Plutonic-related Gold-quartz Veins in Southern British Columbia

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INTRODUCTION

Extending westerly across the Yukon territory and into Alaska for more than 1000 km is a mid-Cretaceous magmatic belt and associated gold mineralization. This belt of rocks hosts plutonic-related gold deposits, such as Fort Knox (127.5 10^6 g Au), Dublin Gulch (35.7 10^6 g Au), Brewery Creek (28.7 10^6 g Au) and Pogo (162.0 10^6 g Au), and has recently been identified as the Tintina Gold Belt (Figure 1). The intrusions belong to the Tombstone-Tungsten Belt, in Yukon and the Fairbanks intrusions in Alaska.

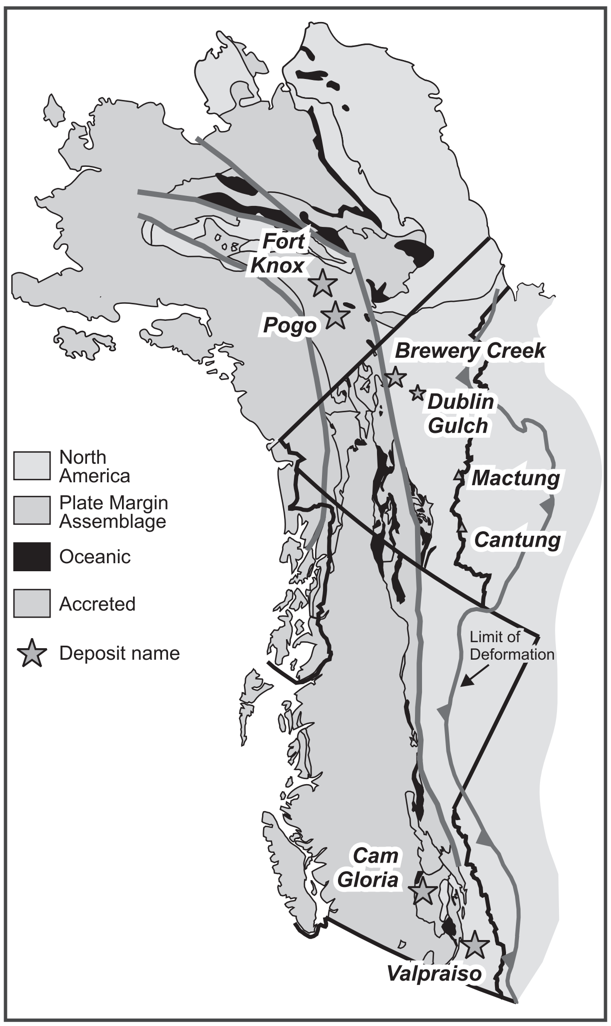

Figure 1. Tectonic assemblage map, after Wheeler and McFeely (1991) showing the distribution of North American, plate margin, oceanic and accreted rocks of the Canadian and Alaskan Cordillera, the location of the Tintina Gold belt and select deposits.

Given the exploration interest in Pogo-type gold mineralization (9.05 million tonnes grading 17.8 g/t Au; Smith *et al*., 1999) and the prospective nature of the province, the British Columbia Geological Survey initiated a field project to provide more information about plutonic-related gold deposits. The Shuswap and Kootenay areas (Figure 1) were selected from the Lefebure *et al*. (1999) data set because they share a number of similarities with the Tintina Gold Belt; including mid-Cretaceous granitic intrusions, solitary, stockwork and sheeted quartz veins with Au-W-Bi metal signatures, and RGS anomalies for pathfinder elements. The Shuswap study focused on the Baldy Batholith area located west of Adams Lake in the Kootenay terrane, where Teck Corporation is evaluating the Cam-Gloria property, while the Kootenay field work concentrated on the Mount Skelly pluton, located north of Creston in North American rocks. These areas were mapped and sampled on a reconnaissance basis to test their potential for Fort Knox and Pogo-style deposits. The results are presented on B.C. Ministry of Energy and Mines Open File maps 2000-7 and 8. In addition, Lett and Jackaman (this volume) carried out multi-media stream sediment sampling to study the geochemical signature of plutonic-related gold mineralization in these areas.

Plutonic-Related Gold-Quartz Deposits

The principal features of plutonic-related gold deposits are reviewed in a number of recent publications, by Baker *et al*. (submitted), McCoy *et al*. (1997), Poulsen *et al*. (1997) and Thompson *et al*. (1999). The major occurrences in the Yukon and Alaska comprise two distinct styles of plutonic-related gold mineralization; the intrusion-hosted low grade, large tonnage sheeted and stockwork low sulphide vein systems at Fort Knox (Bakke, 1995; Bakke *et al*.,1998), Dublin Gulch and Clear Creek, and the high grade quartz veins and bodies that occur proximal to granitoid intrusions on the Pogo claims (Liese Zone) (Smith *et al*., 1999). The main distinguishing factor of this type of gold deposit is the associated metal assemblage of bismuth, tungsten and arsenic and in Alaska and Yukon the association with dikes and cupolas located in or near the apexes of mid-Cretaceous intrusions.

Plutonic-related gold deposits are often associated with a variety of other types of mineralization (Figure 2). For example, peripheral to the sheeted gold-quartz veins in the Eagle Creek Zone of the Dublin Gulch property are gold and tungsten placers, solitary gold-sulphide quartz veins and a tungsten skarn (Hitchins and Orssich, 1995). The tungsten skarn and the gold-sulphide quartz veins are spatially and genetically related to the Dublin Gulch stock (Baker *et al*,. submitted). Further away from the stock are silver-lead-zinc veins which they have interpreted to be distal mineralization related to the intrusion. Similar veins were noted from 2 to 5 kilometres from the source intrusion for other Fort Knox-type deposits by Thompson *et al*. (1999). These associated styles of mineralization provide one of the best methods for identifying areas to prospect for plutonic-related gold deposits.

The key exploration guide for plutonic-related gold deposits is to explore in, and around, highly differentiated granitic intrusions, specifically those intruded in continental marginal settings; a setting shared by tungsten and tin magmatic provinces (Thompson *et al*., 1999). The known prospective areas are underlain by Proterozoic-Paleozoic miogeoclinal rocks of ancestral North America, and the pericratonic Yukon-Tanana and Kootenay terranes. The rocks were deposited along the margin of the North American craton, in shelf and marginal basin environments. Accretion of Quesnellia in the Jurassic led to the deformation, metamorphism and ultimate translation of these rocks along thrust faults onto the craton. These rocks vary from sub-greenschist to amphibolite grade metamorphism. Since the Liese Zone is hosted by gneisses, it is possible that the Pogo-style mineralization is more likely to occur in higher grade metamorphic rocks than typically host other types of gold-quartz lodes.

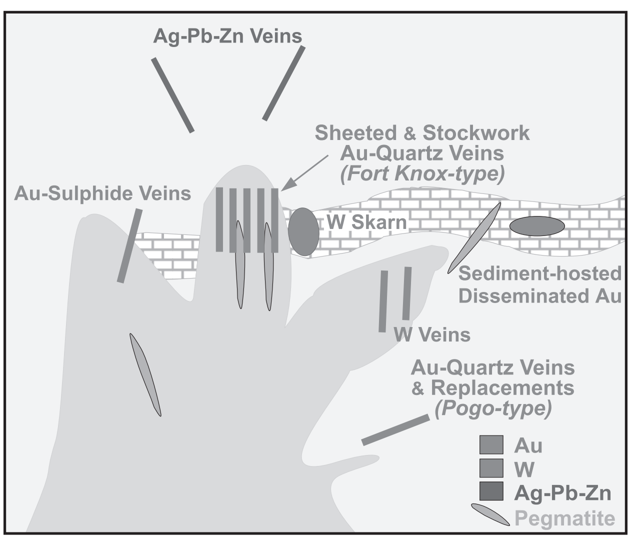

Figure 2. Schematic model of plutonic-related mineral deposits, showing different styles and metal assemblages of intermediate to felsic plutons intruded into continental margin setting (modified from Lefebure and Cathro, 1999).

CORDILLERAN GEOLOGY

The Canadian Cordillera is comprised of five distinct morphogeological belts (Gabrielse *et al.*, 1991). In British Columbia, the Foreland belt is characterized by Proterozoic to Upper Jurassic platformal and miogeoclinal strata that were deposited on the rifted western margin of ancestral North America and then translated northeastward by thin-skinned thrusting and folding to form the Rocky Mountain Fold and Thrust belt. Palinspastic reconstructions indicate at least 200 km of post-middle Cretaceous shortening in the southern foreland belt (Bally *et al.*, 1966; Price and Mountjoy, 1970) and eastward displacement in the north is estimated to be 50 km (Gabrielse *et al.*, 1991). The Omineca belt is the exhumed metamorphic-plutonic hinterland to the foreland belt. In southern BC the Omineca belt consists of the Kootenay terrane and the Barkerville subterrane, which consist of metamorphic rocks probably equivalent to or deposited in proximity with North American miogeoclinal strata (Gabrielse *et al.*, 1991). West of the Omineca belt are the Intermontane, Coast and Insular belts, comprised primarily of Paleozoic to Early Jurassic ocean and island arc terranes. Amalgamation of these terranes and accretion to the western margin of North America occurred in the Middle Jurassic and Early Cretaceous (Monger *et al.*, 1982, Gabrielse and Yorath, 1991). Initial Sr ratios in the Omineca and Foreland belts are commonly greater than 0.705 and those in the western belts commonly less than 0.705 (Armstrong, 1988). The transition between the Omineca and Intermontane belts roughly coincides with the western margin of old radiogenic continental crust and the eastern limit of allochthonous volcanic terranes.

Plutonic rocks comprise a substantial proportion of the Canadian Cordillera, particularly in the Coast and Omineca belts (Figure 3). The mid-Cretaceous plutons of these two belts are markedly different. Those in the Coast belt are primarily I-type, commonly contain hornblende in addition to biotite, and are poor in large-ion lithophile elements (Woodsworth *et al.*, 1991). Those in the eastern belt (Bayonne and Selwyn suites) are S-type, felsic, rich in large-ion lithophile elements and have initial $^{87}Sr/^{86}Sr$ ratios between 0.710 and 0.740 (Anderson, 1988, Armstrong, 1988; Woodsworth *et al.*, 1991). The eastern belt of plutonic rocks intrude North American and marginal assemblage rocks comprising the pericratonic terranes of the northern Cordillera (Figure 1). Molybdenum, tungsten and tin deposits in the northern Canadian Cordillera are related primarily to the mid-Cretaceous (at 110 and 90 Ma) intrusive episodes of the eastern suite (Sinclair, 1995). These include skarn tungsten deposits, such as Cantung and Mactung, and porphyry tungsten-molybdenum deposits at Ray Gulch and Logtung. This tungsten-tin±molybdenum province extends more than 1000 km across the Yukon and into Alaska after restoration of the dextral motion on the Tintina Fault. It also

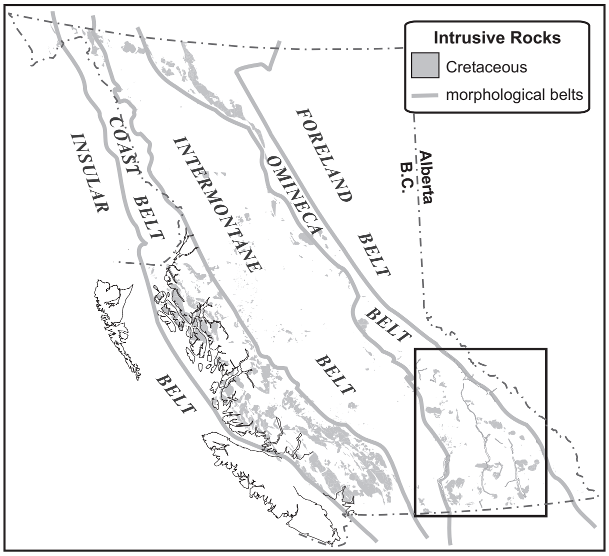

Figure 3. Distribution of Cretaceous plutonic rocks in the Cordillera of British Columbia, showing relationship to the morphogeological belts. Cassiar, Surprise Lake, Cascade and Bayonne suites from Woodsworth *et. al.* (1991).

follows the Omineca Belt southward 1600 km to Salmo near the Canadian-US border.

Bayonne Plutonic Suite of Southeastern British Columbia

In the southeastern Canadian Cordillera, mid-Cretaceous plutons of the Bayonne Suite intrude a wide area extending from North America west across the Omineca and Intermontane belts (Figure 4). Most are post-metamorphic and discordant with the country rocks. They form an arcuate belt of batholiths and stocks, generally composite bodies, comprising several distinctive phases, which follow the eastern edge of the Kootenay Arc and beyond as far northwest as Quesnel Lake. These intrude miogeoclinal rocks of North America affinity. West of the Kootenay Arc, batholiths and large stocks intrude rocks of the Kootenay and Barkerville terranes. North of 51° latitude the batholiths and plutons, such as Baldy and Goldstream, are elongate in an easterly direction.

The mid-Cretaceous suite is comprised of medium to coarse-grained, biotite-hornblende monzogranite to granodiorite and biotite and biotite-muscovite granites. The intrusions are often composite bodies consisting of one or more of these granitoid types and from the available geochemical data there is no simple change from metaluminous to peraluminous along the belt as observed in the Tombstone-Tungsten suite in the Yukon. The Bayonne suite are metaluminous to weakly peraluminous hornblende-biotite granites and strongly peraluminous, 2-mica granites, aplite and pegmatite. Initial Sr and Pb-isotopes suggest an extensive interaction with continental crust. Trace elements (discrimination diagrams of Pearce *et al.*, 1984) are indicative of within-plate tectonic settings for the intrusions cutting North America rocks (Brandon and Lambert, 1993, and this study), but also display volcanic-arc signatures for some of the others (i.e. Goldstream, Honeymoon Bay, Baldy).

At the southern end of the Omineca belt the Bayonne suite intrusions have Sr, Nd and Pb-isotope compositions and REE patterns that can be entirely derived from partial melting of local crustal lithologies (Brandon and Lambert, 1993, Brandon and Smith, 1994). Therefore, these mid-Cretaceous intrusions are likely the result of crustal melting without a mantle derived mafic precursor and were probably generated in response to crustal thickening initiated by thrusting during collapse and obduction of the marginal basin.

REGIONAL GEOLOGY OF SOUTHEASTERN BRITISH COLUMBIA

The present geological architecture of southeastern British Columbia reflects the cumulative effects of Mesozoic accretion of Quesnellia to North America and immediately post-dating compression, substantial extension and exhumation in the Tertiary. Obduction of Quesnellia in the southern Canadian Cordillera began in the earliest Middle Jurassic in response to collision and thrusting of the Intermontane Superterrane over the western margin of North America (Monger *et al.*, 1982; Brown *et al.*, 1986; Murphy *et al.*, 1995). Archibald *et al.* (1983) document Barrovian metamorphism and major deformation *circa* 165-175 Ma in the Kootenay Arc, followed by exhumation and rapid cooling to <300°C prior to the end of the Jurassic. The same Middle Jurassic event was documented in the northern Monashee and Cariboo Mountains (Rees, 1987; Murphy, 1987) and is preserved in the hangingwall rocks of the Eocene extension faults (Johnson, 1994; Parrish 1995). Easterly vergent thrust faults detached the supracrustal rocks from the North America basement and translated them along a major sole thrust, correlative with the Monashee décollement (Brown *et al.,* 1992). Northeast directed motion along the Monashee décollement continued during Cretaceous time, but whether deformation was continuous or episodic is unclear. Contraction caused tectonic wedging that thickened the crust and caused structurally lower rocks to be metamorphosed and the production of anatectic peraluminous melts (in the Cretaceous and Paleocene). In the northern Shuswap, Parrish (1995) evoked a foreland propagating fold-thrust belt to explain the Late Cretaceous to Eocene deformation and metamorphism within the Monashee complex (structurally below the Monashee décollement) and the more varied and long-lived middle Jurassic to Eocene tectonic history of the overlying Selkirk allochthon. This involved westward thrusting of the Monashee complex (basement and sedimentary cover) beneath the hot allochthon in latest Cretaceous to Paleocene. In the allochthon, progressively higher structural levels cross older thrust faults bounding supracrustal rocks with consistently older ages of peak thermal metamorphism. In the southern Kootenay Arc, Leclair *et al*. (1993) provide U-Pb zircon, titanite and allanite dates which constrain penetrative deformation and

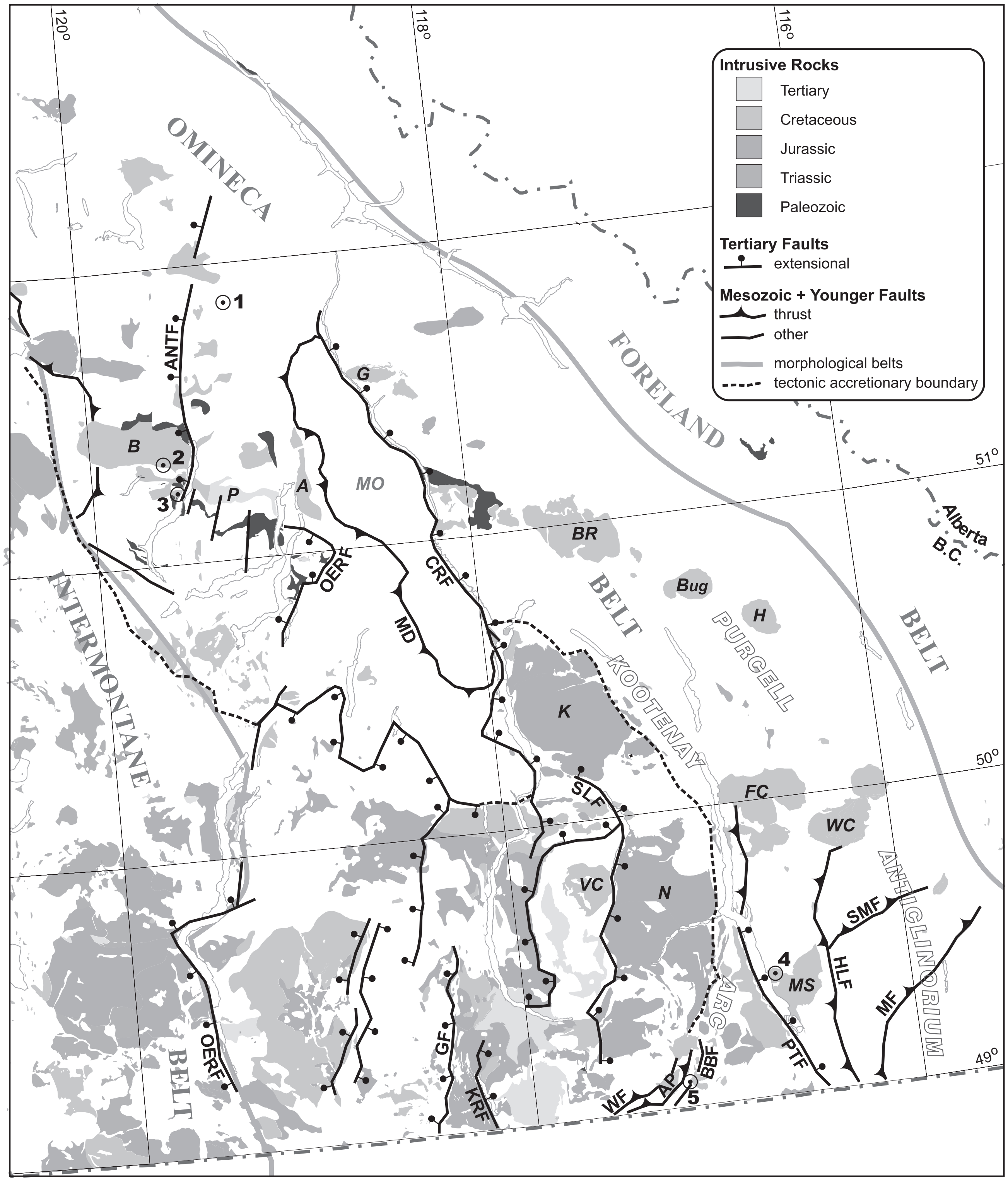

Figure 4. Distribution of Paleozoic, Triassic, Jurassic, Cretaceous and Tertiary plutonic rocks, in southeast British Columbia, also shown are the morphogeological belts and tectonic accretionary boundary. Eocene normal faults (Parrish *et al.*, 1988, Johnson, 1994) bound higher metamorphic grade Shuswap complex rocks, barb on hangingwall side. ANTF=Adams-North Thompson fault, OERF=Okanagan-Eagle River fault, MD=Monashee décollment, MO=Monashee complex, CRF=Columbia River fault, SLF=Slocan Lake fault, VC=Valhalla complex, GF=Granby fault, KRF=Kettle River fault, WF=Wanetta fault, AF=Argillite fault, BBF=Black Bluff fault, PTF=Purcell Thrust fault, HLF=Hall Lake fault, MF=Moyie fault, SMF=St. Mary's fault. Plutonic rocks include; B=Baldy, P=Pukeshun, A=Anstey, G=Goldstream, BR=Battle Range, Bug=Bugaboo, H=Horsethief Creek, K=Kuskanax, FC=Fry Creek, WC=White Creek, N=Nelson, MS=Mount Skelly. Number correspond to mineral occurrences; 1=Bizar, 2=San, 3=Cam-Gloria,4=Valparaiso, 5=Emerald Tungsten.

regional metamorphism to the mid-Cretaceous in amphibolite facies footwall rocks of the Purcell Thrust fault, west of Kootenay Lake (Figure 4). Contraction appears to have continued until the latest Paleocene (Parrish *et al.*, 1988; Carr, 1992) at which time the southern Omineca underwent extension. The wide zone of high-grade metamorphic rocks in the southern Omineca belt reflect the substantial amount of extension the area has undergone.

Shuswap Area - Kootenay Terrane Rocks

The Kootenay terrane of the Adams Lake region comprises Proterozoic and Lower Paleozoic sedimentary, volcanic and plutonic rocks and their metamorphic equivalents. Schiarizza and Preto (1987) subdivided the stratigraphy into a lower sequence correlative with Neoproterozoic and Lower Paleozoic ancestral North American miogeoclinal strata and a stratigraphically higher package of Late Paleozoic volcanic arc rocks. West of Adams Lake in the hangingwall of the Eocene Adams-North Thompson Fault (Figure 4), the rocks are chiefly lower greenschist facies, with chlorite to biotite assemblages, but to the east, footwall rocks are higher grade amphibolite facies sillimanite-bearing rocks of the Shuswap metamorphic complex (Read *et al.,* 1991). The Shuswap metamorphic complex is a large, northerly trending metamorphic core complex (Armstrong, 1982). It is bound on its west side, by the west-side-down Okanagan Valley System (Parkinson, 1985; Johnson, 1994) and to the east by the east-side-down Columbia River-Slocan Lake system (Read and Brown, 1981; Parrish, 1984), both outwardly-dipping Eocene normal faults (Figure 4). Adopting the nomenclature of Brown and Carr (1990), the Shuswap complex includes only those high-grade rocks which lie in the footwall of these Eocene extension faults.

The Baldy Batholith is a west-trending, mid- to Late Cretaceous post accretionary intrusive (Schiarizza and Preto, 1987; Calderwood *et al.*, 1990). It intrudes Proterozoic to mid-Paleozoic Kootenay terrane metasedimentary and metavolcanic rocks and postdates most of the penetrative deformation in the area; however, its emplacement coincided with some of the latest folding and predated late faults which offset its northern contact (Schiarizza and Preto, 1987). The country rocks host a variety of mineral deposits which predate (mafic VMS, bimodal felsic VMS, disseminated Cu-Mo and stratabound Ag-Pb-Zn) intrusion of the batholith and a wide variety of mineral deposits which may be related to its intrusion (polymetallic base metal veins, porphyry Mo, Au-pyrrhotite veins, Au-quartz veins and W veins).

The Baldy Batholith is a multiphase granite intrusion which covers approximately 650 km^2. The western $2/3^{rd}$ of the batholith comprises two compositionally similar, but texturally distinct granite phases, a potassium-feldspar megacrystic hornblende-biotite granite to granodiorite and an equigranular biotite monzogranite (Figure 5). The eastern third of the batholith is predominantly a leucocratic biotite-muscovite granite. Muscovite occurs as euhedral and ragged grains associated with biotite. Coarse grained, biotite-muscovite pegmatite and fine grained feldspar-quartz aplite dikes cut all of these phases.

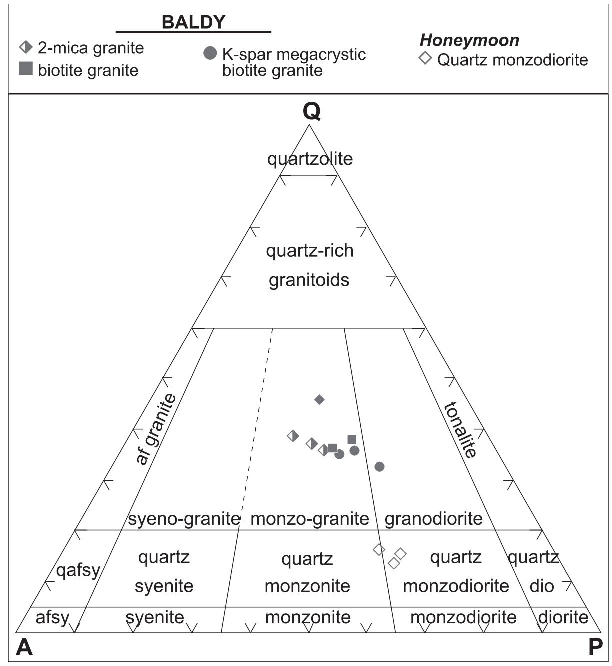

Figure 5. Modal quartz-alkali feldspar-plagioclase feldspar plot for Baldy Batholith and Honeymoon stock. Fields from LeMaitre (1989).

The aeromagnetic survey map for the Adams Lake area distinguishes a weaker magnetic signature for the two-mica granite comprising the eastern end of the batholith, than the two western phases. A ground survey of magnetic susceptibilities of the batholith using a hand held Exploranium KT-9 Kappameter shows the same variation, with distinctive ranges and average values allowing all three phases to be distinguished (Logan and Mann, 2000a).

K-Ar, biotite dates for the Baldy Batholith include the early work by Wanless *et al.* (1966), Kirkland (1971) and Jung (1986) who reported ages of 99±5 Ma; 101±5 Ma and 106±5 Ma; and 104±3 Ma, respectively. These samples provide ages for the north and westernmost biotite ± hornblende granite portion of the Baldy Batholith. A single U-Pb zircon date from this area gave an emplacement age of 115.9±4.6 Ma for the Baldy Batholith (Calderwood *et al.*, 1990). K-Ar dates of biotite from gneiss and orthogneisses located south of Baldy Batholith and west of Adams Lake give ages of 129±4 Ma and 99.7±4 Ma (Belik, 1973) and a small quartz monzonite body also from this area (Figure 6), gave a biotite age of 82±6 Ma (Wanless *et al.*, 1966). Schiarizza and Preto (1987) correlate the granitic rocks located south of the main body (*i.e.* Honeymoon stock) with the Baldy Batholith.

South of the Baldy Batholith, between East Barriere and Adams lakes (Figure 6), an irregular east-trending granite body interfingers with Devono-Mississippian orthogneiss and Neoproterozoic to Paleozoic micaceous

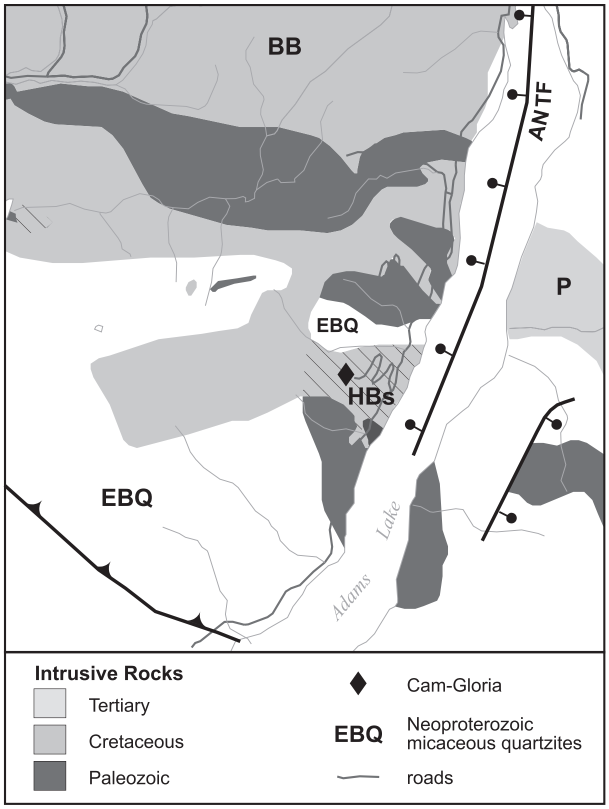

Figure 6. Geology southeastern Baldy Batholith showing location of Honeymoon stock and mineralization at Cam-Gloria. Plutonic rocks include: BB=Baldy, HBs=Honeymoon Bay stock, P=Pukeshun.

quartzites of EBQ (Schiarizza and Preto, 1987). The contacts are irregular and more complex than the steep, clearly crosscutting relationships between the Baldy Batholith and its country rock. Intrusive rocks include hornblende porphyry monzodiorite, biotite-hornblende-epidote quartz monzodiorite and biotite granite. These may represent smaller individual intrusions, but at the present scale of mapping could not be separated. Coarse-grained gneissic units containing sillimanite-staurolite-biotite-hornblende assemblages, calcsilicate gneisses (Schiarizza and Preto, 1987) and rusty-weathering migmatites with felsic leucosomes, pegmatites and sugary-textured aplite dikes host the intrusions in this area. It is not known whether these metamorphic mineral assemblages represent contact or burial metamorphism.

The southeastern-most apophysis of this granitoid body, here called the Honeymoon stock (shaded area in Figure 6), hosts the gold-quartz Cam-Gloria vein. The quartz monzodiorite is typically coarsely crystalline and equigranular (Figure 5). Potassium feldspar megacrysts occur randomly throughout forming as much as 5 % of the rock, but generally few megacrysts are visible in surface outcrops. Major minerals include andesine plagioclase, potassium feldspar, hornblende, biotite, quartz and epidote. Accessories include apatite, sphene, magnetite, and zircon. In thin section euhedral epidote grains, some with amoeboidal intergrowths with plagioclase, are intimately intergrown with hornblende and biotite (Photo 1). The epidote is interpreted as being primary magmatic grains. The mineral assemblage quartz, plagioclase, potassium feldspar, hornblende, biotite, epidote, sphene and magnetite suggest equilibrium pressures of at least 8 kbar (Zen, 1989) and conditions of formation corresponding to greater crustal depths, under fairly oxidizing conditions (Zen and Hammerstrom, 1984). Other intrusions reported to contain magmatic epidote in southeastern British Columbia are middle Jurassic in age and include; the Nelson Batholith (Ghent *et al.*, 1991) and Raft and Mount Toby plutons (Brandon and Smith, 1994). The Honeymoon stock was sampled and submitted to the University of British Columbia, Geochronology Laboratory for mineral separation and U-Pb age-dating.

Mineralization

The Cam-Gloria gold prospect (MINFILE 82M 266) is located three kilometres west of Honeymoon Bay, Adams Lake (Figure 6). The property was staked by prospector Camille Berubé in spring, 1997 following the release of a till geochemical survey (Bobrowsky *et. al.,* 1997) which showed two anomalous sample sites (215 and 43 ppb Au) in the area. The main auriferous quartz vein was discovered on an existing logging road (Photo 2, Cathro, 1998; Lett *et al.*, 1998). The property was optioned to Teck Corporation in early 1999 and surface mapping started during the summer. Initial excavator trenching and diamond drilling were conducted in September-October, 1999.

The Main vein occupies a 35 to 40 metre wide, 700 metre long zone of variable alteration, shearing and quartz veining in quartz monzodiorite of the Honeymoon Bay stock. The alteration zone strikes northeasterly 025 to 045and dips northwest from 45 to 70 and appears to pinch and swell along strike. At the Discovery zone drilling indicates the Main vein is up to 7.3 metres wide. Drilling has intersected two, and in places three, additional (>1 metre wide) veins within the broad alteration zone. Subparallel (sheeted) veins up to 10 cm wide have been encountered over a width of about 20 metres in one drill hole. A second, parallel alteration zone has been discovered by

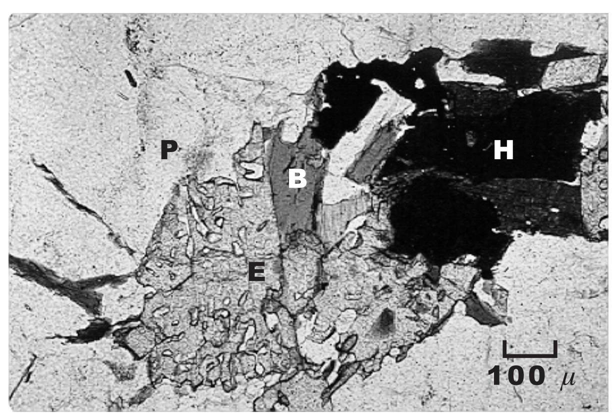

Photo 1. Photomicrograph of Honeymoon Bay - quartz monzodiorite showing typical texture of epidote (E), its euhedral contact with biotite (B) and wormy intergrowths with plagioclase (P).

Photo 2. Large surface exposure of the Main quartz vein at Cam-Gloria gold prospect near Adams Lake, view to the east.

trenching about 100 metres northwest of the main zone. The alteration zones have been affected by moderate to pervasive sericite and clay alteration of feldspars and mafic minerals, and some veins have narrow (2-5 cm) biotite and potassium feldspar selvages. This overprints a low-grade, regional chlorite alteration of the rocks.

The veins contain an average of 1-5 percent, coarse-grained sulphides, mainly pyrite and pyrrhotite, with traces of galena, chalcopyrite, sphalerite and arsenopyrite. Gold values are variable but appear to be associated with galena, fine-grained, bluish-grey sulphides, and local discordant gouge or brecciated zones.

Surface sampling of the Main vein have returned anomalous values in Ag, Bi, Cu, and Pb and weakly anomalous As, Mo, Sb, Te, and W values (Table 1).The highest gold values come from the footwall and hangingwall margins of the vein (samples I, M and J, Table 1). At the southwest end of the Main vein, sericite-altered quartz monzodiorite and vein quartz is exposed in an 8 m trench (sample H). Adjacent to the veins (2 to 8 cm wide), pervasive sericite and coarse muscovite replace feldspars and mafic minerals in the monzodiorite. The footwall zone of the Main vein (exposed north of the road), consists of a 0.2 to 0.5 m thick zone of brecciated vein, flooded by dark grey silica and fine grained sulphides. This is underlain by a variably mineralized, dark grey fault gouge zone which abruptly passes into altered quartz monzodiorite.

Pale green fluorite occurs in the footwall of the Main vein, and as well in several narrow quartz-sulphide veins exposed in road cuts some 100 to 200 metres to the east. The latter (samples A-G) are apparently gold-poor, but do contain locally anomalous Bi , Cu and W values. In addition, float boulders of garnet-pyroxene skarn with traces of pyrrhotite and weakly anomalous Cu and W values have been located on the road about 750 metres northeast of the Main vein.

East of the Cam-Gloria in the higher grade metamorphic rocks of the Shuswap complex prospecting since 1997 has discovered stockwork and sheeted vein, shear zone, manto and skarn showings containing Au, Bi, W, Cu and other metals. The new showings, although gener-

TABLE 1
SELECTED GEOCHEMICAL ANALYSES, MAIN VEIN AND SURROUNDING ZONES, CAM-GLORIA PROPERTY

Au	Ag	As	Bi	Cu	Mo	Pb	Sb	W	Zn	Sample Description
-2	0.1	3.8	0.04	6	<0.2	10.5	0.2	18.7	26	**A**) grab silicified-sericite altered monzonite
17	0.05	2.3	0.13	14	<0.2	9	-0.1	1.7	28	**B**) 25 cm qtz vein, sericite altered HW-FW
-2	0.15	4	0.34	9	<0.2	18	1	3.7	44	**C**) 1 m chip sample across spaced fractures
20	0.25	10.3	398	229	0.2	9	1.1	4.6	18	**D**) 5 cm qtz vein, chlorite + trace po, cpy
6	0.2	6	1.35	31	<0.2	3.5	0.4	0.7	4	**E**) grab 3 sheeted cm-wide quartz veins
13	0.6	108	5.45	676	4.6	25.5	6.7	0.3	6	**F**) 25 cm qtz vein, massive po, trace pyrite
3	<0.05	1.4	0.2	17	<0.2	2	-0.1	0.3	2	**G**) 25 cm wide rusty qtz vein
Main Vein										
20	1.9	5.9	7.7	27	0.2	52.5	0.2	1	4	**H**) grab silicified-sericite altered monzonite
1570	6.6	11.6	17.8	32	1	26.5	0.4	0.4	2	**I**) 3.3 m chip sample starting from the FW
902	9.6	31.4	9.45	49	0.8	169	0.4	1.6	2	**J**) 3.3 m chip from HW side of vein
67	13.2	23.5	31.2	116	0.6	271	0.6	0.3	6	**K**) grab, dissem of po, py, trace cpy, gn
1540	3.15	51.3	30.6	163	1.8	42.5	1.5	0.6	30	**L**) 1.5 m chip sample, SW end of the main vein
18300	15.5	22.5	196	381	3.2	354	2.5	7.8	378	**M**) chip, altered FW-monzonite, brecciated vein
73	11.4	20.8	71.8	251	4	277	2.3	2	526	**N**) 1.5 m chip, coarse and fine grained pyrite
892	60.6	193	240	203	11	1165	1.7	<0.1	576	**O**) grab, fracture filling blebs of po, py, gn

Au, As and Sb by INA; other elements by total digestion-ICP

Au in ppb, rest in ppm

TABLE 2
SELECTED GEOCHEMICAL ANALYSES, GOLDSTRIKE (BIZAR) PROPERTY

Au	Ag	As	Bi	Cu	Mo	Pb	Sb	W	Zn	Sample Description
63	0.05	0.8	77.2	19	76.3	16.5	-0.1	0.5	2	20 cm x-cutting qtz vein, trace py
41400	3.6	5.9	4200	2120	1	6	0.3	<10.0	28	grab, concordant sulphide layer
23400	1.8	3.3	2460	1230	<1.0	12	0.1	<10.0	56	grab, 20 cm massive po+qtz layer
50	0.2	0.7	9.69	383	0.6	0.5	-0.1	0.1	4	x-cutting qtz-plag-andalusite vein
-2	0.3	2	0.9	21	<0.2	16.5	-0.1	0.5	40	x-cutting qtz veins, 1-3 cm
5	1.7	15.2	1.22	393	1.2	24	0.1	4.7	18	grab, py+chlorite in rusty qtz vein
73	0.35	1.2	3.68	39	0.2	14	-0.1	10	12	sericite altered, silicifed bio-schist

Au, As and Sb by INA; other elements by total digestion-ICP
Au in ppb, rest in ppm

ally poorly explored, indicate the potential for plutonic-related gold deposits in the region. Two other new gold prospects with anomalous Bi, Cu, W, Te have been discovered in amphibolite-grade quartzite and schist of the Shuswap complex. The Goldstrike (Bizar) and GQ occurrences are at a very early stage of exploration, but early work by Cathro and Lefebure (this volume) suggests their setting in amphibolite-grade pericratonic rocks with pegmatites is similar to that of the Pogo deposit in Alaska.

The Goldstrike (Bizar) property (MINFILE 82M 267) is located 16 kilometres northeast of the village of Avola (Figure 4). Mineralization consists of semi-concordant and sheeted quartz-sulphide veinlets hosted by amphibolite grade micaceous quartzite and quartz-muscovite-biotite-garnet schist of the Shuswap complex. A semi-concordant layer of auriferous massive pyrrhotite and minor chalcopyrite, up to 20 cm wide, occupies the west end of the Discovery showing. The layer is concordant with dominant synmetamorphic foliation and has been deformed together with the schists into southerly plunging crenulation folds. Tight fractures and narrow centimetre-wide grey quartz veins with limonite selvages trend northerly and dip steeply, crosscutting the micaceous quartzite and schists. Locally as many as 5 veinlets per metre are present, ranging from <1 to 10 centimeters in width. Some high-grade gold assays and anomalous gold values are reported for grab samples from the concordant massive pyrrhotite layers, and quartz veins respectively. Bismuth is particularly enriched and values correlate well with gold values (1:1). In addition anomalous Cu, Ni, Se, Te and W values are present (Table 2). Drilling in October, 1999 intersected narrow zones of quartz sulphide mineralization (*see* Cathro and Lefebure, this volume).

Kootenay Lake Area - North America Rocks

The southern Kootenay Arc coincides with the western margin of the Purcell anticlinorium, a broad, northerly plunging structural culmination of Middle Proterozoic Purcell Supergroup sedimentary rocks. The lower strata consist of the deep water, turbidites of the Aldridge Formation, and extensive Moyie - gabbroic intrusions. Overlying the Aldridge, but beneath the basal unconformity separating the Windermere Supergroup rocks are the fine-grained grey and green clastic quartz-rich rocks of the Creston Formation and fine-grained calcareous rocks of the Kitchener and Dutch Creek formations which underlie the study area. Conglomerates of the Toby Formation, the basal Windermere, unconformably overlie this succession northwest of Sanca stock and define a west-facing succession of North American strata. West of the Purcell Thrust fault are penetratively deformed and metamorphosed Neoproterozoic and Paleozoic rocks of the Kootenay Arc (Figure 4).

The Mount Skelly Pluton (MSP) is a Cretaceous post-accretionary intrusive (Archibald, 1984; Archibald, personal communication). It is another mid-Cretaceous intrusion belonging to the Bayonne Plutonic Suite (Woodsworth *et al.*, 1991; Reesor, 1996). The pluton, located 30 km north of Creston on the east side of Kootenay Lake (Figure 7), trends northeasterly across the structural fabric of Proterozoic Purcell and Windermere supergroup rocks. It consists of three intrusive phases differentiated on the basis of mineralogy, texture, grain size and magnetic signature (Logan and Mann, 2000b). From oldest to youngest, these include a potassium feldspar megacrystic hornblende-biotite granodiorite, a coarse or fine grained biotite granodiorite and a biotite plagioclase porphyritic leucogranite (Figure 8). Fine to medium grained quartz-feldspar-garnet aplite and hornblende-biotite-plagioclase phyric dikes, quartz veins and less commonly, coarse grained pegmatite dikes occur within the plutons, commonly near the margins of the intrusive phases. Biotite porphyry (lamprophyre) dikes occur, locally within and adjacent to mineralized structures. Au quartz veins, W veins and Mo greisen veins are hosted within the multiphase intrusion, while polymetallic base metal veins are found in the surrounding country rocks. Past production of gold is recorded from workings on the Government and Valparaiso crown grants which are hosted in a satellite body of coarse grained, biotite monzogranite located between Sanca and Akokli creeks, two kilometers east of Kootenay Lake (Figure 7).

K-Ar data for biotite and muscovite from the Mount Skelly Pluton and the Sanca Creek stock of the Bayonne Batholith yield conventional dates between 69 and 99 Ma (Archibald *et al.*, 1984; D. Archibald personal communi-

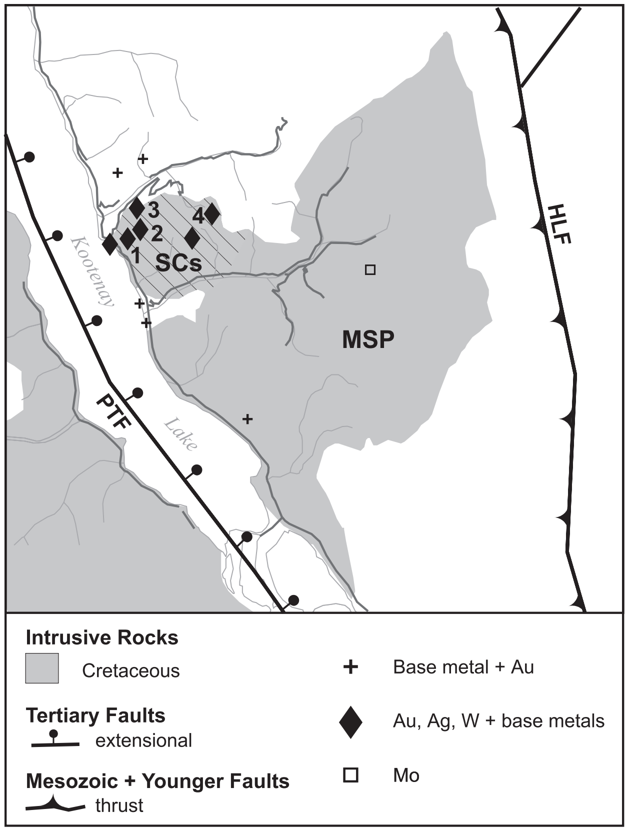

Figure 7. Geology of the Mount Skelly pluton, intrusive phases and mineralization related to the Sanca Creek stock. Mineral occurrences include Au-W deposits; 1=Valparaiso/Government, 2= Sarah, 3= Lost Mine, 4= German Basin, molybdenum and base metal + Au veins.

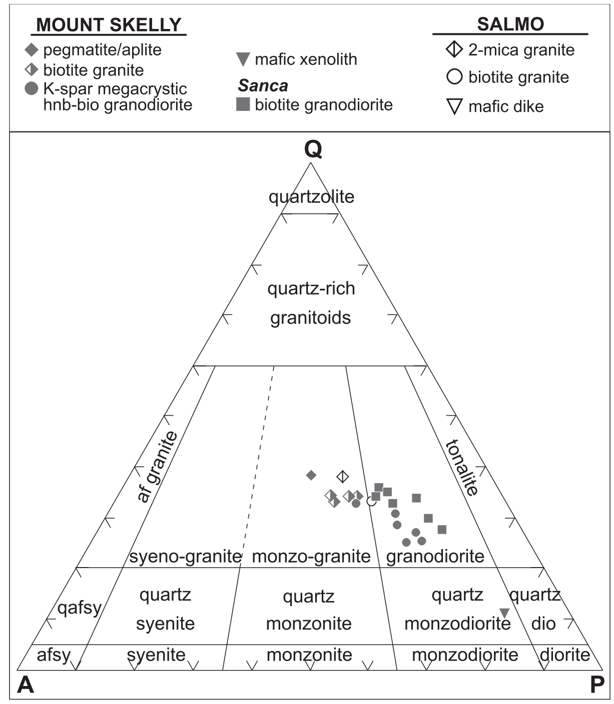

Figure 8. Modal quartz-alkali feldspar-plagioclase feldspar plot for Mount Skelly Pluton (MSP), Sanca Creek stock (SCs) and environs. Fields from LeMaitre (1989).

cation, 1999). The age of the potassium-feldspar megacrystic hornblende granodiorite phase of the MSP is approximately 99 Ma and its southern tail of leucocratic biotite granite averages 70 Ma. Biotite granodiorite of the Sanca Creek stock is approximately 80 Ma. ^{40}Ar-^{39}Ar data yield plateau-shaped age spectra which do not record evidence of a reheating event (Archibald *et al.*, 1984).

The Mount Skelly pluton intruded the Creston Formation and developed a low-pressure, contact-metamorphic aureole. Andalusite and cordierite porphyroblasts overgrow the penetrative fabric in country rock within one kilometre of the northern contact. The presence of adalusite suggests emplacement pressures of less than about 4 kbar. Retrograded garnet-biotite-sericite-cordierite schists are locally present, but for the most part, characteristic pelite mineral assemblages are poorly developed due to the quartzose composition of the Creston Formation. A rusty-weathering, muscovite-biotite, sillimanite-bearing zone of migmatite occupies the innermost zone adjacent to the pluton. The zone is about 100 m wide and comprises ductile deformed, amoeboid-shaped micaceous, quartzose, and calcsilicate country rocks. The zone is cut by tourmaline-muscovite pegmatites and quartz veins. The contact with the intrusion is steep and sharp. The monzonite is neither foliated nor chilled near its margin. The occurrence of sillimanite without kyanite suggests that the pressure did not exceed about 6 kbar (at 600^oC).

The majority of the MSP is comprised of a coarse-grained, biotite-hornblende granodiorite characterized by abundant euhedral potassium feldspar megacrysts and rounded mafic xenoliths. Titanite is commonly visible in hand samples of coarse grained varieties, as are trace amounts of magnetite and epidote. The mafic xenoliths are lenticular to rounded, monzodiorite to quartz diorite in composition, consisting mainly of biotite, plagioclase, quartz and titanite. Close to the northwestern margin of the pluton, the inclusions and potassium feldspar megacrysts define a north-trending, east-dipping foliation which parallels the contact. This is the oldest phase in the pluton and has a stronger magnetic signature than the other phases of the MSP.

Fine to medium grained, generally equigranular, biotite granite crops out between Mount Skelly and Jackson Peak in the eastern portion of the pluton and immediately south of Mount Sherman in the west-central portion of the pluton. This phase cuts the main hornblende biotite megacrystic phase. The granite is leucocratic due to the low amount of biotite (~5%). It is fine to medium-grained, equigranular to locally porphyritic, and rarely contains sparse feldspar megacrysts.

The Sanca Creek stock is located northwest of the Mount Skelly Pluton and is separated from the main body by septa of metamorphosed country rock. It stands out as a separate, low to moderate strength magnetic anomaly on the aeromagnetic survey map suggesting the stock is a separate body. It consists of a medium to coarse grained, biotite± hornblende granodiorite with large (up to 1.5

cm), rounded, violet to pale grey quartz grain aggregates or anhedral crystals. Sparse potassium feldspar megacrysts occur locally throughout.

Mineralization

Mineralization is hosted in all intrusive phases of the Mount Skelly Pluton; the main hornblende-biotite potassium feldspar megacrystic granodiorite, the younger biotite granite and the biotite granodiorite of the Sanca Creek. Gold-arsenic mineralized quartz shear zones have been discovered in the oldest phase and sheeted veins of molybdenum mineralization are known from the younger biotite granite, but the majority of gold-tungsten mineralization is contained within the Sanca Creek stock. It hosts the Valparaiso, Government, Sarah, Lost Mine, and German Basin past producing gold mines (Figure 7). The mineral occurrences are hosted in sub-parallel quartz ± pyrite, sphalerite, galena, scheelite, wolframite, gold veins filling prominent north-trending joint and fault structures (Photos 3 and 4).

The Valparaiso-Government (MINFILE 82F 38) vein was discovered in the early 1900's and has received the most exploration and development to date. Shipments of ore are reported for 1900, 1901 and 1933 and tungsten concentrate was produced in 1955. The vein is a well-defined quartz-filled fissure in biotite granodiorite of the Sanca Creek stock. It is exposed over a strike length of 800 metres in various open cuts and developed underground by 160 metres of drifting in the Government workings and 200 metres of drifting in the Valparaiso workings at its north end. The main vein structure strikes northerly and dips eastward at 40 degrees and averages between 1.6 and 2 metres width. Surface sampling of the main and distal parallel veins returned anomalous Au, As, W, Bi, Cu, Pb and Zn. Centimetre to metre wide parallel quartz-filled sheeted fractures are hosted in hangingwall and footwall sections of the main vein-fault. Two footwall-veins are exposed underground in the Valparaiso workings; a 0.12 m scheelite-bearing vein and a 0.45 m sulphide-rich ribboned quartz vein. These underlie the main vein-fault, a 1.1 m oxidized zone comprised of six, 1-3 cm quartz veinlets hosted in sheared hematite and limonite-stained granodiorite. The granodiorite contains discrete, centimetre wide, clay altered shear planes. Sampling indicates gold is associated with the higher sulphide content. Mineralization consists of pyrite, arsenopyrite, wolframite, galena, sphalerite and rare chalcopyrite which occur as streaks, blebs and disseminations irregularly distributed along the vein, but appear concentrated along the vein walls. Gold and silver values are proportional to the amount of sulphides in the vein. A biotite lamprophyre dike occupies the footwall to the vein at the Government.

East of, and 200 m above the Government shaft, are the Imperial-Sarah workings (MINFILE 82F 55), which explore a parallel mineralized quartz vein (Figure 7). Surface cuts expose narrow, north-trending quartz veins hosted by sericite altered biotite granodiorite. A 0.5 m quartz vein with biotite lamprophyre hangingwall is exposed in one trench located north of the caved adit. Mineralization consists of pyrite, arsenopyrite, wolframite, sparse sphalerite and galena and traces of chalcopyrite.

The northern extension of the Valparaiso vein was explored by 40 metres of drifting in the Lost Mine workings (MINFILE 82F 131) located approximately 1000 metres north of the Valparaiso tunnel (Figure 7). Here the structure is comprised of two fractured quartz veins, 0.4 and 0.6 m thick and a narrow footwall gouge zone containing oxidized pyrite.

The German Basin showing (MINFILE 82F 039) is located 3.6 km east of the Vaparaiso-Government high on the ridge between Sanca and Akokli creeks (Figure 7). The vein strikes north, dips west and can be traced on surface for 100 metres. It is developed by two adits and a shaft, as well as numerous open cuts and several raises to surface from the adits. The vein pinches and swells from 2 m at the portal to a minimum width of 0.15 m (Greene, 1981). Adjacent to mineralized structures the granodiorite is altered; biotite is replaced by chlorite and sericite, and feldspars are replaced by sericite. The quartz contains sparse pockets and disseminations of pyrite, sphalerite, galena and rare, orange-coloured scheelite.

Surface drilling to assess the extent of mineralization in the Government showing has been hampered by broken ground conditions which prevented completion of a 1981

Photo 3. Sheeted fractures and quartz veinlets in biotite granodiorite of the Sanca Creek stock.

Photo 4. Parallel quartz vein, mineralized with pyrrhotite and aplite dike hosted by coarse-grained biotite granodiorite of the Sanca Creek stock.

TABLE 3
SELECTED GEOCHEMICAL ANALYSES, MOUNT SKELLY PLUTON
REGIONAL AND PROPERTY SPECIFIC SAMPLES

Au	Ag	As	Bi	Cu	Mo	Pb	Sb	W	Zn	Sample Description
3	0.15	0.8	344	16	3.6	38.5	0.3	8.4	38	spaced fractures-sericite, py, qtz
6	0.25	4.3	2.74	10	1.2	41	3.7	5.2	46	silicified fault zone
-2	0.5	2.2	1.95	3	<0.2	32	0.7	4.7	28	brecciated chalcedony zone
4	0.05	4.6	0.32	3	0.2	26.5	5	1.9	78	0.35 m fault gouge
4	0.05	2.2	0.29	10	<0.2	24.5	0.3	0.7	52	grab silicified fractures
154	1.65	1100	1.98	45	0.6	517	6.8	1.2	478	drusy qtz with botryoidal hematite
247	20.8	38.5	22	765	<1.0	>10000	5.6	<10.0	2590	0.35 m chip alteration+qtz vein
287	>100.0	3	86	320	<1.0	>10000	2.6	<10.0	2000	grab mineralization from trench
3	0.6	2.5	1.56	158	63.9	92.5	0.1	22.4	30	1-2 cm altered fractures, qtz, py
4	0.05	2.1	0.89	12	1.6	43.5	0.1	0.2	14	grab-tight qtz fractures, py, chl
2	<0.20	2	778	24	18	52	0.5	<10.0	30	16 cm drusy qtz vein
21	6.9	32.8	20.4	114	15	490	1.3	3	28	vuggy silicified pyritized intrusive
138	1.2	47.8	2	12	3	86	1.2	10	146	grab - 0.75 m silicifed zone
35	1.3	38.2	1.79	27	1	247	1.6	7.8	116	grab- veins across 16 m zone
German Basin										
954	83.4	13	56.1	211	2.8	7720	0.5	1.3	1780	grab qtz vein, py, sph, galena
Sarah-Imperial										
132	8.9	33.7	0.6	340	0.2	315	1.9	67.4	4460	grab vein, drusy quartz, sph, gal
Valparaiso-Govertment Property										
647	28.3	1470	26.2	718	9	8370	3.1	10.2	1145	5 cm qtz vein, sericite alteration
8	2.3	216	7.66	35	0.8	576	-0.1	96.1	372	0.5m limonitic drusy qtz, traces py
456	9.05	3790	14.85	406	1	441	-0.1	105.5	632	altered monzonite
371	8	10600	8	544	2	1160	2.2	10	730	0.9 m chip, altered-sheared HW
2690	23.6	26200	22	615	5	492	2.2	1150	162	0.50 m chip sample of qtz vein
10	1.2	9600	<2.00	2820	3	210	2.5	40	4050	lamprophyre dike Fw to vein
14400	>100.0	126000	140	8140	<1.0	234	5.2	3160	80	grab, high grade sulphide- in HW
95	3	1110	9.57	124	1.4	1065	3.1	41.7	2520	1.1 m chip granite+qtz veinlets
55	6.6	643	2	140	6	4680	4.1	1810	486	12 cm scheelite-bearing qtz vein
5310	71.8	41400	72	542	11	6350	7.8	7100	354	0.45 m sulphide-rich ribboned vein
1040	12.4	89.3	<2.00	285	4	1630	2.3	2130	16	scheelite, py 3-4 cm qtz vein
2330	24	12.8	0.45	144	12	8420	4	51	568	qtz vein, sericite alteration selvage
28	0.25	9.5	2.29	6	18.8	60.5	0.3	9.4	28	grab 3 veins & alteration selvage
157	3.4	9.3	2.93	21	0.2	113.5	0.2	5.4	18	grab, altered granite + qtz veins
Tungsten Creek vicinity										
1040	12.4	89.3	<2.00	285	4	1630	2.3	2130	16	scheelite, py 3-4 cm qtz vein
2330	24	12.8	0.45	144	12	8420	4	51	568	qtz vein, sericite alteration selvage
28	0.25	9.5	2.29	6	18.8	60.5	0.3	9.4	28	grab quartz veinlets & alteration
157	3.4	9.3	2.93	21	0.2	113.5	0.2	5.4	18	2.5 m sericite-altered qtz veinlets

Au, As and Sb by INA; other elements by total digestion-ICP
Au in ppb, rest in ppm
Sample locations *see* Logan and Mann (2000b).

diamond drill program. Percussion drilling was attempted in 1988 to completed the objectives of the 1981 program but ground conditions again proved insurmountable. The intersection of numerous centimeter to metre wide parallel mineralized and altered fractures, however is encouraging and indicates that mineralization is not restricted to the main zone (Valparaiso fault), but occupies sheeted fractures over a wide vertical range in the intrusive (Greene, 1981). The low-grade bulk-tonnage potential for the showings has not been fully tested.

CONCLUSIONS

The 1999 mapping program carried out reconnaissance mapping, sampling and deposit studies in the vicinity of two mid-Cretaceous Bayonne suite intrusions in southern British Columbia. Results from age-dating, Pb-isotopic studies and geochemistry are pending but field observations and petrography support the permissiveness of the plutonic-related deposit model for gold exploration in British Columbia.

Gold mineralization at Cam-Gloria is associated with Bi, As, Pb, W and Cu metal assemblages in multiple vein structures enclosed by wide pervasive sericite alteration zones. The wide zone of pervasive sericite alteration accompanying quartz veining and mineralization is not a well developed characteristic of Plutonic-related deposits.

Limited past production of gold and tungsten from quartz-filled sheeted veins at the Valparaiso and Government deposits and the distribution of low-grade mineralization throughout the Sanca Creek stock indicate this is a good British Columbia example of a Fort Knox-type of intrusion-hosted, gold-quartz vein deposit. The distribution of low-grade gold mineralization warrants assessment for potential bulk tonnage resources.

This years study focused on intrusion-hosted, gold-tungsten veins of the Fort Knox-type, where a direct relationship between mineralized vein and the pluton is apparent, subsequent work will attempt to establish criteria that recognize areas peripheral to prospective intrusions with Pogo-type potential.

Exploration programs for plutonic-related gold deposits in British Columbia should focus inboard of the accreted terranes in marginal basin rocks of the pericratonic terranes or North American platformal rocks, particularly in, and around, highly differentiated granitic intrusions. As in Alaska and the Yukon, the best targets are mid-Cretaceous plutons and batholiths in structural settings which expose and/or juxtapose deposits formed at different crustal levels. The discovery of the high-grade Pogo gold deposit within amphibolite grade gneisses in Alaska indicates potential in equivalent high grade metamorphic rocks of the Omineca Belt in the Canadian Cordillera.

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REFERENCES

Anderson, R.G., 1988, An overview of some Mesozoic and Tertiary plutonic suites and their associated mineralization in the northern Canadian Cordillera: *in* Recent Advances in the Geology of granite-related mineral deposits, ed., R.P. Taylor and D.F. Strong, *The Canadian Institute of Mining and Metallurgy*, Special Volume 39, p. 96-113.

Archibald, D. A., Glover, J. K., Price, R. A., Farrar, E. and Carmichael, D. M. (1983): Geochronology and Tectonic Implications of Magmatism and Metamorphism, Southern Kootenay Arc and Neighbouring Regions, Southeastern British Columbia. Part I: Jurassic to mid-Cretaceous; *Canadian Journal of Earth Sciences*, Volume 20, p. 1891-1913.

Archibald, D. A., Krogh, T.E., Armstrong, R.L. and Farrar, E., 1984, Geochronology and Tectonic Implications of Magmatism and Metamorphism, Southern Kootenay Arc and Neighbouring Regions, Southeastern British Columbia. Part II: mid-Cretaceous to Eocene; *Canadian Journal of Earth Sciences*, Volume 21, pages 567-583.

Armstrong, R. L., 1982, Cordilleran metamorphic core complexes - from Arizona to southern Canada: *Annual Reviews of Earth and Planetary Science Letters*, v. 10, p. 129-154.

Armstrong, R. L., 1988, Mesozoic and Early Cenozoic Magmatic Evolution of the Canadian Cordillera: *in* Processes in Continental Lithospheric Deformation, ed., Clark, S. P., Jr., Burchfield, B. C. and Suppe, J., *Geological Society of America*, Special Paper 218, pages 55-91.

Bally, A.W., Gordy, P.L. and Stewart, G.A, 1966, Structure, seismic data and orogenic evolution of southern Canadian

Rocky Mountains: *Bulletin of Canadian Petroleum Geology*, v. 14, p. 337-381.

Baker, T., Lang, J.R. and Mortensen, J.K., submitted, Characteristics of mineralization associated with intrusions of the mid-Cretaceous Tombstone-Tungsten magmatic belt, Yukon: *Economic Geology*.

Bakke, A., 1995, The Fort Knox 'porphyry' gold deposit - structurally controlled stockwork and shear quartz vein, sulphide-poor mineralization hosted by a Late Cretaceous pluton, east-central Alaska: *in* Porphyry Deposits of the Northwestern Cordillera, *Canadian Institute of Mining, Metallurgy and Petroleum*, Special Volume 46, p. 795 -802.

Bakke, A., Morrell, B. and Odden, J., 1998, The Fort Knox porphyry gold deposit, east-central Alaska: An overview and update: in Porphyry and Hydrothermal Copper and Gold Deposits, Australian Mineral Foundation, Conference Proceedings, November, 1998, p. 89-98.

Belik, G.D., 1973, Geology of the Harper Creek copper deposit: Unpublished M.Sc. thesis, The University of British Columbia, Vancouver, British Columbia, 86 p.

Bobrowsky, P.T., Leboe, E.R., Dixon-Warren, A., Ledwon, A., MacDougall, D. and Sibbick, S.J., 1997, Till Geochemistry of the Adams Plateau-North Barriere Lake Area, 82M/4 and 5: *B.C. Ministry of Employment and Investment*, Open File 1997-9, 262 p.

Brandon, A.D. and Lambert, R.St.J., 1993, Geochemical characterization of mid-Cretaceous granitoids in the Kootenay Arc in the southern Canadian Cordillera: *Canadian Journal of Earth Sciences*, 30, p. 1076-1090.

Brandon, A.D. and Smith, A.D., 1994, Mesozoic granitoid magmatism in southeast British Columbia: implications for the origin of granitoid belts in the North American Cordillera: *Journal of Geophysical Research*, volume 99, p. 11,879-11,896.

Brown, R. L. and Carr, S. D., 1990, Lithospheric thickening and orogenic collapse within the Canadian Cordillera: Australasian Institute of Mining and Metallurgy, 1990 Pacific Rim Congress Proceedings, v. II, p.1-10.

Brown, R. L., Carr, S. D., Johnson, B. J., Coleman, V. J., Cook, F. A. and Varsek, J. L. (1992): The Monashee DQcollement of the Southern Canadian Cordillera: A Crustal-scale Shear Zone Linking the Rocky Mountain Foreland Belt to Lower Crust beneath Accreted Terranes; *in* Thrust Tectonics, McClay, K. R., ed., *Chapman & Hall*, London, pages 357-364.

Brown, R. L., Journeay, M. J., Lane, L. S., Murphy, D. C. and Rees, C. J. (1986): Obduction, Backfolding and Piggyback Thrusting in the Metamorphic Hinterland of the Southeastern Canadian Cordillera: *Journal of Structural Geology*, Volume 8, pages 255-268.

Carr, S.D., 1992, Tectonic setting and U-Pb geochronology of the early Tertiary Ladybird leucogranite suite, Thor-Odin-Pinnacles area, southern Omineca Belt, British Columbia: *Tectonics,* v. 11, p. 258-278.

Calderwood, A.R., van der Hayden, P., and Armstrong, R.L., 1990, Geochronometry of the Thuya, Takomkane, Raft and Baldy batholiths, south-central British Columbia: Geol. Assoc. Can. Mineral. Assoc. Can. Ann. Meet. Programs with Abstr., 15, A19.

Cathro, M.S., 1998, Exploration and Development Highlights in South-Central British Columbia - 1997: *Ministry of Energy and Mines*, Exploration in British Columbia - 1997, p. 33-41.

Cathro, M. and Lefebure, D.V., this volume, Several new intrusive-related gold, bismuth and tungsten occurrences in Southern British Columbia: *British Columbia Ministry of Energy and Mines*, Geological Fieldwork 1999.

Gabrielse, H., and Yorath, C. J., 1991, Tectonic synthesis, Chapter 18, *in* Gabrielse, H., and Yorath, C.J., eds., Geology of the Cordilleran Orogen in Canada: *Geological Survey of Canada*, Geology of Canada, no. 4, p. 677-705 (*also* Geological Society of America, The geology of North America, v. G-2).

Gabrielse, H., Monger, J.W.H., Wheeler, J.O. and Yorath, C. J., 1991, Part A, Morphogeological belts, tectonic assemblage, and terranes, in Chapter 2 of Gabrielse, H., and Yorath, C.J., eds., Geology of the Cordilleran Orogen in Canada: *Geological Survey of Canada*, Geology of Canada, no. 4, p. 15-28 (*also* Geological Society of America, The geology of North America, v. G-2).

Ghent, E.D., Nicholls, J., Simony, P.S., Sevigny, J. and Stout, M., 1991, Hornblende geobarometry of the Nelson Batholith, southeastern British Columbia: tectonic implications: *Canadian Journal of Earth Sciences*, v. 28, p. 1982-1991.

Ghosh, D.K., 1995, Nd-Sr isotopic constraints on the interaction of the Intermontane Superterrane with the western edge of North America in the Southern Canadian Cordillera: *Canadian Journal of Earth Sciences*, v. 32, p. 1740-1758.

Greene, A.S., 1981, Property Evaluation Report, Destiny Bay Properties, Hot Group of Claims, 82F/7: *British Columbia Ministry of Energy, Mines, and Petroleum Resources*, Assessment Report 10811.

Hitchins, A.C. and Orssich, C.N., 1995, The Eagle Zone gold-tungsten sheeted vein porphyry deposit and related mineralization, Dublin Gulch, Yukon Territory: *in* Porphyry Deposits of the Northwestern Cordillera, *Canadian Institute of Mining, Metallurgy and Petroleum*, Special Volume 46, p. 803-810.

Hollister, V.F., 1992, On a proposed plutonic porphyry gold deposit model: *Nonrenewable Resources*, Volume 1, pages 293-302.

Johnson, B.J., 1994, Structure and tectonic setting of the Okanagan Valley fault system in the Shuswap Lake area, southern British Columbia: unpublished Ph.D. thesis, *Carleton University*, 266 pages.

Jung, A., 1986, Geochronometry and Geochemistry of the Thuya, Takomkane, Raft and Baldy batholiths, west of the Shuswap metamorphic complex, south-central British Columbia: Unpublished B.Sc. thesis, *The University of British Columbia*, Vancouver, British Columbia, 140 p.

Kirkland, K.J., 1971, Sulfide deposition at Noranda Creek, British Columbia: Unpublished M.Sc. thesis, *University of Alberta*, Edmonton, Alberta, 107 p.

Leclair, A.D., Parrish, R.R. and Archibald, D.A., 1993, Evidence for Cretaceous deformation in the Kootenay Arc based on U-Pb and 40Ar/39Ar dating, southeastern British Columbia: *in* Current Research, Part A: *Geological Survey of Canada*, Paper 93-1A, p. 207-220.

Lefebure, D.V. and Cathro, M., 1999, Plutonic-related gold-quartz veins and their potential in British Columbia: *in* Short Course on Intrusion-Related Gold- *Kamloops Exploration Group*, p. 185-219.

Lefebure, D.V., Fournier, M.A. and Jackaman, W., 1999, Prospective areas in British Columbia for gold-tungsten-bismuth veins: *British Columbia Ministry of Energy and Mines*, Open File 1999-3, 1:2 000 000 scale map with marginal notes and digital files.

Lett, R.E., Bobrowsky, P., Cathro, M, and Yeow, A., 1998, Geochemical Pathfinders for Massive Sulphide Deposits in the Southern Kootenay Terrane: *B.C. Ministry of Employment and Investment* Geological Fieldwork 1997, p. 15-1-9.

Lett, R.E. and Jackaman, W., this volume, Geochemical Exploration Techniques for Intrusive Hosted Gold Deposits in Southern B.C. (parts of 82M/4, 5, 6 and 82F/7): *in* Geological Fieldwork 1999, *British Columbia Ministry of Energy and Mines,* Paper 2000-1.

Logan, J.M. and Mann, R.K., 2000a, Geology and Mineralization in the Adams -East Barriere lakes area, South-central British

Columbia, 82M/04: *British Columbia Ministry of Energy and Mines*, Open File 2000-7.

Logan, J.M. and Mann, R.K., 2000b, Geology and Mineralization around the Mount Skelly Pluton, Kootenay Lake, Southeastern British Columbia, 82F/07: *British Columbia Ministry of Energy and Mines*, Open File 2000-8.

Logan, J.M., Lefebure, D.V. and Cathro, M., submitted, Plutonic-related gold-quartz veins and their potential in British Columbia: *in* The Tintina Gold Belt Concepts, Exploration and Discoveries, ed., J.L. Jambor, *British Columbia and Yukon Chamber of Mines,* Cordilleran Exploration Roundup 2000, Extended abstracts volume.

Marsh, E.E., Hart, C.J.R., Goldfarb, R.J. and Allen, T.L., 1999, Geology and geochemistry of the Clear Creek gold occurrences, Tombstone gold belt, central Yukon Territory: *in* Yukon Exploration and Geology, *Indian and Northern Affairs, Canada*, Volume 21, p. 185-196.

McCoy, D., Newberry, R.J., Layer, P., DiMarchi, J.J., Bakke, A., Masterman, J.S., and Minehane, D.L., 1997, Plutonic-related Gold Deposits of Interior Alaska: *Economic Geology*, Monograph 9, p. 191-241.

Monger, J.W.H., Price, R.A. and Tempelman-Kluit, D.J. 1982, Tectonic accretion and the origin of the two major metamorphic and plutonic welts in the Canadian Cordillera: *Geology*, Volume 10, pages 70-75.

Mortensen, J.K., Murphy, D.C., Hart, C.J.R. and Anderson, R.G., 1995, Timing, tectonic setting and metallogeny of Early and Mid-Cretaceous magmatism in Yukon Territory: *Geological Society of America*, Abstracts with Programs, v.27, no. 5, p.65.

Murphy, D.C., 1987, Suprastructure-infastructure transition, east-central Cariboo Mountains, British Columbia: geometry, kinematics, and tectonic implications: *Journal of Structural Geology*, No. 9, p. 13-29.

Murphy, D.C., van der Heyden, Parrish, R.R., Klepacki, D.W., McMillan, W., Struik, L.C. and Gabites, J., 1995, New Geochronological constraints on Jurassic deformation of the western edge of North America, southeastern Canadian Cordillera: in Magmatism and tectonics of the North American Cordillera, ed., D.M. Miller and C. Busby, *Geological Society of America*, Special Paper 299, p. 159-171.

Parkinson, D.L., 1985, U-Pb geochronometry and regional geology of southern Okanagan Valley, British Columbia: The western boundary of a metamorphic core complex: Unpublished MSc thesis, The *University of British Columbia*, Vancouver, British Columbia, 149 p.

Parrish, R.R., 1984, Slocan Lake fault: A low angle fault zone bounding the Valhalla gneiss complex, Nelson map area, southern British Columbia: in Current Research, Part A: *Geoogicall Survey of Canada*, Paper 84-1A, p. 323-330.

Parrish, R.R., 1995, Thermal Evolution of the Southeastern Canadian Cordillera: *Canadian Journal of Earth Sciences*, v. 32, p. 1618-1642.

Parrish, , R.R., Carr, S.D. and Parkinson, D.L., 1988, Eocene extensional tectonics and geochronology of the southern Omineca Belt, British Columbia and Washington: *Tectonics*, v. 7, p. 181-212.

Pearce, J.A., Harris, N.B.W. and Tindle, A.G. (1984): Trace element discrimination diagrams for the tectonic interpretation of granitic rocks: *Journal of Petrology*, Volume 25, pages 956-983.

Poulsen, K.H, Mortensen, J.K. and Murphy, D.C., 1997, Styles of intrusion-related gold mineralization in the Dawson-Mayo Area, Yukon Territory: *in* Current Research 1997-A, *Geological Survey of Canada*, p. 1-10.

Price, R.A. and Mountjoy, E.W., 1970, Geological structure of the Canadian Rocky Mountains between Bow and Athabasca rivers - a progress report: in Wheeler, J.O., ed., Structure of the southern Canadian Cordillera: *Geological Association of Canada*, Special Paper 6, p.7-25.

Read, P. B. and Brown, R. L., 1981, Columbia River Fault Zone: Southeastern Margin of the Shuswap and Monashee Complexes, Southern British Columbia: *Canadian Journal of Earth Sciences*, V. 18, p. 1127-1145.

Read, P.B., Woodsworth, G.J., Greenwood, H.J., Ghent, E.D. and Evenchick, C.A., 1991, Metamorphic Map of the Canadian Cordillera: *Geological Survey of Canada*, Map 1714A, scale 1:2 000 000.

Rees, C.J., 1987, The Intermontane-Omineca belt boundary in the Quesnel Lake area, east-central British Columbia: Tectonic implications based on geology, structure and paleomagnetism: Unpublished Ph.D. thesis, *Carelton University*, Ottawa, Ontario, 421 p.

Reesor, J.E., 1996, Geology, Kootenay Lake, British Columbia, *Geological Survey of Canada,* map 1864A, scale 1:100 000.

Schiarizza, P. and Preto, V.A., 1987, Geology of the Adams Plateau-Clearwater-Vavenby area: B.C. *Ministry of Energy, Mines and Petroleum Resources*, Paper 1987-2, 88 p.

Sinclair, W.D., 1995, Molybdenum, tungsten and tin deposits and associated granitoid intrusions in the Canadian Cordillera and adjacent parts of Alaska: *in* Porphyry Deposits of the Northwestern Cordillera of North America: *Geological Society of the Canadian Institute of Mining, Metallurgy and Petroleum*, Special Volume 46, p. 58-76.

Smith, M. , Thompson, J.F.H., Bressler, J., Layer, P., Mortensen, J.K., Abe, I. and Takaoka, H., 1999, Geology of the Liese Zone, Pogo Property, East-Central Alaska, *SEG Newsletter*, No. 38, July 1999 p. 12-21.

Thompson, J.F.H., Sillitoe, R.H., Baker, T., Lang, J.R. and Mortensen, J.K., 1999, Intrusion-related gold deposits associated with tungsten-tin provinces: *Mineralium Deposita*, Volume 34, Number 4, p. 323-334.

Wanless, R.K., Stevens, R.D., Lachance, G.R. and Rimsaite, J.Y.H., 1966, Age Determinations and Geological Studies K-Ar Isotopic Ages, Report 6: *Geological Survey of Canada*, Paper 65-17.

Woodsworth, G.J., Anderson, R.G. and Armstrong, R.L., 1991, Plutonic regimes, Chapter 15: in Geology of the Cordilleran Orogen in Canada: *Geological Survey of Canada*, Number 4, p. 491-531 (also *Geological Society of America*, The Geology of North America, volume G-2).

Zen, E., 1989, Plumbing the depths of batholiths: *American Journal Science*, 289, p. 1137-1157.

Zen, E. and Hammarstrom, J.M., 1984, Magmatic epidote and its petrologic significance: *Geology*, 12, p. 515-518.