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# Mineral Deposit Studies

# METALLOGENIC STUDIES OF LODE GOLD-SILVER OCCURRENCES IN SOUTH-CENTRAL BRITISH COLUMBIA: A PROGRESS REPORT (82E, 82L)

By R.E. Meyers and W.A. Taylor

**KEYWORDS:** Economic geology, metallogeny, lode gold-silver, epithermal, mesothermal, Okanagan.

## INTRODUCTION

The recent success experienced by the exploration industry in newly discovered mining camps in northwestern British Columbia, combined with new discoveries and the successful regeneration of historical mining camps of the Canadian Shield and in the Western United States has encouraged industry re-assessment of the potential for precious metal lode deposits in southern British Columbia.

The objective of this study is to provide the explorationist with a review of precious metal occurrences in south-central British Columbia, their geologic setting and their character. Attention is drawn to the nature and potential of current exploration targets and the contrasts between them, and the type of deposits that have been historically exploited. The initial focus is in the Okanagan region, specifically on map sheets 82E/W and 82L/SW (Figure 2-1-1), where two recent epithermal discoveries have prompted a substantial increase in exploration activity.

This preliminary report summarizes the results of field observations and compilation of data from 127 precious metal lode occurrences in the Okanagan region. Other types of gold occurrences, such as copper-gold porphyries and gold-bearing skarns are not dealt with in this study, although a few skarn-related vein deposits are included.

## SOURCES

Information has been compiled from 31 property visits, property descriptions researched from British Columbia Minister of Mines Annual Reports, MINFILE, assessment reports, Geological Survey of Canada publications and district property files, as well as from some earlier compilations (Dawson *et al.*, 1984). Occurrences were selected on the basis of having a "reasonable" tenor of mineralization. Very small, isolated veins with only geochemically anomalous values were avoided. In most cases the historic property names have been used in preference to more recent claim names. All properties are tabulated and plotted at 1:250 000-scale in Open File 1989-5 (Meyers *et al.*, 1989).

The geology of the Okanagan region is presented in the context of new interpretations by Parrish *et al.* (1988) and others. Geological information for the Penticton map sheet (82E/W) has been primarily derived from Tempelman-Kluit (in press) and for 82L/SW from Wheeler and McFeely (1987).

## REGIONAL GEOLOGY

The Okanagan region is underlain by a diverse assemblage of rocks, ranging in age from late Paleozoic to early Cenozoic (Bostock, 1941; Jones, 1959; Little, 1961). The region is bisected by the Okanagan Valley, which represents a major tectono-stratigraphic break separating high-grade metamorphic rocks of the Okanagan metamorphic complex to the east from lower grade Carboniferous to Triassic metasedimentary and metavolcanic rocks to the west. The fault system is projected from Washington State along the full length of the Okanagan Valley to north of Shuswap Lake (Tempelman-Kluit and Parkinson, 1986; Parrish *et al.*, 1988).

The Okanagan metamorphic complex occupies the western flank of the Omineca Belt and includes amphibolite-grade orthogneiss and paragneiss intruded on a broad scale by deformed granitoid plutonic rocks of the middle Jurassic Nelson suite and the Jura-Cretaceous Valhalla suite. The age of the gneiss complex was previously thought to be as old as Precambrian (Bostock, 1941; Little, 1961; Okulitch and Woodsworth, 1977), however, studies by Medford (1975), Mathews (1981), Parkinson (1985) and Parrish *et al.* (1988) have produced fission-track, uranium-lead and potassium-argon isotopic ages as young as late Eocene.

On the west side of the Okanagan Valley, late Paleozoic to middle Mesozoic sedimentary and volcanic rocks of island arc and oceanic derivation have preserved Mesozoic penetrative deformation and are metamorphosed to greenschist facies. As on the eastern side, these rocks are intruded by Nelson and Valhalla plutonic rocks but contrast dramatically in their metamorphic history.

Pre-Tertiary rocks on both sides of the Okanagan Valley are unconformably overlain, in places, by thick accumulations of Eocene volcanic and sedimentary rocks that are generally unmetamorphosed. Church (1982) and Tempelman-Kluit (in press) have correlated outliers of the Eocene sequence, and Parrish *et al.* (1988) interpret them as remnants of a continuous depositional basin that covered the southern Okanagan.

Recently presented evidence (Parrish *et al.*, 1988, Tempelman-Kluit and Parkinson, 1986, Bardoux, 1985) indicates that the Okanagan fault system formed as a series of low-angle, west-dipping normal faults with east to west movement, placing lower grade rocks to the west against higher grade rocks to the east.

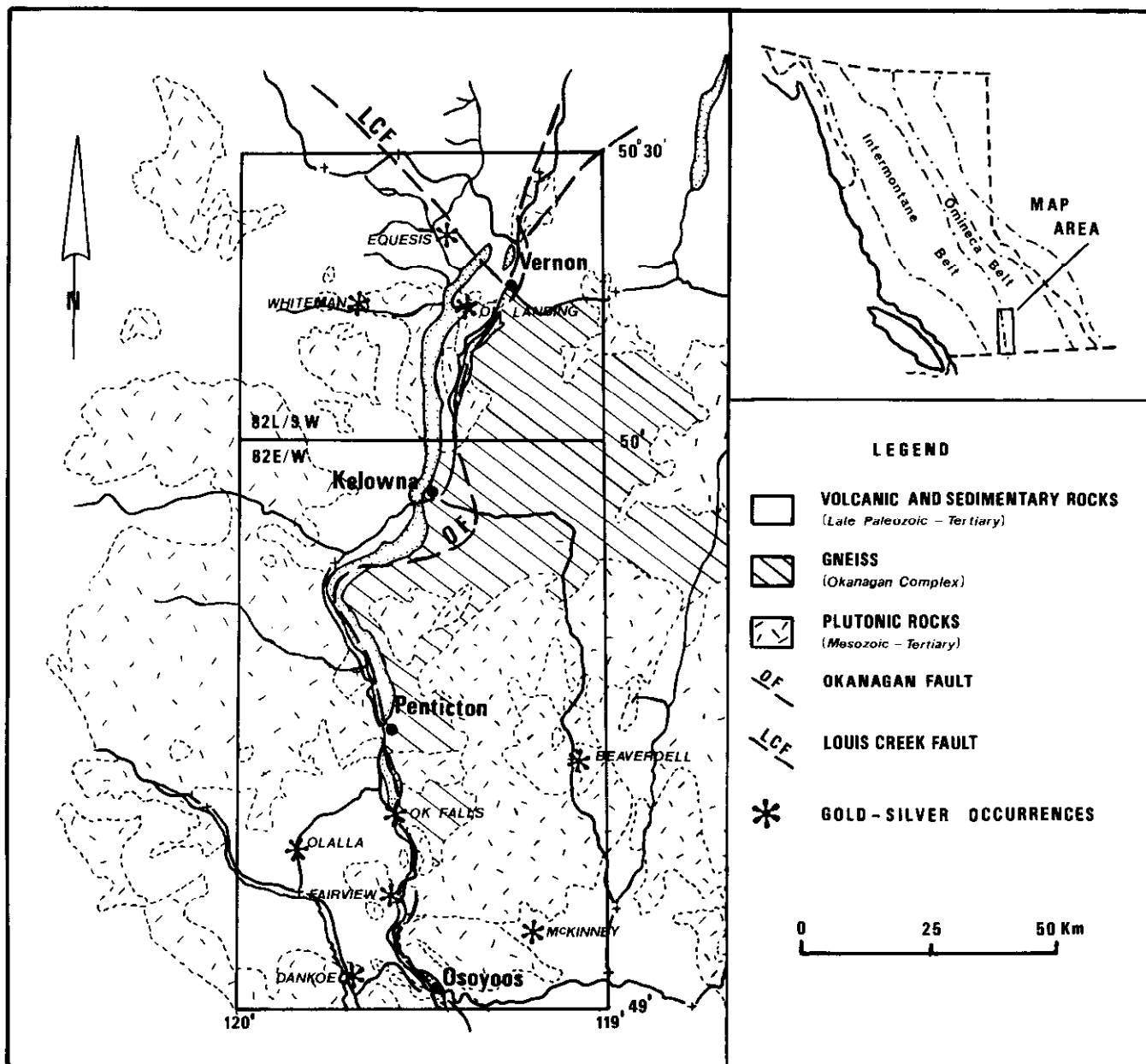


Figure 2-1-1. Okanagan region showing location of study area and main localities of lode gold-silver occurrences. Geology simplified after Wheeler and McFeely (1987) and Parrish *et al.* (1988).

## DISTRIBUTION, SETTING AND CHARACTER OF PRECIOUS METALS DEPOSITS

### NORTHERN OKANAGAN

In the northern Okanagan region (82L/SW) most occurrences are centred around Vernon, at Okanagan Landing, Equisis Creek and the Whiteman Creek – Terrace Mountain area. The majority of these prospects occur in greenschist facies, Upper Triassic to Lower Jurassic Nicola Group volcanic and sedimentary rocks and in metasedimentary rocks of the Upper Triassic Slokan Group (Okulitch, 1979), while comparatively few occurrences have been discovered in Tertiary rocks.

### OKANAGAN LANDING AND VERNON

Mineralized veins in this area are mesothermal in character and associated with north, northwest and west-trending structures that may be splays of the northern Okanagan fault system or the Louis Creek fault. The veins are gold-bearing with secondary silver, copper, lead and zinc. Some veins occur in fractures oriented oblique to foliation (Plate 2-1-1). Alteration is graphitic, with clay and limonite. On the east shore of Okanagan Lake, near the Ruby Gold prospect, the stratified rocks have a strong northwest-dipping penetrative fabric that is distinctly mylonitic in texture.

### EQUESIS CREEK

Several precious metal bearing quartz-vein prospects occur in chloritic volcanic rocks and phyllitic sedimentary



Plate 2-1-1. Imperial property. Deformed quartz vein and felsic dyke in schistose, chloritized metasedimentary rocks, which are truncated by lower grey breccia zone.



Plate 2-1-2. Brett property. Banded, vuggy and brecciated quartz veins. Wallrock material is silicified and clay (illite) altered; Trench No. 1, Main Shear Zone.

rocks of the Nicola and Slocan groups, between Equis Creek and the Salmon River. The veins are subparallel to host-rock foliation and are mainly gold-rich with low silver values. A minority, however, are silver-rich, gold-poor veins that contain galena and sphalerite. Alteration is variable and generally not well defined over large areas. Chlorite, limonitic carbonate, sericite and weak graphitic alteration are the most common.

### WHITEMAN CREEK

In contrast to the areas described above, gold-silver mineralization in the Whiteman Creek – Terrace Mountain area occurs within, or close to relatively unmetamorphosed volcanic rocks of the Eocene Kamloops Group. The most notable occurrence is the Brett property, which is characterized by banded and vuggy, epithermal gold and silver-bearing quartz veins (Plate 2-1-2) associated with illite, sericite and silica alteration (Meyers, 1988a). The veins occur in northwest striking, highly fractured fault zones, which tend to coincide with feldspar porphyry dykes. A broad silicified breccia zone (Plate 2-1-3) northeast of the mineralized areas is believed to represent a major epithermal system. Recent drill-hole data indicate that silicification and gold mineralization in the main shear zone may extend laterally into porous tuff units, where they are intersected by the steeply dipping, mineralized fault zones. Southeast of the mineralized area, the volcanic sequence is intruded by a syenitic stock dated at 50.3 Ma (Church, 1980a).

The White Elephant property which was exploited briefly in the 1920s and 1930s, is several kilometres south of Whiteman Creek. Precious metals occur in fractured and faulted



Plate 2-1-3. Brett property. Silicified and pyritized breccia, Gossan Zone.

quartz-rich and sulphide-rich veins that are hosted in propylitically altered middle Jurassic granodiorite. The deposit is exposed a few hundred metres east of Eocene volcanic rocks and the veins are cut by basaltic dykes.

### SOUTHERN OKANAGAN

Occurrences in the southern Okanagan region (82E/W) are grouped in several well-known mining camps, where a number of past producers are still being explored. The Fairview Camp, Orofino Mountain, Olalla, Camp McKinney and Beaverdell are of particular note. In most areas, mesothermal veins occur in deformed late Paleozoic to Mesozoic sedimentary-volcanic sequences. At Okanagan Falls, however, Eocene volcanic rocks of the Marama and White Lake formations host epithermal gold mineralization.

### OKANAGAN FALLS

At the south end of Skaha Lake epithermal mineralization at the Dusty Mac mine occurs in quartz-vein breccia in laharic deposits of the Eocene White Lake Formation (Church, 1969, 1973). The geology of the area is dominated by a northwest-trending fault system and dissected locally by numerous normal and reverse faults. Fracture-controlled veins are commonly banded (Plate 2-1-4), or exhibit cockscomb quartz intergrowths. The deposit was mined



Plate 2-1-4. Dusty Mac property. Multiple banding in quartz vein in laharic breccia.

briefly between 1969 and 1975 and is currently undergoing further exploration.

Several kilometres southeast, at the Venner property, gold-silver mineralization is related to quartz-carbonate breccias and veining within Eocene Marama andesitic breccias, rhyolitic flows and crystal tuffs. This unit underlies the White Lake Formation.

A new epithermal gold-silver prospect has been discovered recently northwest of Okanagan Falls, at the Vault property. Mineralization is characterized by crustiform-banded chalcidonic quartz veining (Plate 2-1-5) and widespread silicification in brecciated and tuffaceous trachyandesites of the lower Marama Formation. Normal faulting is a complicating structural feature.

### FAIRVIEW CAMP

At the Fairview mine, deformed gold-silver veins (Plate 2-1-6) occur in refolded and faulted Kobau metaquartzites of Carboniferous to Permian age (Okulitch, 1969, 1973) that are wedged between Oliver granite and the Fairview granodiorite. Renewed exploration has been hampered by the structural complexities of early polyphase folding and superimposed normal and reverse faulting (Meyers, 1988b). Veins are typically mesothermal, with precious metals associated with iron, lead, zinc and copper sulphides. The Stemwinder and Morning Star mines lie immediately southeast of the Fairview property and are interpreted to be part of the same quartz lode system cutting the Kobau stratigraphy. Operations in the Fairview camp were intermittent between 1895 and 1961, with total production amounting to 473 000 tonnes of ore which yielded 1944 kilograms of gold and 23 021 kilograms of silver.



Plate 2-1-5. Vault property. Banded gold-bearing quartz vein in tuffaceous trachyandesite. Core is 4.5 cm in diameter.



Plate 2-1-6. Fairview mine. Cleavage development in quartz vein, oriented parallel to  $S_1$  foliation in wallrocks. Crossfracturing is subperpendicular to cleavage; No. 6 level.



Plate 2-1-7. Standard property. Steeply dipping quartz vein enclosed in granodiorite (Jog) adjacent to adit portal.

A similar setting exists at Orofino Mountain where the host rocks are greenschist metasedimentary rocks of the Upper Triassic Old Tom and Shoemaker groups, intruded by dioritic and gabbroic rocks. Northeast and northwest-trending quartz veins carry gold and silver associated with polymetallic sulphides and chlorite-sericite alteration. The host strata and mineralization are cut by a number of northeast-oriented normal faults.

Other deposits in the same area, such as the Suzie mine and Standard prospect, occur in northeast and northwest-trending dilatant fracture zones within the granitoid rocks of the Oliver intrusion (Plate 2-1-7).

### OLALLA

Veins in the Olalla area occur within or peripheral to the mid-Jurassic Olalla pyroxenite and related syenitic rocks, where they intrude hornfelsed Upper Triassic Shoemaker Group metasedimentary rocks. Most structures trend east-northeast and are sheared or brecciated. Gold-silver mineralization is associated with base metals in quartz veins, quartz breccia zones and weakly mineralized gold and copper-bearing skarns. Alteration is variable, but predominantly silica, carbonate, clay and minor sericite. At least two properties (Sunrise, Juniper) are associated with skarn mineralization.

### DANKOE

In the Dankoe (Horn Silver) mine area, south of Mount Kobau, flat-lying quartz veins are generally oriented east-west subparallel to shearing. They occur within the Kruger syenites, monzonites and related pegmatites (Plate 2-1-8). Precious metals occur with pyrite, chalcopyrite, galena and tetrahedrite. Native silver, argentite, pyrargyrite and silver halides have also been reported from this deposit. Some veins display banded and bladed sulphides and quartz, suggesting open-space filling. Alteration is strongly propylitic in character. During intermittent operation between 1915 and 1984 the Horn Silver mine produced 391 111 tonnes of silver-gold ore, containing 333 kilograms gold and 127 194 kilograms silver.

### CAMP MCKINNEY

Camp McKinney deposits occur in greenstones, amphibolites, minor ultramafic rocks and schistose metasedimentary rocks of the Carboniferous to Permian Anarchist Group. The veins are generally conformable to the northwest and west-trending regional foliation and are reported to have similarities in structure and texture to the deformed mesothermal veins in the Fairview Camp (Cockfield, 1935). However, a few banded and vuggy veins are present, suggesting that low-temperature epithermal activity may have had an effect on vein development. Gold is by far the dominant precious metal, although modest silver values were reported, together with appreciable quantities of lead, zinc and copper. At the War Eagle property, fractured and brecciated veins contain zones partially replaced by massive sulphides. Alteration is quartz-carbonate rich, with associated sericite and chlorite. The Cariboo-Amelia mine produced 124 452 tonnes of ore containing 2538 kilograms gold and 1009 kilograms silver between 1894 and 1962.

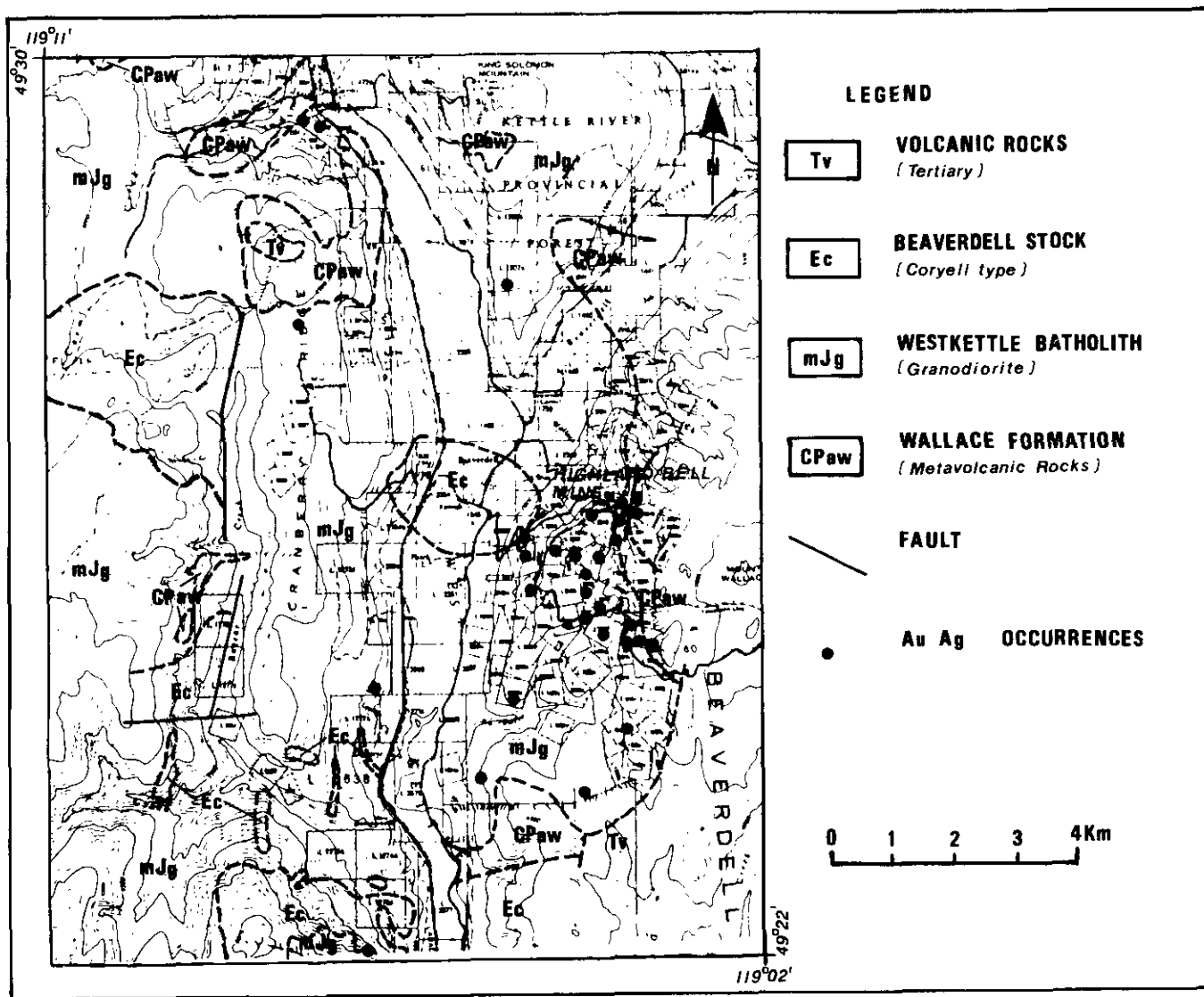


Figure 2-1-2. Distribution of silver and gold occurrences in the Beaverdel-Carmi district. Geology after Watson *et al.* (1982) and Godwin *et al.* (1986).

## BEAVERDELL

The Highland-Bell mine, an amalgamation of the former Highland Lass, Bell and Beaver properties, is the oldest continuously operating mine in British Columbia. Between 1900 and 1988 the mine has produced 1278 tonnes of silver and approximately 500 kilograms of gold from 830 743 tonnes of ore.

In the Beaverdel – Carmi district, silver and gold vein mineralization occurs in predominantly northeast and east-trending structures in the Middle Jurassic Westkettle granodiorite. The batholith also contains pendants of the Wallace Formation, a volcanic-sedimentary component of the Anarchist Group (Figure 2-1-2). The granodiorite is intruded by the Beaverdel quartz monzonite, an Eocene Coryell-type intrusion, dated at 58.8 Ma, which has been correlated with the timing of silver-rich mineralization at

the Highland Bell mine (Godwin *et al.*, 1986). Watson and Godwin (1983) reported arsenopyrite, tetrahedrite, pyrargyrite, chalcopyrite, polybasite, acanthite and pyrrhotite associated with the silver-lead-zinc mineralization. Alteration in the camp is mainly propylitic with accessory sericite and clay.

In contrast with the Beaverdel area, vein mineralization at Carmi is gold rich, with generally lower sulphide content (Watson *et al.*, 1982). No major production has come from this area.

## DISCUSSION

The majority of lode gold-silver occurrences compiled for this study are mesothermal and occur in remnants of late Paleozoic to early Mesozoic eugeosynclinal rocks. The fact that many of them lie within well known established mining



Plate 2-1-8. Dankoc mine. Pegmatite dykes cutting Kruger syenite (mJg) near adit portal.

camp, reflects the historical exploration bias toward pre-Tertiary rocks.

Only five of the properties occur in Tertiary volcanic rocks. Most of these have distinct epithermal characteristics and were discovered during the last twenty years. The more recent discoveries are particularly significant in that they reaffirm the potential for epithermal gold mineralization related to Tertiary volcanism in the Okanagan region.

The deposits fall into three general settings:

- (1) **Greenschist-hosted Deposits.** Deposits occurring in sedimentary and volcanic sequences, metamorphosed to greenschist grade, occur as intrafolial veins parallel to bedding or cleavage, breccia fillings, multiple veins and stringers in ductile shears, and in discordant brittle cross-fractures. Host-rocks are deformed, foliated rocks originating as accretionary arc or oceanic assemblages (Wheeler and McFeely, 1987). Precious metals are usually intimately associated with base metals, and the sulphide and alteration mineral assemblages are typical of mesothermal lode deposits (Hodgson, 1985).

Deposits of this type are common in greenschist terranes, particularly in the Archean of central Canada (Colvine *et al.*, 1984, 1988) and Western Australia (Barley *et al.*, 1986). They are believed to have formed from metamorphogenic fluids contemporaneous with ductile deformation and syntectonic plutonism.

However, to avoid direct comparisons between Cordilleran and Archean terranes, a better analogy might be drawn with lode deposits in the Juneau gold belt of southeastern Alaska, where Goldfarb *et al.* (1988) have determined a subduction-related metamorphic origin for mesothermal vein mineralization in greenschist to amphibolite-grade rocks of late Paleozoic to Cretaceous age.

- (2) **Intrusive-hosted Deposits.** Except for the Beaverdell deposits, intrusive-hosted occurrences in the region are generally less well known. They occur in faults, dilational fractures or fissures, shear zones and breccia zones. The most significant of these are the Beaverdell deposits, which are fault and fissure controlled and silver rich. Although they occur in Jurassic granodiorite of the Westkettle batholith, they are considered to be Tertiary in age (Godwin *et al.*, 1988). The Sunrise/Shepherd veins at Olalla occur within the Olalla pyroxenite and are breccia and skarn-related. The latter association suggests that metasomatic activity related to intrusion may have been important during vein development.
- (3) **Epithermal Deposits.** The important epithermal prospects in the region occur at Okanagan Falls and Whiteman Creek. They are hosted by Eocene volcanic and sedimentary sequences that are inferred to be related in time, to "detachment-type" extensional tectonics associated with the Okanagan fault system (Parrish *et al.*, 1988).

Mineralization is best developed in porous tuffs, tectonic fracture zones, and laharic and epiclastic breccias. It is associated with faulting, intense brittle fracturing, widespread silicification and moderate to strong pyritization of adjacent wallrocks. Clay (illite), sericite and to a lesser extent, carbonate are common alteration products. Quartz veins are vuggy, banded, bladed and rebrecciated, all of which are features characteristic of boiling in a hot spring environment (Buchanan, 1981).

Relationships between epithermal mineralization and extensional deformation have been proposed for deposits in the western United States (Spencer and Welty, 1986) and in Spain (Doblas *et al.*, 1988). The fact that normal faulting is widespread throughout Eocene sequences in the Okanagan (Church, 1979, 1980a, b) and is spatially related to Eocene volcanic centres and mineral deposits, is indicative that extensional tectonism likely gave rise to Eocene volcanism. The open-space textures in epithermal quartz veins are further evidence, on a local scale, that dilatant deformation took place. Consequently, one can expect that the evolving models for extensional tectonics and Eocene volcanism in the region will have important and far-reaching genetic implications for epithermal precious metals exploration in the Okanagan.

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## NOTES