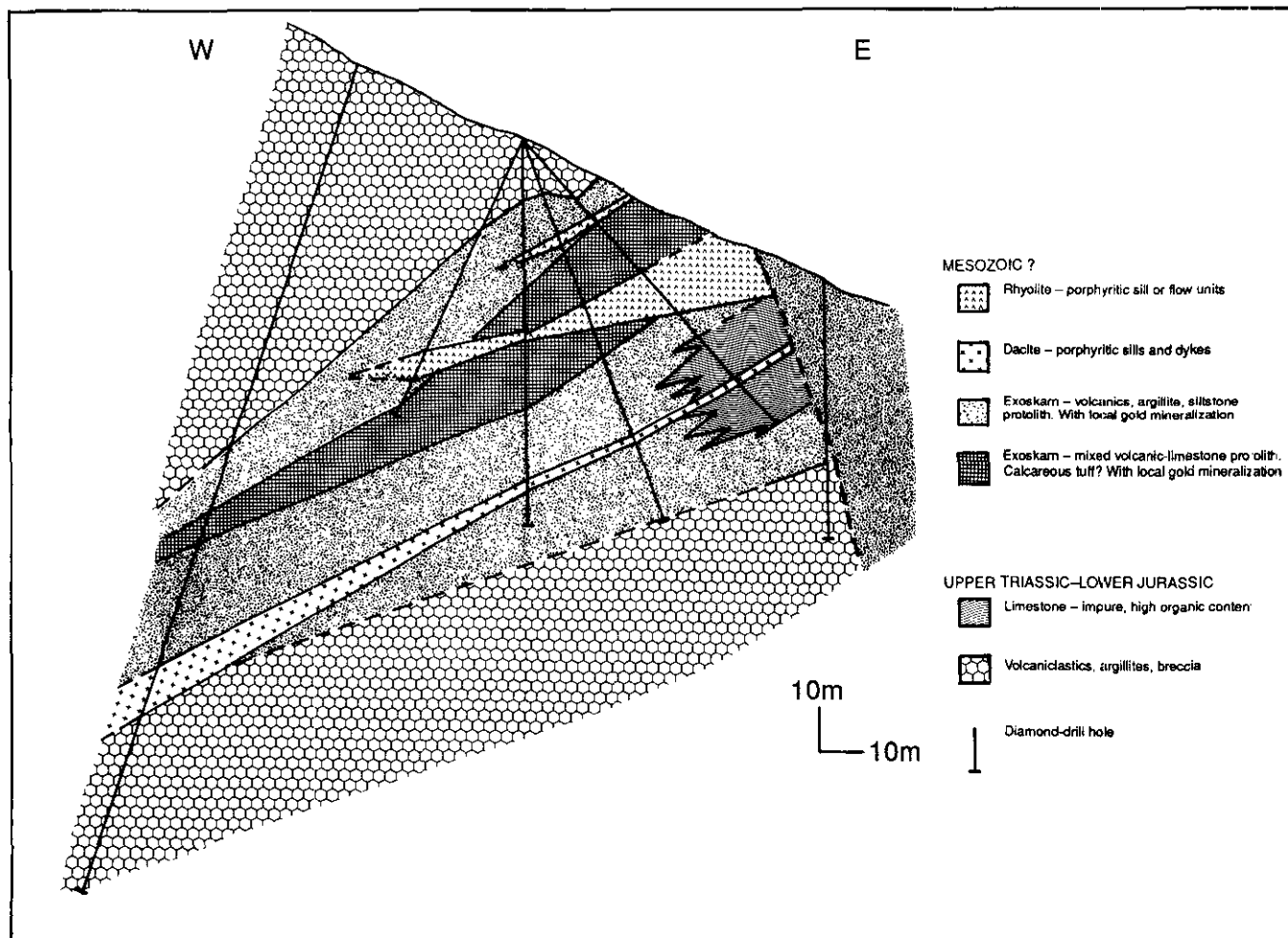


Figure 2-1-7. Cross-section through A-25 (Hiller) showing, Zeballos.



bottom of Bingo Creek canyon, at an elevation of about 760 metres. This showing is described by Muller *et al.* (1981) as a pyrrhotite-rich actinolitic skarn occurring in Bonanza volcanics. Mineralization consisting of fibrous actinolite, pyrrhotite and lesser chalcopyrite, is hosted by a limestone unit intruded by diorite. Quartz-carbonate veins containing auriferous pyrrhotite are also reported.

The showings along the west rim of the canyon, at the head of an old aerial tramway, were visited by the senior author. Workings consist of an adit and a stripped area on a heavily rusted outcrop of massive, fine to coarse-grained amphibole skarn containing pyrrhotite, arsenopyrite and pyrite.

Dark greenish grey fine-grained volcanic rock was the only rock type observed. The volcanics are hornfelsed and have undergone minor silicification. Dark green amphibole veins with white albitic(?) envelopes cut the hornfelsed volcanics.

### **MERRY WIDOW, KINGFISHER, OLD SPORT (MINFILE 092L-035, 044, 045; 92L/6)**

The area south of Benson Lake, approximately 30 kilometres southwest of Port McNeill, contains iron and copper skarn mineralization described by Lund (1966), Sangster (1969) and Meinert (1984). During the period from 1962 to 1973, the Old Sport mine produced 3869 kilograms of gold, 1731 kilograms of silver and 41.2 million kilograms of copper from 2.7 million tonnes of ore. From 1957 to 1967, 3.4 million tonnes of iron ore were mined from the Merry Widow and Kingfisher pits. While no gold production is reported from these two mines, seven grab samples collected from sulphide mineralization in the Merry Widow orebody returned an average of 19.2 grams gold per tonne (Eastwood and Merrett, 1962). Collectively, these mines form a series of gold-copper and iron-gold-enriched skarns associated with the same batholith and occurring at limestone-volcanic contacts.

### **HOST ROCK LITHOLOGY AND MINERALIZATION**

The orebodies lie at the contact between the Coast Copper stock and the Karmutsen, Quatsino and Bonanza formations. The Merry Widow and Kingfisher iron-gold skarns are located where a gabbroic phase of the batholith intrudes Bonanza volcanoclastics and underlying Quatsino limestone. Gold-copper skarn mineralization at the Old Sport mine is localized near the contact between the Coast Copper stock, Quatsino limestone and underlying Karmutsen basalts.

The occurrence of iron-gold and gold-copper-enriched skarns within the same district, and with intrusive rocks of similar composition and age relationships, was observed by the authors elsewhere (Jessie and Lily mines, South Moresby Island; Texada Iron and Little Billie mines, Texada Island; and Phoenix and Emma mines, Greenwood). The recognition of metallogenic zoning within individual skarn camps may have increasing exploration significance in the future (see Ray *et al.*, 1988, This Volume).

Skarn at the Merry Widow mine occurs primarily in volcanoclastic rocks of the Bonanza Group (Figure 2-1-8). Lapilli and crystal tuffs are replaced by garnet-epidote-diopside-amphibole skarn and illustrate the potential for

skarn development in carbonate-poor hosts. Several discontinuous magnetite-calcite breccia zones, rimmed by coarse brown garnet, occur at the volcanic-limestone contact and may crosscut the stratigraphy. The skarn is commonly characterized by repetitive bands of massive magnetite inter-layered with zones rich in epidote, amphibole, calcite or garnet (Plate 2-1-1).

Massive, dark grey, fine-grained volcanic rock is commonly recrystallized to a brown biotite hornfels and crosscut by a pale green diopside stockwork. This style of alteration is also observed in the Hedley gold camp and on the JTKL claims near Nanaimo Lakes.

Sulphide mineralization is best developed either within limestone, or along volcanic-limestone contacts. Sulphides present include chalcopyrite, pyrite, sphalerite and arsenopyrite. Cobalt mineralization occurs as erythrite in a zone of light-coloured calc-silicate alteration with possible manganese-rich pyroxene and potassium feldspar replacing volcanics.

The Old Sport mine is located approximately 3 kilometres north of the Merry Widow pit. The workings are no longer accessible, however Jeffrey (1960) and McKechnie and Merrett (1967) describe the geology of the mine area. The ore zone is located in a series of sills and skarn replacing basic volcanic rocks and marble. Samples collected from the dump indicate the skarn is pyrrhotite and chalcopyrite rich. Fibrous magnetite is intergrown with calcite and dark green amphibole. Considerable epidote, lesser dark green-black garnet and minor diopside were also observed.

### **OKA CLAIM GROUP (MINFILE 082E-025; 82E/13W)**

This occurrence is situated along Greata Creek, approximately 15 kilometres west-northwest of Peachland (Figure 2-1-9). During the 1987 field season Fairfield Minerals Ltd. was actively engaged in a surface stripping and sampling program at the Bolivar and Iron Horse showings within the claim block.

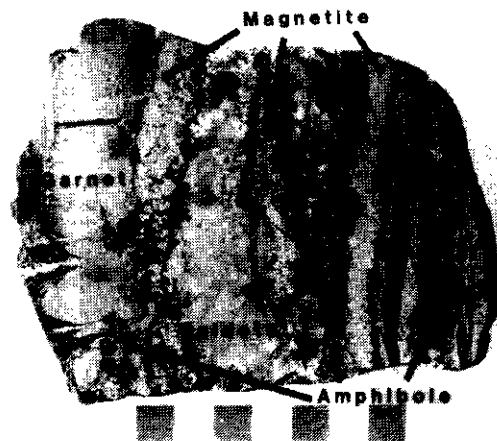


Plate 2-1-1. Banded magnetite-actinolite-epidote skarn, Merry Widow mine.

## HOST ROCK LITHOLOGY

The district was mapped by Little (1961) who identified granodioritic and dioritic rocks of the Cretaceous(?) Nelson batholith underlying much of the area. Upper Triassic Nicola Group rocks form pendants within the diorite and consist of crystal tuff, argillite, limestone and conglomerate. These sediments are believed to be similar in age to the Hedley

Formation which hosts the gold skarns at the Nickel Plate mine to the south.

## SKARN MINERALIZATION

The Iron Horse claim is underlain by Nicola Group limestones which have been recrystallized to a light to medium grey, medium-grained marble. These rocks are intruded by

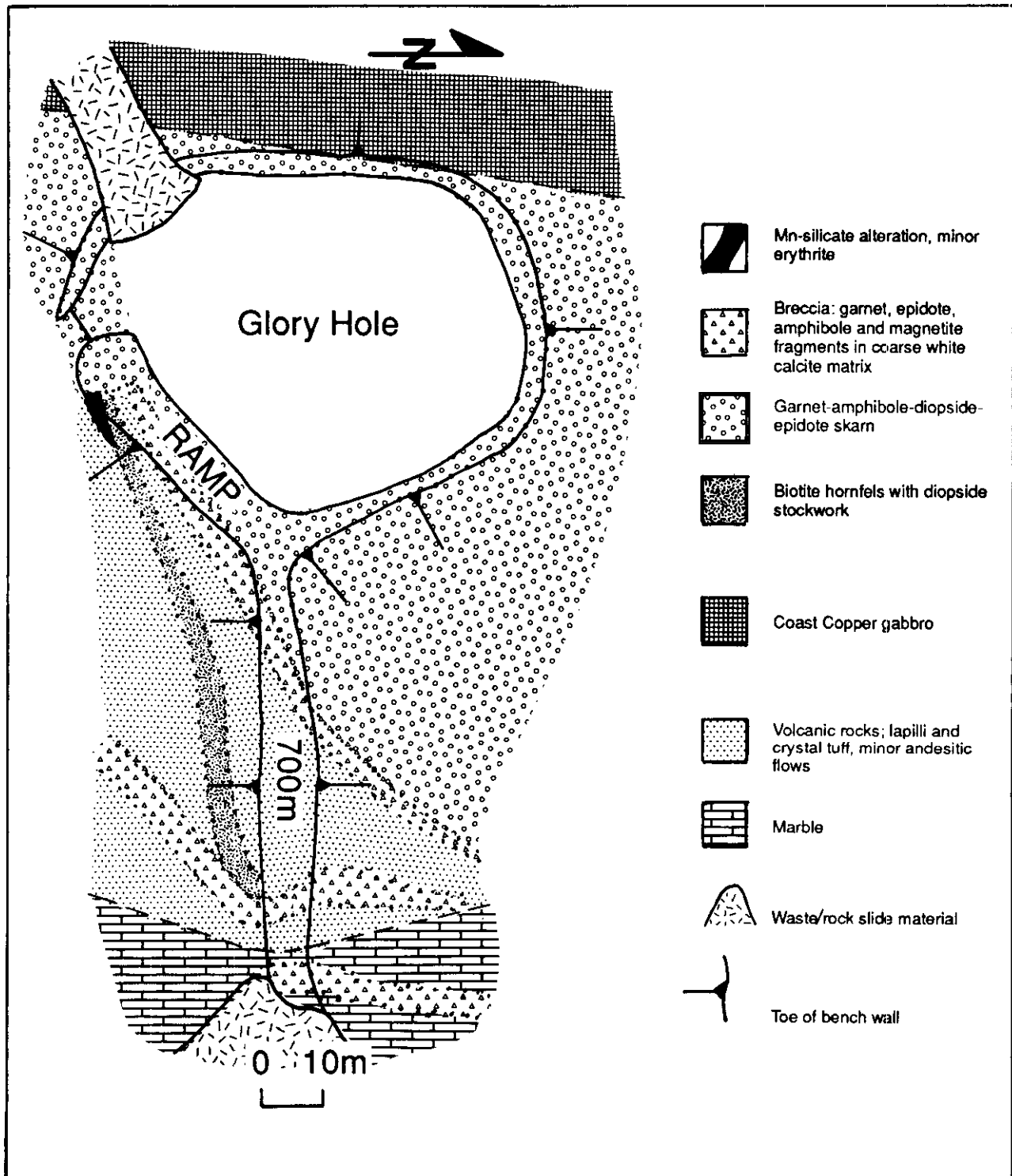


Figure 2-1-8. Geology of Merry Widow pit.

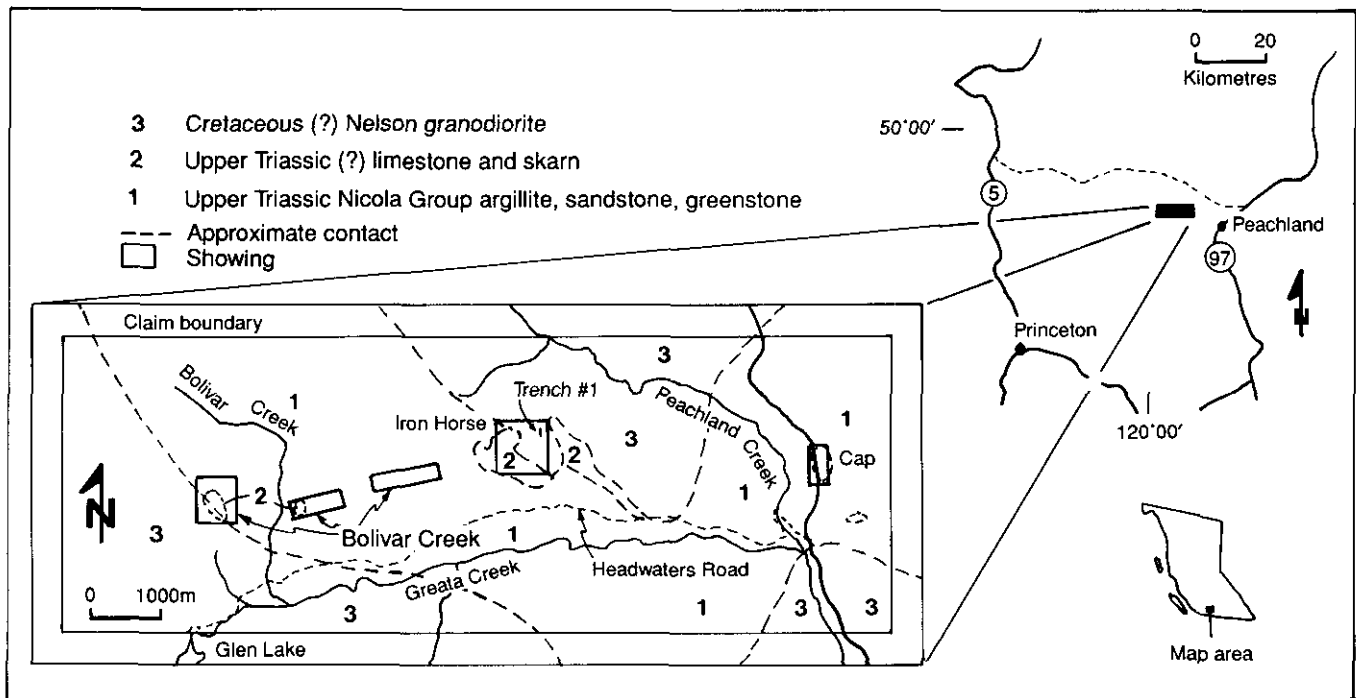


Figure 2-1-9. Location map of OKA deposits.

small stocks, dykes and sills of variable composition. Plugs of dioritic composition appear to be the earliest intrusions and result in skarn formation. The diorite has a poorly developed porphyritic texture with variable amounts of hornblende, biotite and plagioclase phenocrysts.

A general zoning pattern is seen in the stripped areas. Endoskarn within diorite consists of dark red-brown garnet and medium green diopside with variable amounts of dark green epidote and tan tremolite. Adjacent to the diorite, in the marble, skarn consists of medium brown garnet, pale green diopside, quartz and calcite. Further into the marble, a zone of fine-grained wollastonite and light brown garnet is sometimes present. Sulphides, comprising pyrite, pyrrhotite, arsenopyrite and chalcopyrite, occur at the skarn front, immediately adjacent to the unaltered marble. The sulphides form irregularly shaped massive pods, generally less than 20 metres across, which contain fine-grained quartz and diopside disseminated with the sulphides. Minor interbedded tuffaceous or cherty units have been hornfelsed to a fine-grained dark green diopsidic rock. This pattern can be seen in Trench 1 (Figure 2-1-10) where a biotite quartz diorite intrudes limestone and forms skarn. Remnant patches of quartz diorite are contained within a coarse garnet-diopside skarn and, toward the marble, the calc-silicate minerals become generally paler in colour, possibly representing decreasing iron content. Only sporadic minor amounts of pyrite are present.

The controls to the primary gold mineralization on the OKA properties are currently uncertain; in addition to the primary skarn-related gold, some secondary enrichment along late fractures may be present. Gold assays in chip samples "greater than 1 gram per tonne" are reported by Fairfield Minerals from diorite and massive sulphides, although not all sulphide pods contain this amount of gold.

Similar anomalous gold values occur in the footwall of a northeasterly striking reverse fault which crosscuts one of the sulphide pods.

#### DIVIDEND-LAKEVIEW MINE (MINFILE 082/SW-001; 82E/3W, 4E)

Gold-enriched skarn mineralization occurs approximately 3 kilometres southwest of Osoyoos (Figure 2-1-1). During the period from 1907 to 1939, 504 kilograms gold, 88 kilograms silver and 73 000 kilograms copper were produced from 111 300 tonnes of ore. This deposit consists of garnet-epidote skarn that replaces volcanic rocks and thinly interbedded marbles of either the Anarchist Group or Kobau Group of probable Permo-Triassic age.

#### HOST ROCK LITHOLOGY

Cockfield (1935) placed the rocks in the property area within the Anarchist Group, but later work by McKechnie (1964) suggested they belong to the Kobau Group. They comprise micaceous quartzites, mica and chlorite schists, limestone and greenstone; all rocks, other than the limestones, are sheared and exhibit schistose textures. The limestones form discontinuous lenses which have been totally recrystallized near ore-bearing horizons. Within the claims there are also andesitic to basaltic flows which are altered to an epidote-calcite-sericite rock and garnet-quartz-epidote-hematite skarn.

Intrusive rocks outcropping on the property are part of the Cretaceous Nelson batholith which is exposed over a wide area of southeastern British Columbia and northern Washington. This pluton is quartz dioritic to dioritic in composition and generally comprised of medium-grained and equi-

granular subhedral biotite, hornblende and plagioclase phenocrysts in a groundmass of anhedral quartz, plagioclase and potassium feldspar. However, no diorite was identified in the pit area and the closest dioritic outcrops are about 1 kilometre to the north.

### SKARN MINERALIZATION

The immediate area of the Dividend-Lakeview mine is underlain by altered andesitic flows and tuffs that exhibit a weak to moderate schistose foliation. An epidote stockwork

and intense chlorite-carbonate alteration of the volcanics extends throughout the property and is overprinted by skarn in the mine area. Quartz-calcite veining with pyrite, chalcopyrite and minor malachite and azurite staining cuts the sheared volcanics and extends well beyond the area replaced by skarn.

Garnet, epidote, amphibole and minor diopside replace greenstone and a thin limestone lens at the minesite. Where coarse-grained calc-silicate minerals are not developed, the volcanic rocks are hornfelsed and the limestone has been recrystallized to a light grey to white, medium-grained marble.

Skarn silicates and magnetite are more common in the volcanic host while sulphides are more abundant in skarn that replaces limestone. Arsenopyrite, pyrrhotite, pyrite and minor chalcopyrite occur in irregular massive pods surrounded by a light yellowish brown oxidation product. Limestone is totally replaced by sulphides while the volcanics above and below the marble lens are altered to garnet-epidote skarn. Massive magnetite with minor chalcopyrite occurs in a mine pillar and is associated with deep brown, coarse-grained garnet at the limestone-volcanic contact. Elsewhere, garnet is pale amber in colour and fine to medium grained.

Similar mineralization can be followed along a westerly strike from the Dividend-Lakeview pit. Several small exploration pits expose garnet-epidote skarn with disseminated pyrrhotite, arsenopyrite, pyrite and chalcopyrite. This linear trend of mineralization, together with strong shearing of the volcanics in the mine area, is a strong indication of a structural control to skarn mineralization.

### GREENWOOD MINING CAMP

(MINFILE 082/SE-013, 014, 020, 021, 025, 026, 031, 034, 062, 063; 83E/2E)

Gold-bearing copper and/or iron skarn mineralization occurs at several locations in the Greenwood mining camp. The Greyhound, Mother Lode, Oro Denoro, Phoenix and Marshall deposits (Figure 2-1-11) produced a total of 36 tonnes of gold, 217 tonnes of silver and 270 000 tonnes of copper from 31.8 million tonnes of ore.

The district is the site of several styles of mineralization resulting from multiple stages of intrusive activity and a complex structural history characterized by north-northwest-trending basin-and-range faulting. The economic geology, structural evolution and stratigraphy of the Greenwood camp have been described by Peatfield (1978), Little (1983) and Church (1986).

### HOST ROCK LITHOLOGY

The oldest rocks in the area are the Paleozoic Attwood and Knob Hill groups. Bedded argillites, limestones, turbidites and mafic lavas characterize the Attwood Group while cherts, mica schists, amphibolite and marble dominate the Knob Hill Group. The Brooklyn Group unconformably overlies these Paleozoic basement rocks and is host to most of the economic skarn mineralization in the district. The lower part of the Brooklyn Group consists of a sharpstone conglomerate unit, which is altered to skarn in the southern end of the Phoenix pit. A massive light grey limestone with minor

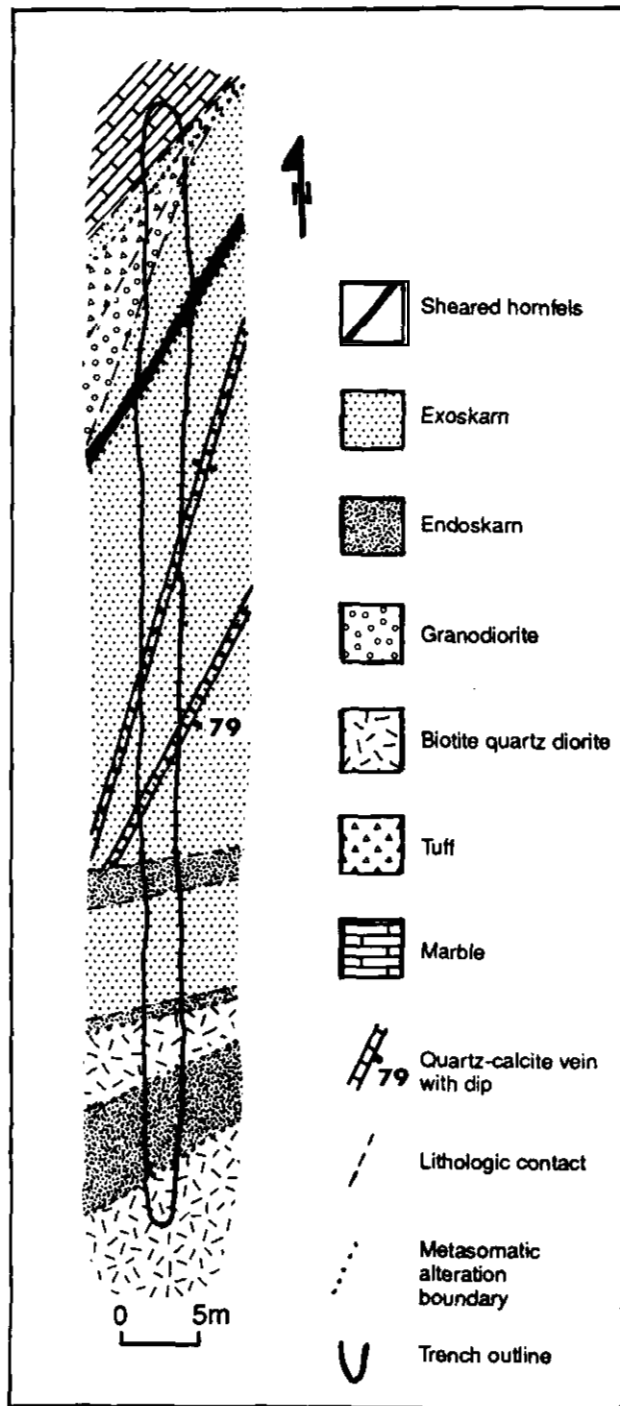


Figure 2-1-10. Iron Horse trench geology, OKA deposit.

siliceous partings overlies the conglomerate in the Phoenix and Brooklyn mines. Locally it has been highly brecciated as at the Greyhound and Oro Denoro mines. Skarn development in the district is preferentially controlled by this limestone and the underlying conglomerate beds. The upper part of the Brooklyn assemblage contains limestones, tuffs, volcaniclastic rocks and minor flows. Fossil evidence from an interbedded limestone lens shows this unit to be Late Triassic (Little, 1983). The Brooklyn Group is unconformably overlain by the Tertiary Pentiction Group described by Church (1986). This sequence is made up of the Kettle River Formation and overlying Marron Formation.

Eight intrusive phases have been identified by Church (1986). The major intrusive event is represented by the Cretaceous Greenwood and Wallace Creek batholiths which are considered to be part of the Nelson batholithic mass and genetically related to skarn development in the Greenwood camp. Earlier intrusive activity involves diorite, micro-diorite, quartz feldspar porphyry and gabbro bodies that show varying degrees of alteration, but are not considered to be associated with economic skarn mineralization.

Post-Nelson intrusive activity includes several small late Mesozoic ultrabasic bodies, monzodiorite and pulaskite sills

and dykes, and the alkalic Coryell intrusions, all of Tertiary age. These intrusions are associated with several types of mineralization exposed at numerous showings throughout the district. None have received much attention for their gold skarn potential.

### SKARN MINERALIZATION

There are two main types of skarn within the Greenwood district: gold-enriched copper skarn as represented by the Mother Lode, Phoenix and Marshall deposits; and gold-enriched iron skarn as represented by the Oro Denoro and Emma deposits. In both skarn types, garnet, epidote and diopside are the primary calc-silicate minerals. The copper-bearing skarns contain chalcopyrite, pyrite, specular and earthy hematite, and lesser magnetite and pyrrhotite as the primary opaque phases; the iron-rich skarns contain magnetite, chalcopyrite and pyrite.

At the Marshall deposit, approximately 1.5 kilometres northwest of the Phoenix pit, skarn is developed at the contact between Brooklyn limestone and an underlying siliceous siltstone. At the main showing, massive pyrrhotite with minor chalcopyrite replaces limestone, remnants of which are recrystallized to a medium-grained marble. Fine-

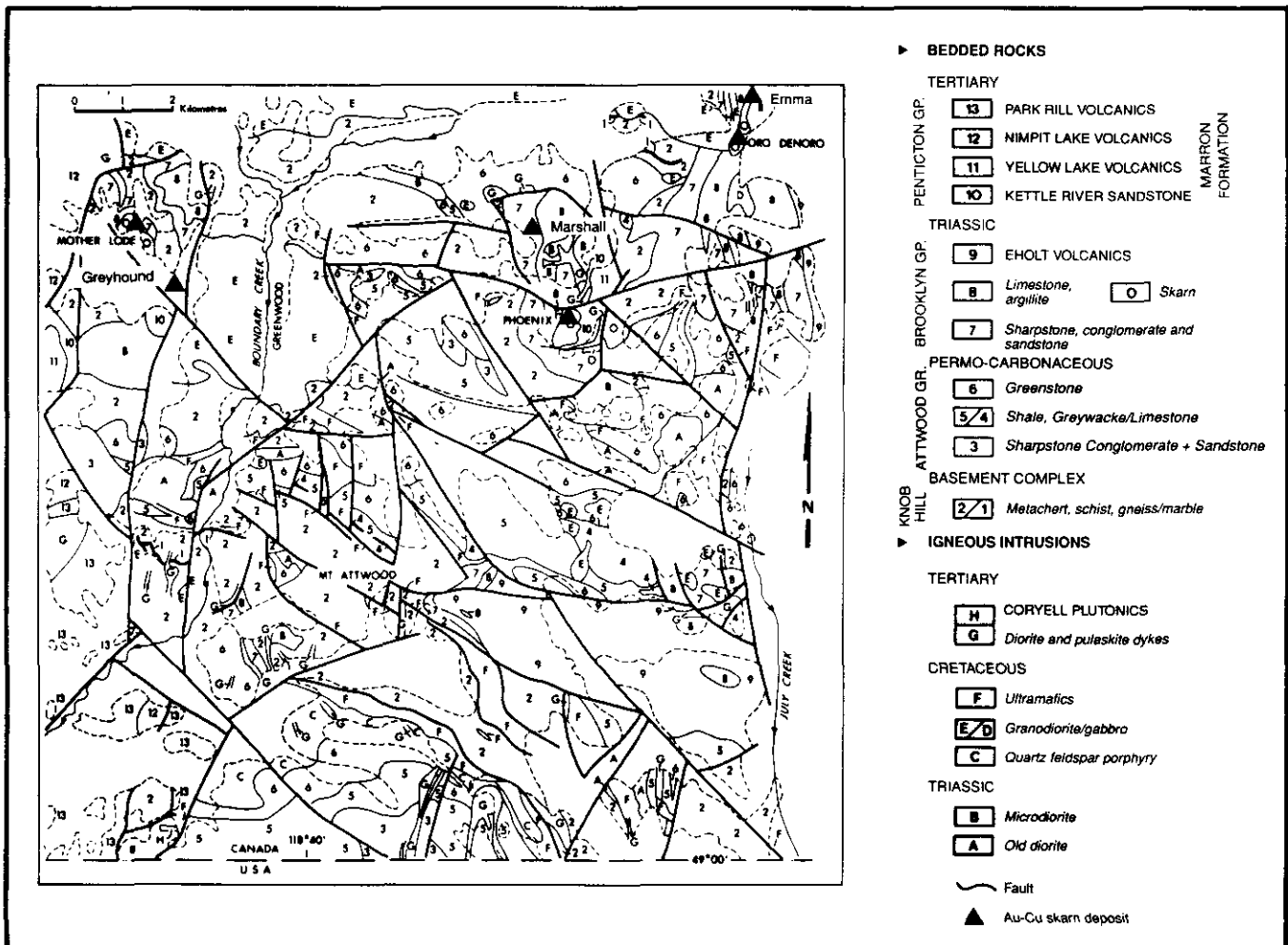


Figure 2-1-11. Location map of skarn deposits in Greenwood camp.

grained, dark green amphibole occurs sporadically in the marble and adjacent hornfelsed siltstone. At one location, a small pod of diopside-amphibole skarn is separated from marble by a lens of massive pyrrhotite-chalcopyrite-magnetite. An altered outcrop of microdiorite occurs in the area. This deposit may represent skarn formation resulting from pre-Nelson intrusive activity.

In the Phoenix mine, sharpstone conglomerate contains angular chert clasts and greenstone fragments in a sandy, chloritic matrix. However, due to skarning, clasts are generally hard to distinguish. Dark brown garnet, chlorite and epidote are the primary minerals replacing both the matrix and fragments. Chalcopyrite and pyrite are observed in skarn near the contact between the conglomerate and Brooklyn limestone along the southern benches. Magnetite was only found in waste piles. However, specular hematite occurs in veinlets crosscutting garnet skarn over a wide area; it commonly occurs as coarse plates associated with calcite and chalcopyrite (Plate 2-1-2), but also as fine disseminations in skarn.

Skarn at the Oro Denoro mine consists of massive reddish brown garnet and magnetite with coarse megacrystal calcite. Later chlorite and amphibole(?) veinlets can be seen replacing the garnet. Skarn is localized in limestone and possibly sharpstone conglomerate beds at a contact with Nelson granodiorite. At the north end of the main workings, endoskarn occurs in the granodiorite. Minor epidote-hematite-chlorite alteration, with bleaching of the intrusion, grades to massive garnet-epidote-chalcopyrite skarn and overprinting of original igneous textures. This type of alteration and mineralization is seen in many calcic iron skarns elsewhere in British Columbia.

The Emma deposit lies approximately 1.5 kilometres north of the Oro Denoro mine. This deposit follows the contact between the northerly striking Brooklyn limestone and underlying siltstone beds close to the margin of Cretaceous granodiorite. It is uncertain whether the skarn is genetically related to this granodiorite body or to a suite of Early Mesozoic microdiorite bodies in the area. The microdiorites grade into greenstone of the Eholt Formation and are interpreted to be feeder dykes for these volcanics. Skarn

consists of reddish brown garnet, epidote and massive magnetite which is preserved in pillars in the mine area.

## NICKEL PLATE MINE

(MINFILE 092H/SE-037, 038, 062; 92H/8E)

The Hedley camp has had a long history of gold production from several skarn deposits (Camsell, 1910; Billingsley and Hume, 1941; Dolmage and Brown, 1945), but most of the production was derived from one very large deposit which was worked in the Hedley Mascot and Nickel Plate mines. Recent work by Ray *et al.* (1986, 1987, 1988) indicates that the deposits are surrounded by exceedingly large skarn envelopes, and that the auriferous mineralization represents a very small proportion of the total alteration. Mineralization in the camp is unusual in being sporadically enriched in arsenic, bismuth, nickel, tellurium and cobalt. The gold-bearing sulphide zones normally form semi-conformable tabular bodies situated less than 100 metres from the lower, outer skarn margin.

A cross-section through the Nickel Plate orebody currently being mined by Mascot Gold Mines Ltd. is shown in Figure 2-1-12. Three rock types are observed in this section: Sunnyside limestone and marble, altered Hedley intrusion sills and dykes (endoskarn), and exoskarn. Three of four drill holes bottomed in marble. The marble is white to greenish grey and commonly includes irregularly distributed lenses of silica replacement that contain disseminated pyrrhotite, arsenopyrite and pyrite. The limestone is dark grey to black, fine grained and contains small fossil fragments, abundant organic material, finely disseminated pyrite and small black euhedral amphibole crystals.

The Hedley intrusions form concordant sills and near-vertical dykes in the mine area. They are commonly altered to skarn, although complete metasomatic replacement of igneous texture is unusual. These sills and dykes are calc-alkaline I-type diorites to gabbros (Ray *et al.*, 1987, 1988). Relatively fresh diorite contains up to 15 per cent subhedral tabular plagioclase and 0.5 to 2 per cent anhedral hornblende phenocrysts in a dark, fine-grained matrix of plagioclase and amphibole. Alteration in the intrusions is highly variable in style. In the "north-45 dyke", intersected in hole MG85-229, it is limited to chlorite and epidote replacement of the plagioclase phenocrysts. Bleaching of the phenocrysts also occurs rimming a chlorite-epidote stockwork. This dyke is near vertical and strikes subparallel to the line of section, resulting in the large apparent width of dyke depicted in Figure 2-1-12. Another style of alteration forms a milky dark brown flooding of the matrix, similar in appearance to a biotite hornfels. Further chemical analyses and petrographic work are required to identify this mineralogy.

As illustrated by Section 33 + 50, essentially all country rock above the marble has been altered to skarn. Remnant lithologies are present only as thin discontinuous lenses of hornfelsed argillite and tuffaceous siltstones. Skarn development is strongly controlled by lithology and the thinly laminated, alternating zones of garnet-rich and diopside-rich skarn follow the original bedding. Minor wollastonite is generally associated with diopside adjacent to garnet stringers. Retrograde alteration of garnet and diopside to amphibole, chlorite or epidote is rare although Simpson and Ray

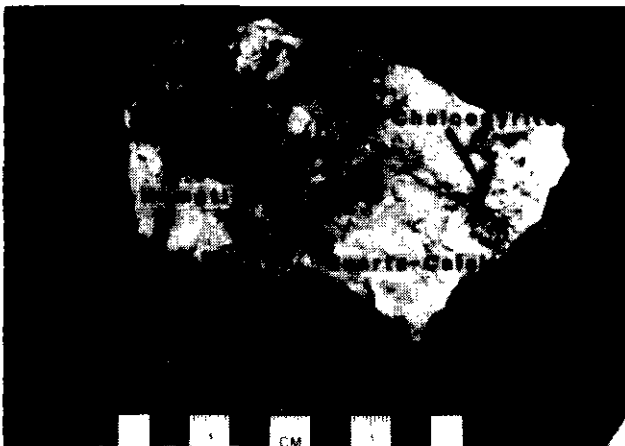


Plate 2-1-2. Specular hematite and chalcopyrite in quartz-calcite vein, Phoenix mine, Greenwood.

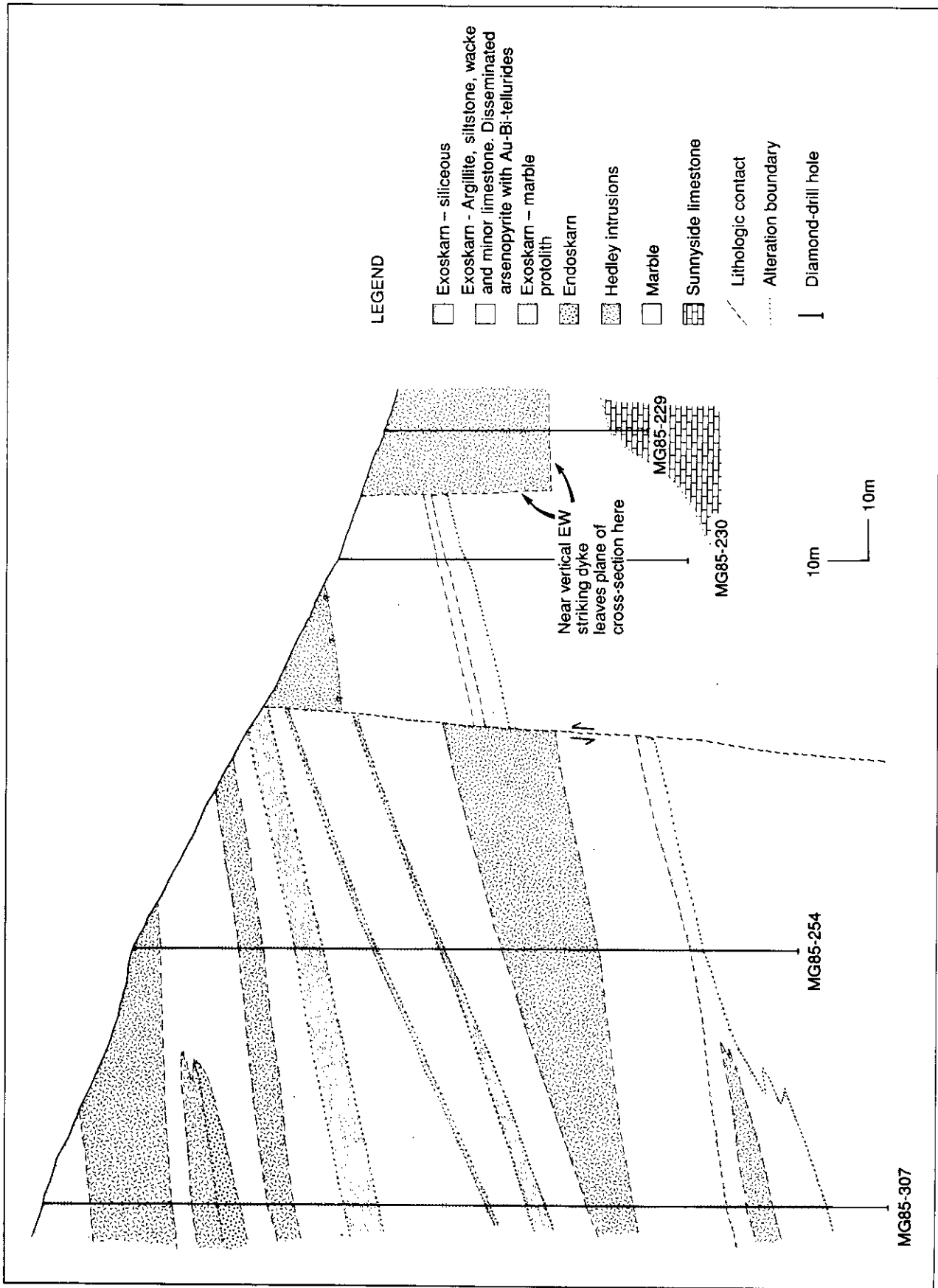


Figure 2-1-12. East-west cross-section through Nickel Plate orebody.

(1986) postulate an early and late stage of retrograde alteration replacing the prograde skarn minerals. The early stage, as described by Ray and Simpson, consists of tremolite, calcite, quartz and epidote; however, recent electron microprobe analyses indicate much of the "tremolite" is wollastonite, an unlikely retrograde product.

Gold mineralization is associated with the latest stage of alteration. Calcite, quartz and gold-bearing sulphides (pyrrhotite, pyrite, arsenopyrite, hedleyite, native bismuth and maldonite) were deposited near the skarn-marble boundary (Figure 2-1-12). The quartz-calcite-sulphide assemblage may result from low-temperature hydrous alteration of aluminum-poor calc-silicate minerals (granditic garnet and diopside/hedenbergite). This alteration may have occurred late in the skarn-forming process during cooling of the intrusive components and invasion of the hydrothermal system by cool meteoric fluids.

### TP CLAIMS

#### (MINFILE 104M-048, 050; 104M/10E)

Gold and cobalt mineralization occurs in skarn on the southwest flank of Teepee Peak, 50 kilometres west of Atlin (Figure 2-1-1). The main skarn zone measures approximately 15 by 200 metres and consists of four skarn types: magnetite with minor calcite, garnet and amphibole; calc-silicate skarn with calcite, garnet and epidote; amphibole skarn; and marble-rich skarn (T.G. Schroeter, personal communication, 1987). Mineralization is hosted by pre-Triassic gneisses and schists of the Yukon Group (M. Mihalynuk, personal communication, 1987). Exploration work completed in 1983 outlined two northwesterly trending fracture zones that cut the amphibole skarn. Gold and cobalt/erythrite mineralization is primarily hosted within these fracture zones. Chip samples from trenches across the fracture zones returned composite average assays up to 15.0 grams per tonne gold and 3.91 per cent cobalt over 3.5 metres. Minor amounts of arsenopyrite are also reported.

Cobalt enrichment in skarns is seen elsewhere in British Columbia, in the Hedley district (*see Ray et al.*, 1988) and at the Merry Widow mine. Einaudi and Burt (1982) and Meinert (1984) report that cobalt enrichment is characteristic of calcic-iron skarns, however, cobalt is present in some other gold-enriched skarns (Cox, 1986; Cox and Theodore, 1986; Orris *et al.*, 1987) and may be a useful pathfinder element for these deposits.

### CONCLUSIONS

Skarns are hosted by a variety of lithologies, but the more auriferous skarns are found in assemblages characterized by one or more of the following:

- (1) Sequences of impure clastic rocks containing massive to thinly bedded limestones and calcareous pelites. The argillites and siltstones commonly have a fine tuffaceous component.
- (2) Submarine volcanic flows, crystal and lapilli tuffs, and their hypabyssal equivalents in the form of dykes and sills, may be interlayered with argillites, cherts and calcareous tuffs.

- (3) The host rocks have not undergone significant regional metamorphism and do not generally exhibit a strong metamorphic foliation. Hornfelsing and recrystallization of limestone are common and may result from thermal effects during intrusive emplacement.
- (4) Structural deformation is manifest as one or more of the following: pre-skarn normal and reverse faults which act as fluid conduits and facilitate metasomatic alteration; microfracturing and jointing of intrusive and country rocks; post-skarn remobilization of gold and sulphide minerals into later faults and fractures; and pre or syn-skarn folding of the host rocks resulting in skarn formation in the fold hinges.

Geochemical and mineralogical signatures of gold-bearing skarns make them distinct from base metal skarns as classified by Einaudi *et al.* (1981). Many are sporadically enriched in arsenic, bismuth, tellurium, cobalt and tungsten present as arsenopyrite, hedleyite, bismuthinite, native bismuth, maldonite, hessite, tetradymite, cobaltite, erythrite and scheelite. Sulphide and oxide mineralogies are simple with pyrrhotite, pyrite, chalcopyrite, arsenopyrite and magnetite being by far the most common. Hematite may be important locally. Gold anomalies in soils above skarn zones are sometimes spectacular, with values over 10 000 ppb being reported from several deposits.

Two intrusive phases are present in some gold skarn camps, (for example, Tillicum Mountain and Hedley; *see Ray et al.*, 1988). The initial skarn-related intrusions are often small and dioritic or gabbroic in composition. The later phase is represented by granodiorite or quartz monzonite plutons, often of batholithic proportions. It is uncertain whether the two phases are genetically related.

Preliminary data suggest that the Nickel Plate and Tillicum Mountain deposits and the OKA occurrence are associated with calc-alkaline I-type intrusions as are the calcic iron skarns of western British Columbia (Meinert, 1984). These are distinct from certain gold-enriched copper porphyries such as Copper Mountain (Preto, 1972) and Cariboo-Bell (Simpson and Saleken, 1983) which contain some skarn-like alteration minerals including garnet, epidote, scapolite and carbonate. This skarn-like mineralization differs from the Hedley, Tillicum Mountain and Texada Island gold-bearing skarns in being associated with high-level, alkalic intrusives.

### ACKNOWLEDGMENTS

Several companies extended logistical and technical support for the fieldwork phase of this study. The authors wish to acknowledge the invaluable assistance offered by Stanley Beale and Mike Ryan of Vananda Gold Ltd.; Ron Simpson and Peter Thomas of Mascot Gold Mines Ltd.; Barney Bowen and Andrew Hamilton of Fairfield Minerals Ltd.; Mohan Vulimiri and Sheila Crawford of Trader Resource Corporation; and Dr. James Fyles of Kettle River Resources Ltd. Dr. John Gammon and Falconbridge Ltd. are gratefully acknowledged for their assistance during the 1985 and 1986 field seasons. The senior author also wishes to thank Nick Gibson for his assistance while in the field.



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