Homestake Ridge

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From: Pinsent, Robert EM:EX
Sent: Thursday, October 26, 2000 10:55 AM
To: Schroeter, Tom EM:EX
Subject: Mineral Deposits of the Upper Kitsault River Area
Sensitivity: Private

Tom,

I would appreciate it if you would take a look at this draft when you have time. Note there are no maps yet, for obvious reasons. In the absence of new data, my feeling is that it would be more appropriate for Exploration and Mining in British Columbia than Fieldwork - let me know what you think.

Robert

I agree, wholeheartedly!
TGS
Nov. 6/00

Robert,
Text looks in relatively good shape to me. I doubt I'll have time to assist you with diagrams until the first week of December (i.e. when I leave for Spokane) — sorry, but that's life.

edits by Jan Schroeter Nov. 6/00

Mineral Deposits of the Upper Kitsault River Area, British Columbia (103P)

103P/?E ?W

By R.H. Pinsent

KEYWORDS: *Economic geology, Lower Jurassic, Hazelton Group, silver production, quartz-barite-carbonate-sulphide-oxide (Ag) deposits, quartz-sericite-chlorite-sulphide (Cu, Au) deposits, stockwork deposits, mesothermal, epithermal vein deposits, exhalative deposits, silver, lead, zinc, barium, strontium, copper, gold, Red Point, Homestake, Wolf, Torbrit, Northstar, Dolly Varden,, Kit/Sault, Red Mountain, Eskay Creek.*

INTRODUCTION

describes / outlines / discusses

This report ~~is a discussion~~ of the mineral deposits of a portion of the northern Coast Mountains southeast of Stewart, British Columbia. It is based on public domain reports and visits to some of the sites. However, none of the underground workings were examined. The work was funded under the Provincial Government's Corporate Resource Inventory Initiative (CRII) as part of the Ministry's contribution to the North Coast land resource management planning process.

selected

? → (MI 103P 188)

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The Upper Kitsault River area hosts two past-producing silver mines (Dolly Varden (103P 188) and Torbrit (103P 191)) and numerous other prospects that range in size from small showings to developed deposits (Northstar (103P 189) and Wolf (103P 198)). There are four types of mineral deposit: 1) Cu-Au chlorite-pyrite vein stockwork deposits (Red Point (103P 196) and Homestake (103P 216)); (2) epigenetic Ag-Pb-Zn quartz-carbonate vein deposits (Wolf); (3) either epigenetic or syngenetic Ag-Pb-Zn-Ba deposits (Torbrit, Northstar and Dolly Varden) and (4) exhalative Ba-Sr-Zn-Ag deposits (Kit/Sault (103P 233)). They are all in Lower Jurassic volcanic and sedimentary strata, near the top of the Hazelton volcanic arc succession. There are conflicting opinions as to the origins of some of the Upper Kitsault River deposits. In the absence of new data, this report makes no attempt to resolve the conflicts. It describes some of the more important occurrences and comments on possible similarities to precious-metal deposits at Red Mountain and Eskay Creek.

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PREVIOUS WORK

Most of the mineral deposits in the Stewart area were located in the late 1800s and early 1900s, and those in the Anyox area were located shortly thereafter. Prospectors moved into the Kitsault River area, north of Alice Arm, in the early 1900s and staked the first showings in the Upper Kitsault River area in 1913. Most of the better documented showings had been found by 1921, the end of the first phase of production at the Dolly Varden mine.

The showings in the Kitsault River area are mentioned in Ministry of Mines Annual Reports and described in some detail by Hanson (1922, 1935) and Black (1951). Carter and Grove (1972) produced a 1:250 000-scale compilation of the geology of the area in the early 1970s, and Grove (1986) produced a bulletin on the geology and metallogeny of the "Stewart Complex", a term he applied to the volcanic and sedimentary rocks between the eastern margin of the Coast Plutonic Complex and the western margin of the Bowser Basin in the mid-1980s. He noted a broad regional zonation of mineral deposits within the Complex and recognized the silver potential of the Alice Arm portion. The area was mapped at 1:50 000-scale by Alldrick et al. (1986) and described by Dawson and Alldrick (1986). Alldrick also discusses the stratigraphy of the area in a review of the distribution of volcanic centres in the Stewart Complex (Alldrick, 1989).

The Stewart Complex was primarily known for the abundance of its epigenetic precious metal deposits (Grove, 1986; Alldrick, 1993) up until the late 1980s. However, the discovery of a major gold-enriched, volcanogenic massive sulphide deposit at Eskay Creek (approximately 100 km northwest of Stewart), in 1988, added considerably to its exploration interest. This was reinforced by the discovery of a major, intrusion-related, gold deposit at Red Mountain (approximately 20 kilometres east of Stewart) the following year. There were numerous exploration programs in the Kitsault River area in the late 1980s and early 1990s. Many of them are described in Assessment Reports filed with the Ministry.

Although there were no major government mapping programs in the Kitsault River area in the 1990s, several more modest programs help to constrain the geology. Godwin et al. (1991) used plots of lead isotope values from galena samples from a broad area of northern British Columbia to differentiate between Jurassic and Tertiary-age mineralization. The same year, Greig (1991) mapped the top of the Hazelton volcanic arc southeast of Kitsault Lake. In 1992, Mortensen and Kirkham (1992) obtained an approximate U-Pb zircon age for syngenetic mineralization near Kitsault Lake and, in 1994, Greig et al. (1994) mapped the geology of the Cambria Icefield area, including the uppermost part of the Kitsault River drainage. Most recently, Evenchick and Mustard (1996) studied the stratigraphy and structure of Bowser Lake Group sediments on the east side of the Stewart Complex. The geology of the Skeena-Nass area has been compiled by MacIntyre et al. (1994), at 1:250 000-scale, and it is this map that is available on the Ministry website (www.em.gov.bc.ca/geology).

GEOLOGY

The simplified geological map of the Kitsault River area, Figure 1, is from MacIntyre et al. (1994). It is based on the work of Alldrick et al. (1986) who identified six stratigraphic units formed during two cycles of arc volcanism. From bottom to top, they include: 1) a thick flysch-siltstone layer (base unseen), topped by black limestone [uTrss]; (2) a mixed succession of locally-pillowed augite, feldspar and olivine porphyritic basalt flows/breccias and derived conglomerates [uTrSvm]; (3) mixed clastic sediment and volcanic breccia capped by a distinctive polymictic (chert or siltstone supported) conglomerate [lJHs]; (4)

porphyritic andesitic pyroclastics (tuffs and breccias) and related flows and sills with 10-15% intercalated argillite, limestone and chert [lJHvi]; (5) alternating maroon and green volcanic breccias and conglomerates with discontinuous dacite flows and pyroclastics that are thought to be derived from discrete volcanic centres [lJHvf] and (6) black marine, fossiliferous shale, siltstone and wacke [lmJHs].

Units 1 [uTrss] and 2 [uTrSvm] are similar to Upper Triassic-age, Stuhini Group, strata found elsewhere in northern British Columbia (MacIntryre et al., 1994). Units 3 [lJHs], 4 [lJHvi] and 5 [lJHvf] are broadly correlatable with Lower Jurassic-age rocks of the Hazelton Group, as defined by Grove (1986) in the Stewart area. Unit 3 is equivalent to the Unuk River formation and Units 4 and 5 include rocks similar to those found in the overlying Betty Creek formation. The latter is discontinuous in the Kitsault River area and contains felsic rocks near its top that may be equivalent to the Mount Dilworth formation, as defined by Alldrick (1993). Unit 6 [lmJHs] resembles the Salmon River formation. It disconformably overlies older Hazelton Group strata (Dawson and Alldrick, 1986) and is, in turn, overlain by Bowser Lake Group sediments.

The strata are deformed into a series of relatively open, doubly (northwesterly and southeasterly) plunging folds that limit the exposure of sub-Bowser Group strata in the Kitsault River area to a belt approximately 40 kilometres long and 25 kilometres wide (Alldrick et al. 1986). The Kitsault river more or less follows the axis of the Kitsault River syncline, a major structure that has infolded volcanic and sedimentary rocks near the top of the Hazelton arc at both ends of the belt. The syncline is bounded by the Varden Glacier anticline to the west and the Mount McGuire anticline the east (Figure 1). The folds affect the distribution of Units 4 [lJHvi] and 5 [lJHvf], which host most of the mineral showings in the area (Dawson and Alldrick, 1986).

Although there are relatively few faults mapped in the area, Greig et al. (1994) identified a high-angle, northeasterly dipping fault west of Homestake Ridge while mapping around the southern edge of Cambria Icefield. There may be other, unmapped, structures of this type, formed during the shortening event that affected Bower Lake Group and older rocks in the Cretaceous (Evenchick and Mustard, 1996).

Property scale mapping by Devlin and Godwin (1986) and Devlin (1987), shows that the northern axis of the Kitsault River syncline has been disrupted by at least two sets of faults. Rocks in the nose of the syncline are cut by near-vertical, northwesterly trending structures that down-drop to the west. Later, near-vertical, north to northeasterly trending faults display moderate up and down motion (Figure 2).

Although the map area is bounded by rocks of the Coast Range Batholith to the west, there are relatively few intrusions mapped within it. Those present, appear to be (1) subvolcanic intrusions emplaced during or shortly after Stuhini and Hazelton Group volcanism; (2) quartz monzonite intrusions of Eocene-age and (3) a variety of late-Tertiary, cross-cutting dykes. Fine-grained intrusions are relatively common in Unit 4 (lJHvi) and they are an important feature of the area known as the "Copper Belt", west of

the headwaters of the Kitsault River (Black, 1951; Carter, 1970; Grove, 1986). Grieg et al. (1994) mapped Goldslide intrusions (similar to those found at Red Mountain on the north flank of the Cambria Icefield) west of Homestake Ridge. These intrusions are more or less contemporaneous with Hazelton volcanism as Greig et al. (1995) obtained a U-Pb age of 201.8 +/- 0.5 ma (Early Jurassic) from zircons from one of the intrusions near Red Mountain and a K-Ar age of 194 +/- 8 ma from hornblende from a nearby Hazelton Group tuff breccia.

MINERALIZATION

There are numerous mineral occurrences in the Kitsault River area (Figure 1). Compositionally, they conform to three principal types: 1) copper and gold-rich quartz-chlorite stockwork deposits; (2) silver-rich quartz-barite-carbonate deposits and (3) molybdenum-rich quartz stockwork deposits. The first two types are most abundant and most commonly found in Units 4 [lJHvi] and 5 [lJHvf] and are of particular importance in the Upper Kitsault River area. They are considered to be Lower Jurassic in age, formed more or less contemporaneously with the Hazelton volcanic arc (Alldrick et al., 1987; Godwin et al. 1991). The third type is considerably younger. It is associated with a suite of Eocene-age (Alice Arm) quartz monzonite intrusions (Alldrick et al., 1986).

The relationship between gold-rich and silver-rich deposits in the Upper Kitsault River area is uncertain. They form different styles of deposits that are in close proximity to each other, on either side of the Kitsault River syncline. Both occur at approximately the same stratigraphic level below the Salmon River formation [lmJHs] disconformity. The Homestake (103P 216), Red Point (103P 196) and related copper-gold deposits are part of the "Copper Belt" (Black, 1951, Thompson and Michna, 1978), an extensive zone of dyke injection and gossan development in Unit 4 [lJHvi] and Unit 5 [lJHvf] on the southwest side of the Kitsault River syncline. The Dolly Varden (103P 188), Torbrit (103P 191) and related silver deposits ~~are found~~ without appreciable pyrite in tuffs and breccias in Unit 4 [lJHvi] on the northeast flank of the same structure.

Something missing here?

occur or are characterized e.g. by ...

The silver-rich quartz-barite-carbonate deposits in the Upper Kitsault River area (Dolly Varden and Torbrit) were historically considered to be structurally controlled (Black, 1951; Campbell, 1959; Thompson and Michna, 1978). However, Devlin and Godwin (1986) and Devlin (1987) suggest that they may be of exhalative in origin. This conflict remains to be resolved. Tupper and McCartney (1990) provide evidence that suggests that the Kit/Sault (103P 233) deposit is stratiform; formed through exhalation into a restricted marine basin near the top of the Hazelton volcanic arc.

Red Point (103P 196)

The Red Point Cu-Au-Ag prospect (latitude 55° 41 28' N, longitude 129° 31 14' W) is approximately 24 kilometres north of Alice Arm. It is on the north side of Evindsen Creek, west of its junction with the Kitsault River (Figure 1). It is 1.5 kilometres northwest of the

Torbrit portal and it was, at one time, linked to the Dolly Varden - Torbrit road by a trail. It is now only accessible by helicopter.

The area was explored by Granby Consolidated Mining, Smelting, and Power Company in the early 1910s, and short adits were driven on several of the more attractive copper prospects in the area in late 1920s. Dolly Varden Mines Limited acquired the area in 1961 and Dolly Varden Minerals Incorporated ran geological, geochemical and geophysical exploration programs and located a wide-spread, precious-metal, soil geochemical anomaly in 1986. The company trenched and sampled the Red Point and several of the neighbouring showings three years later, and diamond drilled 25 holes for an aggregate depth of 2257 metres (Drown et al., 1990b).

The volcanic rocks at the south end of the "Copper Belt" (Figure 1) are predominantly grey-green andesites and andesitic tuffs (Unit 4, [lJHvi]) that have a northwesterly strike, consistent with their location on the western limb of the Kitsault River syncline (Alldrick et al., 1986; Devlin, 1987; Drown et. al., 1990). The rocks are intruded by dykes, and early workers (Black, 1951; Carter, 1970; Grove, 1986) describe a belt of feldspar porphyry intrusions ("Kitsault Intrusions") extending from the Cambria Icefield south to the Kitsault River, a distance of approximately 15 kilometres. These intrusions are not specifically mapped by Alldrick et al. (1986), Devlin (1987) or Drown et al. (1990b). They are considered to be included with the volcanics.

The rocks are cut by numerous, steep, northwesterly trending faults that predate and control much of the later alteration and mineralization. The rocks ~~over a broad area~~ were deformed and weakly to intensely, pervasively, altered to sericite, quartz and pyrite. Altered rocks along some of the major northwesterly trending faults were then overprinted by potassium feldspar and re-deformed to form extensive areas of "crackle-breccia". This was later cemented by chlorite and pyrite. Fragments of intensely potassically altered rock are commonly caught up in the crackle-breccias and enveloped and cemented by chlorite and pyrite. Economic minerals were deposited relatively late in the development of the breccias. Chalcopyrite, sphalerite and galena are reported to occur with chalcedonic and normal quartz, carbonate and chlorite in veins and as breccia cement (Drown et al., 1990b). Mineralized rocks are cut by northeasterly trending faults.

The Red Point and other prospects in the area are structurally controlled, northwesterly trending, "replacement zones" or quartz veins that locally contain appreciable amounts of copper, gold and silver. They are widespread and erratically distributed throughout the broad deformation and alteration zone. The rocks are locally highly pyritic and oxidized surface rocks are highly gossanous.

Homestake: (103P 216)

The Homestake Cu-Au-Ag prospects (latitude 55° 45 32' N, longitude 129° 35 15' W) is on Homestake Ridge, between the West Kitsault River and the Kitsault River, south of the Cambria Icefield (Figure 1). It is approximately 35 km southeast of Stewart.

The property is at the north end of the "Copper Belt". It covers a prominent gossan that was located in the early 1900s and explored for copper and gold prior to the Second World War. Consolidated Homestake Mining and Development Company drove an adit on the Homestake claim in the 1920s and British Lion Mines Limited drove two more on the same structure in the 1930s. The latter extracted a small (7.9 tonnes) sample with an average grade of 140 g/t gold, 203 g/t silver, 7.5% copper and 3.8% zinc.

Other prospects on the ridge (including Vanguard Gold (103P 091), which is two kilometres to the southeast, and Vanguard Copper (103P 210), three kilometres to the southeast) were explored by Canex Aerial Explorations Limited in the 1960s. Newmont Exploration of Canada Limited consolidated ownership in the area in the late 1970s. The company interpreted some of the more siliceous rock as rhyolite and explored the area for volcanogenic massive sulphide deposits. In the mid 1980s, Cambria Resources Limited reinterpreted the accumulated data and changed the exploration focus back to epithermal, vein-type, deposits. Noranda Exploration Company Limited acquired the property in 1989. It conducted a substantial amount of grid work and diamond drilled twelve holes, for an aggregate depth of 1450 metres.

The geology of the area is described by Black (1951), Coombes (1986) and Chinn et al. (1990). The ridge is underlain by a northwesterly trending package of andesitic agglomerates, flows and related tuffs and intercalated argillic sediments (Units 4 and 5, [lJHvi and lJHvf]). However, there has been extensive injection of dykes and sills of hornblende feldspar porphyry subparallel to the regional trend. As at Red Point, the intrusions are broadly coincident with the Copper Belt gossan. The dykes and sills are reported to pre and post-date mineralization (Coombes, 1986).

The volcanic and intrusive rocks are cut by northwesterly and easterly trending brittle faults, fractures and breccia zones that have focused fluid flow and allowed weak to strong alteration and mineralization. The rocks have been sequentially silicified, and sericitized, chloritized and carbonatized. They have also been locally intensely pyritized and some of the more more altered zones have been mineralized with chalcopyrite, sphalerite, galena, trace amounts of arsenopyrite and tetrahedrite. The economically significant sulphides occur with quartz, calcite and lesser barite in vein and stringer stockworks and as interstitial pods and blebs in breccias.

Petrographic work suggests a minimum three stages of vein development. Quartz veins containing pyrite, chalcopyrite and sphalerite are crosscut by carbonate veins and veinlets enriched in galena, arsenopyrite and tetrahedrite and both of the above are overprinted by barite (Coombes, 1986). Rock and soil data also suggest multiple events. Copper is enriched with gold at Homestake, at the north end of the gossan. However, lead and zinc are more commonly found with silver near the Vanguard prospects. According to Chinn et al. (1990), the Vanguard area geochemical anomalies overlie altered volcanic rock on the west side of a major, westerly dipping, fault. The age of the fault is uncertain, however it

marks the eastern contact of the volcanic unit in the area. The sediments in its footwall are barren.

At the Homestake mine, the mineralization occurs in a structurally controlled zone of intense silica-sericite-pyrite alteration in deformed, brecciated, andesite and hornblende feldspar porphyry. It is in a quartz vein stockwork that contains variable amounts of chalcopyrite, galena, sphalerite, pyrite and barite. The altered breccia is locally cemented by interstitial pods and lenses of chalcopyrite. High grade copper samples are locally strongly enriched in gold and, at this locality, in mercury (Black, 1951; Chinn et al., 1990). Similarly, the best copper and gold values at the Vanguard Copper prospect are found in a pervasively chloritized, brecciated volcanic rock and the best silver values are from a quartz-carbonate vein (Chinn et al., 1990). The zone has a reported inventory of 11 800 tonnes grading 8.6 % Cu, 2.4 g/t Au and 141 g/t Ag.

Wolf: (103P 198)

The Wolf Pb-Zn-Ag property (latitude 55° 42 27' N, longitude 129° 31 01' W) is on the east side of the Kitsault River, approximately 25 kilometres upstream from Alice Arm and 6.0 kilometres southwest of Kitsault Lake (Figure 1). Prior to the mid-1980s, the property was connected to the Dolly Varden/Torbrit mine road. It is now only accessible by helicopter.

The Wolf deposit was located at the same time as the Dolly Varden and Torbrit deposits. It had seen considerable exploration by 1916, when it was expected to supply low-grade ore to a proposed concentrator at the nearby Dolly Varden mine (Muralt, 1985). In 1964, the Sunshine Mining Company optioned the property, drove an adit and crosscut and further developed the deposit (Carter, 1964). Dolly Varden Mines Limited extended the drift and drilled the property four years later. In 1980, during a period of high metal prices, the Company contracted for Derry, Mitchener and Booth to make an independent assessment of the reserves at the Wolf and the neighbouring Northstar (103P 189) mines. It also arranged for Wright Engineers Limited to evaluate the feasibility of mining the two deposits at a rate of 275 tonnes/day for six months of the year (Thompson and Pearson, 1981). The Wolf deposit currently has a reported resource (in two principal zones) of 485 324 tonnes grading 336 g/t silver, 0.59% Pb and 0.12% Zn. ~~However, it is limited by accessibility.~~

The geology of the deposit is described by Carter (1964) and Thiersch (1986). It is composed of three north-northeasterly trending, near vertical, quartz-carbonate "replacement" zones, in one or more sheared fault in deformed andesitic tuffs and agglomerates near the apparent top of the Hazleton volcanic arc (Unit 4, [lJHvi]). The zones may be fault off-set portions of a single deposit (Thompson and Pearson, 1981). The faults that control the zones are discordant to regional stratigraphy and project towards the northeast and southwest. It is not known whether they cut Salmon River formation strata (Unit 6, [lmJHs]) in the core of the Kitsault River syncline (Figure 1).

The zones are composed of quartz and carbonate with local concentrations of barite, jasper and sulphide. They are strongly internally brecciated and they appear to have formed in stages, as a result of intermittent movement on the controlling structure. Early-formed quartz was deposited with pyrite to create a vein with a variety of open space filling textures. This was later brecciated and cemented by a second generation of pyrite, with sphalerite, galena and chalcopyrite. This was, in turn, brecciated and the sulphides present were recrystallized, giving the latest pyrite a distinctive "framboidal" texture. The final stage was marked by the introduction of carbonate with sphalerite and galena (Thiersch, 1986). The silver minerals may have been introduced relatively late in the deposit's development as Carter (1964) states that pyrite, galena, sphalerite, magnetite, hematite and silver-bearing minerals (pyrargyrite, tetrahedrite and native silver) are in small fractures in zones of fine-grained, crushed, quartz interstitial to larger quartz fragments (Carter, 1964).

Sulphur and oxygen isotope studies carried out at the Universities of Calgary and Alberta suggest the fluid that generated the Wolf deposit was of mixed origin. Sulphur isotopes indicate a combination of magmatic and sea water sources, and oxygen isotopes suggest derivation from volcanogenic and marine sediments released during burial compaction (Thiersch, 1986). The results show similarities between the fluids that generated the Wolf and the neighbouring Dolly Varden and Torbrit deposits (Devlin, 1986), and Thiersch (1986) considers that they are derived from related hydrothermal systems.

Torbrit/Toric: (103P 191)

The Torbrit Ag-Pb-Zn mine (latitude 55° 41 14' N, longitude 129° 30 21' W) is on the east side of the Kitsault River, approximately 23 kilometers upstream from Alice Arm (Figures 1). In the 1920s it could be accessed by trail or narrow-gauge railway from Alice Arm. In the mid-1940s, the railway was replaced by a road but, since the late 1980s, it has only been accessible by helicopter.

The Torbrit deposit was located and explored while the neighbouring Dolly Varden mine was in production. It was first developed in the mid to late-1920s, when a small tonnage of high-grade ore was removed and processed through a small (45 tonnes/day) mill. The operation closed in 1930. Torbrit Silver Mines Limited bought the property in 1946 and constructed and operated a 350 tonne/day, hydroelectric-powered, mill, flotation concentrator and cyanidation plant. The mine produced 1 251 387 tonnes of ore containing 579 996 kilograms of silver (80% in concentrate shipped to Trail and 20% as bullion), 3.5 kilograms of gold, 4 868 323 kilograms of lead and 283 037 kilograms of zinc between 1949 and 1959. It is reported to have a residual resource of 786 285 tonnes grading 311.90 g/t Ag, 0.42% Pb and 0.50% Zn.

The main deposit (Figures 1 and 2) is a crudely arcuate, northwesterly plunging lens in an otherwise sub-economic, sheeted "vein" in a moderately northwesterly dipping shear zone in massive Hazelton volcanic rock (Unit 4, [lJHvi]). The higher-grade, mineable,

zones are defined by assays and are conformable with the main vein. Early workers considered that the deposit formed through replacement of a complex tension-fracture system (Black, 1951; Campbell, 1959). According to Campbell, the controlling shear was likely deformed and folded prior to the introduction of the fluid that formed the "vein" and the enriched portion probably formed in a tensional zone, where the shear was folded about a tight synform. The mineralized lenses plunge to the northwest, parallel to the axis of a minor fold. Campbell (1959) describes the presence of horse-tail veins extending into the hanging wall of the deposit and an abundance of more or less altered country-rock fragments close to its footwall.

The vein is composed of barite, three varieties of silica (quartz, jasper and chalcedony) and carbonate. It also contains a small amount of sulphide and oxide (magnetite, hematite, pyrite, sphalerite, galena, chalcopyrite, tetrahedrite, pyrargarite (ruby silver)) and a trace amount of native silver, which is probably of secondary origin. The gangue minerals are locally composition and/or colour banded and they show evidence of open space filling. The bands are commonly subparallel to local deposit contacts and to the schistocity of the surrounding rock. The vein gangue minerals contains vugs lined by quartz crystals with well-shaped terminations. In some localities, the deposit is reported to have a pronounced mottled appearance as different gangue mineral assemblages selectively replace country-rock fragments (Campbell, 1959).

Campbell (1959) used sphalerite composition data to obtain an estimate of approximately 270° C for the temperature of formation of the deposit. He considers it to be intrusion-related and epigenetic in origin, formed during deformation in the late Cretaceous to early Tertiary period.

In 1985, Devlin mapped parts of the Upper Kitsault River valley at 1:5000 and 1:2000-scale to provide more detailed geology to establish the stratigraphic and structural setting of the principal deposits and related showings (Figure 2). He also studied the petrography and lithogeochemistry of the host rocks and determined whole-rock potassium-argon age dates. In addition, Devlin studied the sulphur, oxygen, carbon and lead isotope contents of selected minerals. Based on the above on the presence of sub-rounded ore fragments in tuffs found in the hanging wall of the deposit, and on the recognition of a stockwork vein system in the footwall of some of the deposits, Devlin concluded that the Torbrit, Northstar and Dolly Varden deposits were disrupted, fault off-set segments of a single, stratiform deposit (Devlin and Godwin, 1985; Devlin, 1987).

Devlin (1987) mapped a thick succession of shallow-water Hazelton Group volcanic and related volcano-sedimentary rocks under the fossiliferous sediments (Unit 6, [lmJHs]) exposed in the core of the northwesterly plunging Kitsault River syncline. Within it, he identified a distinctive silica, carbonate, sulphate and sulphide-bearing inter-bed that he considered to be exhalative in origin. His mapping shows that the silica-carbonate-sulphate horizon is underlain by a minimum 1200 metres of weakly altered green-maroon basaltic tuff, green-maroon porphyritic andesite and green andesite shard tuff (Unit 4, [lJHvi]) and overlain by approximately 1000 metres of pale grey basalt-andesite tuff, maroon basaltic

andesite ash-lapilli tuff, dark green andesite tuff, grey-green porphyritic andesite and pale green andesite ash tuff (Units 4 and 5, [lJHvi and lJHvf]?).

The exhalative unit can be traced for several kilometres along strike on the northeast side of the Kitsault River syncline and it hosts all the major silver deposits in the area. According to Devlin (1987), it exhibits local and property scale zonation that is consistent with changing fluid chemistry, brought about by mixing of exhalative fluids and sea water, and differing depths of deposition. The horizon shows gradation from a silica-sulphide exhalite facies (Dolly Varden), through a carbonate-sulphate-sulphide exhalite facies (Northstar) to a sulphate-oxide-sulphide exhalite facies (Torbrit). The Dolly Varden deposit is inferred to have formed under less oxidizing, deeper water conditions than that at Torbrit (Devlin and Godwin, 1986; Devlin, 1987).

Stable isotope data for selected samples from Wolf, Torbrit, Northstar and Dolly Varden indicate that the sulphur in the sulphide species probably came from a source that was predominantly magmatic, and that in the associated barite most likely came from oxygenated Lower Jurassic sea water. The oxygen isotopes in barite, quartz and carbonate are compatible with a sedimentary marine origin and derivation from hot (ca. 245° C) sea water (Devlin, 1987).

Mapping around the Torbrit and other deposits shows considerable structural complexity in the Lower Jurassic Hazelton volcanic and sedimentary rocks on the east flank of the Kitsault River syncline (Alldrick et al, 1986). Devlin and Godwin (1986) show that there has been a considerable amount of post-mineral faulting. Northwesterly trending faults are off-set by north to northeasterly trending block faults (Figure 2). Devlin and Godwin found that it was possible to reconstruct the postulated exhalite horizon. They infer continuity between the Torbrit, Northstar and Dolly Varden deposits (Devlin and Godwin, 1986; Devlin, 1987).

Lead isotope ratios for galena crystals from the Wolf, Torbrit, Northstar, Dolly Varden and Red Point deposits in the Upper Kitsault River area support the contention that the mineralization is, more or less, contemporary with the development of the Hazelton volcanic arc (Devlin, 1987). The samples have 206Pb/204Pb, 207Pb/204Pb, 208Pb/204Pb ratios that cluster with those of other Early Jurassic deposits in the Stewart-Iskut area (Godwin et al., 1991). Three whole-rock potassium-argon age dates (68.1 - 72.2 +/- 2.5 Ma.) for volcanic rocks collected in the area yielded Late Cretaceous ages, inconsistent with the inferred age of the Hazelton volcanic arc. The samples are thought to have suffered argon loss during lower-greenschist facies metamorphism (Devlin, 1987).

Dolly Varden Minerals Inc. drilled a single diamond drill hole under the Torbrit deposit in 1990, as part of a major exploration program for exhalative silver deposits associated with the known deposits in the area (Drown et. al, 1990; McGuigan and Melnyk, 1991). The hole was collared to the northwest of the Torbrit glory hole. It intersected 30 metres of "clastic" chalcedonic quartz, barite and minor sulphide and returned anomalous concentrations of silver, copper, lead and zinc.

Northstar: (103P 189)

The Northstar Ag-Pb-Zn deposit (latitude 55° 41 06' N, longitude 129° 30 30' W) is on the west side of the Upper Kitsault River, approximately 23 kilometres north of Alice Arm (Figures 1 and 2). It is across the river from the Torbrit mine and has had a similar access history.

The deposit was located at the same time as that at Dolly Varden and, by the time the Dolly Varden mine closed in 1930, three adits had been driven on it and several high-grade samples had been removed. Torbrit Silver Mines Limited explored the deposit, while the Torbrit mine was in operation but, at 1959 prices, felt that the grade was too low to allow for its production to extend the life of the Torbrit mill. At the request of Dolly Varden Minerals Inc., Derry, Mitchener and Booth resampled and redrilled the Northstar deposit in 1979/80 and identified a diluted reserve (using a 137 g/t Ag cut-off) of 128 424 tonnes grading 401.4 g/t Ag (Thompson and Pearson, 1981). This reserve, along with comparable data for the Wolf deposit, was factored into a combined feasibility study conducted by Wright Engineers Limited. (year?)

Early workers described the Northstar deposit (Figure 1) as being a high-grade lens in a replacement "vein" in Hazelton Group volcanic rocks (Unit 4, [lJHvi]). The vein has a northeasterly strike and a moderate to steep northwesterly dip. Although it is less well documented than the Torbrit deposit, it is reported to be composed of barite, quartz and carbonate and displays similar banding and crustiform textures to those found at the mine. Torbrit? The deposit is cut by minor faults subparallel to its contacts and by numerous post-mineral lamprophyre dykes that have a similar strike but a more vertical dip. The latter have also been noted at Torbrit. The vein contains a minor amount of sulphide (pyrite, marcasite, galena, sphalerite, chalcopyrite, pyrargarite and argentite) and native silver. However, the distribution is uneven and the main deposit is a tabular body within the plane of the vein. and sulphosa minerals

According to Devlin (1987), the Northstar deposit is off-set by faults from adjacent deposits at Torbrit and Dolly Varden (Figure 2). Based on the apparent lack of oxide at Northstar, he suggests that it may have been deposited in slightly deeper water, under slightly less oxidizing conditions than operated at Torbrit. existed (?)

Dolly Varden Minerals Inc. applied Devlin's exhalative model to the Dolly Varden area and conducted major exploration programs in 1989 and 1990. It diamond-drilled the Northstar deposit down dip of the main adit and located the mineralized "exhalite" horizon below an andesitic debris flow unit. The "exhalite" unit is described as having a lower, carbonate-rich (silica-calcite-barite) facies that is essentially barren and an upper, sulphide and oxide-bearing facies that is weakly mineralized. The latter contains knots and patches of pyrite and trace amounts of chalcopyrite, honey coloured sphalerite, galena and jasper. It is partially fragmental (Drown et. al., 1990a and McGuigan and Melnyk, 1991). Some of the holes drilled though the exhalite unit intersected substantial thicknesses of chlorite-calcite-pyrite alteration stockwork in its footwall. (Drown et. al., 1990a). - sulphosalts?

Dolly Varden: (103P 188)

The Dolly Varden Ag-Pb-Zn mine (latitude 55° 40 55' N longitude 129° 30 32' W) is on the west side of the Upper Kitsault River, approximately 22 kilometres upstream from Alice Arm (Figure 1 and 2). It was the first mine opened in the area and it triggered the development of much of the early infrastructure. It is now only accessible by helicopter.

The original crown granted claim was located in 1910. By 1917, the ore shoots at Dolly Varden were sufficiently well delineated that Dolly Varden Mines Company arranged for a contractor to build a narrow-gauge railway up the valley from Alice Arm. Unfortunately, the cost proved to be far higher than anticipated and the mining company was forced into bankruptcy. The contractor operated the mine between 1919 and 1921 and shipped high-grade "direct shipping" ore to smelters at Anyox and Tacoma (Muralt, 1985). Including intermittent production between 1935 and 1940, the mine produced 33 434 tonnes of ore containing 42 451 kg of silver. In 1989, it was reported to have an inventory of 42 633 tonnes grading 754.1 g/t Ag. (reference? — Open File?)

The Dolly Varden deposit was developed on five levels and several sublevels and from three small glory-holes. Early workers, including Black (1951), describe a single, arcuate, northerly dipping replacement "vein" deposit within a package of massive, altered and pyritic volcanic agglomerates and tuffs (Unit 4, [lJHvi]). The deposit is composed of quartz with lesser carbonate, barite and pyrite and trace amounts of galena, sphalerite, chalcopyrite, tetrahedrite, pyrargarite and native silver. It contains fragments of locally derived wall rock, is banded and ranges in colour from white though grey to black. The economic minerals are restricted shoots within the vein. Sulphide contents are thought to increase with depth. Near surface, the shoots are strongly enriched in native silver and the glory-hole stopes produces are reported to have produced bonanza grades. The enrichment was probably a result of weathering (Black, 1951). The controls on the ore shoots are unknown; however, Black (1951) notes their proximity to a major synclinal fold axis.

Devlin's mapping shows that the deposit is bounded on the north by the Dolly Varden fault, an early, northwesterly trending structure (Figure 2). The deposit is also cut by moderate to steep northerly to northeasterly trending faults. Some contain lamprophyre dykes. To the west, the deposit terminates on the Mitchell Fault (Figure 2). The Hanson Fault, a similar structure (Figure 2), divides the Dolly Varden deposit into western and eastern portions that have distinctly different mineralogies. The fault may have controlled deposition as Devlin (1987) attributes the higher sulphide content found east of the fault to formation under deeper water conditions than present further west or further north.

Dolly Varden Minerals Inc. traced out the mineralized horizon in 1989 and drilled four diamond drill holes looking for the down-dip extension of the mineralized zone in 1990. The holes intersected several zones of possibly exhalite, quartz-sulphide breccia composed of jasper, chalcedonic quartz and pyrite with trace amounts of economic

sulphides. Two of the holes also encountered chlorite-calcite-pyrite stockwork in the footwall of the deposit. The rock is similar to that found under the Northstar deposit (Drown et al., 1990a; McGuigan and Melnyk, 1991).

Kit/Sault:Kit:Frog:Kitsault: (103P 233)

The Kit/Sault property (latitude 55° 45 04' N, longitude 129° 29 24' W) includes several Zn-Pb-Ag-Ba-Sr prospects on the south shore of Kitsault Lake. It is at the head of the Kitsault River, approximately 30 kilometres upstream from Alice Arm (Figure 1). Access is by helicopter or float plane.

The showings were located in 1966 and explored intermittently until 1984. That year, Cominco Limited undertook a variety of geological, geochemical and geophysical surveys and diamond-drilled eight holes for an aggregate depth of 1269 metres (Tupper and McCartney, 1990). The property was acquired by Oliver Gold Corporation (50%), Aber Resources Limited (25%) and Tanqueray Resources Limited (25%) in 1988. The venture partners conducted regional and local exploration programs and drilled a further five diamond-drill holes, for a depth of 998 metres, the following year (Tupper and McCartney, 1990). Lac Minerals Limited held the property in the mid-1990s (Sieb, 1995).

The Kit/Sault property (Figure 1) straddles the disconformity mapped at the top of the Hazelton volcanic arc. It is underlain by volcanic and sedimentary rocks (Units 4 [lJHvi] and 5 [lJHvf]) and by fossiliferous sediments (Unit 6 [lmJHs]). The rocks straddle the axis of the Mount McGuire anticline (Alldrick et. al., 1986) and commonly display easterly to northeasterly strikes and a relatively shallow dips towards the north or northwest. Greig (1991), mapping under the disconformity to the southeast of Kitsault Lake, found a significant but volumetrically small amount of intermediate to felsic volcanic and associated clastic rock on top of more abundant maroon and green andesite pyroclastic rocks.

The mineralization is in a carbonate unit interbedded with volcanic rock, a short distance below the disconformity. It is underlain by feldspar-rich andesite to rhyolite tuff and lesser epiclastic material and is overlain by andesite to basaltic tuff, intercalated with minor flows and intermixed with epiclastic material. The mineralized carbonate is layered and crenulated by micro-folds that plunge at a shallow angle to the northnortheast. It is composed of a lower section of metalliferous carbonate diamictite, limestone and mudstone; a central volcaniclastic interval; and an upper sequence of laminated carbonate, sulphate and sulphide that contains a minor amount of tuff, chert and volcanic rock (Tupper and McCartney, 1990).

The carbonate unit is up to 8.0 metres thick; however, rapid facies variation and block faulting have made it difficult to trace down-dip. Tupper and McCartney (1990) refer to company reports by MacRobbie (1988), that suggest the deposit may be restricted to syn-sedimentary grabens that have acted as traps for local accumulations of carbonate,

sulphate and minor sulphide. The mineralized unit has been traced for approximately 5.0 kilometers along strike.

Base and precious metal values are low. Diamond drill hole K89-11 contained the best intersection reported in 1989. It assayed 1.3% Zn, 0.12% Pb and 26.5 g/t Ag over 4.95 metres. Metal values may improve towards the west where the companies located several pyritic quartz-breccia veins enriched in silver, lead and zinc (Tupper and McCartney, 1990). The mineralized carbonate contains laminated to bedded and locally framboidal pyrite, fine-grained sphalerite and galena and locally well-bedded celestite and barite.

Mortensen and Kirkham (1992) analyzed zircons from a feldspar-phyric unit (probably a welded dacitic ash-flow tuff) 100 to 200 metres stratigraphically below the mineralized horizon and determined a 206Pb-238U age of 193.5 +/- 0.4 Ma (Pleinsbachian). This provides an approximate age for the mineralization and for the cessation of volcanism in the Upper Kitsault River area.

DISCUSSION

The principal difference between the rocks exposed on the western and eastern flanks of the Kitsault River syncline is the presence of numerous, subvolcanic, feldspar porphyry dykes on the western side. These intrusions pre- and post-date mineralization in the Copper Belt and are clearly involved in the mineralizing event. Although poorly differentiated, they include Goldslide intrusions similar to those mapped at Red Mountain, approximately 30 kilometres to the northwest (Greig et al., 1994).

Although different in many respects, there are similarities between the styles of mineralization at Red Mountain and on Homestake Ridge. Rhys et al. (1995) suggest that the Red Mountain gold deposit has "porphyry" affinities and that it formed above a propylitic quartz stockwork/molybdenum zone. They speculate that fluids derived from a hornblende-biotite-quartz porphyry phase of the Goldslide intrusion suite altered intrusive and volcanic rocks to sericite-quartz-pyrite, chlorite-K-feldspar-sericite-titanite, formed tourmaline veins and K-feldspar-pyrite-titanite-actinolite and created a semi-tabular body of gold-silver mineralization within a pyrite-pyrrhotite stockwork. The Copper Belt showings are similarly dyke related. They are associated with widespread potassic alteration and chloritization, are highly pyritic and precious-metal bearing. However, the reports also indicate that they are locally overprinted by veins and veinlets containing carbonate and traces of galena, sphalerite, tetrahedrite and barite.

Based on mineralogy, Thompson and Michna (1987) suggest that the deposits in the Upper Kitsault River area are epigenetic and epithermal in origin, and that they are zoned, from west to east, away from the Copper Belt feldspar porphyry dyke swarm ("diorite to granodiorite" intrusion). They describe four zones:1) copper and gold mineralization within and along the northeastern extremity of the intrusion (Homestake); 2) copper within the intrusion and copper-silver within volcanics adjacent to the intrusion (Vanguard showings); 3) silver and silver lead showings in Hazelton volcanic rocks (Dolly Varden,

Torbrit etc.) and (4) silver properties further east, including the Kit/Sault occurrence (Figure 3).

The Wolf deposit is epigenetic. It has had a prolonged history of mineralization and deformation, starting with deposition of quartz and pyrite (but without gold) and ending with precipitation of carbonate, sphalerite and galena. The time of introduction of silver is uncertain, but was probably late. Thiersch (1986) found sufficient points of similarity between the sulphur and oxygen isotopes in the various minerals at Wolf and Torbrit to conclude that, whatever the origin of the latter, the deposits were formed by related hydrothermal systems.

The Northstar, Tobrit and Dolly Varden deposits are similar and they may be fault off-set portions of a single, large occurrence (Devlin and Godwin, 1986). Their origin remains problematic. They may be epigenetic deposits, as suggested by Campbell (1959), or exhalative in origin, as proposed by Devlin and Godwin (1986). Devlin's isotope studies suggest that they are Lower Jurassic in age, more of less contemporary with development of the Hazelton volcanic arc, and that their formation may have involved sea water. However, the isotopes do not address the controls on deposition.

The Dolly Varden and Northstar deposits are partially underlain by a stockwork breccia that contains abundant interstitial dark green to black chlorite and stringers of carbonate, pyrite and trace amounts of chalcopyrite. The breccia is similar to rock at Red Point and Homestake (McGuigan and Melnyk, 1991). It is cemented by quartz, chlorite and pyrite with minor amounts of chalcopyrite and sphalerite. Drown et al. (1990a,b), note that the rock resembles a form of footwall alteration commonly found underlying volcanogenic massive sulphide deposits

The Kit/Sault deposit appears to be a rare example of a carbonate-sulphate exhalative deposit that formed near the top of the Hazelton volcanic arc. The barite-celestite zone is well layered, conformable to bedding and shows little sign of deformation. Although it is only weakly mineralized, the association with silver, lead, zinc, barium and strontium is consistent with a genetic connection to the silver-rich deposits in the nearby Upper Kitsault River valley. Despite the absence of appreciable gold or silver in the Kit/Sault occurrence, the geological setting is similar to that of the Eskay Creek gold deposit, 120 kilometres to the northwest.

Evidence - not present earlier in paper

The Eskay Creek Au-Ag-Pb-Zn subaqueous hot-spring deposit also formed during the waning stages of volcanism in the Hazelton volcanic arc. It formed as a result of intra-arc rifting that occurred at an equivalent time to the transition between Unit 5 [lJHvf] and Unit 6 [lmJHs] in the Kitsault River area. The succession at Eskay Creek includes, from bottom to top, basal andesite, marine sedimentary rocks, intermediate to felsic volcaniclastic rocks, rhyolite flow domes, (mineralized) carbonaceous shales and basalts. Unit thickness and facies distribution suggest that rhyolite domes, emplaced along active faults, breached the sea floor and partially filled an adjacent basin or trough with debris. They also focused fluid flow which led to the creation of chimneys and mounds on the seafloor. These later collapsed to form

barite and clastic sulphide-sulphosalt debris that was redeposited with argillaceous sediment on top of the volcaniclastic detritus in the basin (Roth et al., 1999). The Kitsault Lake showings also appear to have been formed in restricted basins at the top of the volcanic arc. They show sign of extreme thickness and facies variation and influx of clastic debris into basins otherwise filled with carbonate, sulphate and minor sulphide.

SUMMARY AND CONCLUSIONS

Hazelton Group strata in the Alice Arm area are well mineralized. The volcanic and sedimentary rocks contain numerous mineral prospects and host two significant past producing silver mines (Dolly Varden and Torbrit). In the Upper Kitsault River area, the showings are of four, possibly related, types. They include: 1) Cu-Au chlorite-pyrite vein deposits (Red Point, Homestake); (2) epigenetic Ag-Pb-Zn quartz-carbonate vein deposits (Wolf); (3) either epigenetic or syngenetic Ag-Pb-Zn-Ba deposits (Torbrit, Northstar, Dolly Varden) and (4) exhalative, Ba-Sr-Zn-Ag deposits (Kit/Sault). The showings have been explored since the early 1910s. The mines produced 622 407 kilograms of silver between 1919 and 1959.

in the study area (?)

Which "data"

Data shows...

The data show there were two mineralizing events in the Upper Kitsault River area. There was an early, sulphide-rich event, that introduced gold and copper and a later, sulphide-poor event, that deposited silver, lead, zinc and barite. Prospect descriptions suggest that the latter is a late overprint in the Copper Belt area, where it occurs either as late fracture fill in early formed veins or as a new generation of veins and veinlets. There is a rapid reduction in copper and gold and increase in silver, lead and zinc in the mineral occurrences to the south and east of the Copper Belt and silver deposits in the Dolly Varden - Torbrit area are low in sulphide.

native gold (i.e. mineral or element)

The copper and gold-rich deposits are located restricted to the west side of the Kitsault River syncline. There, the mineralization is clearly structurally controlled and related to the emplacement of subvolcanic dykes. Volcanic, sedimentary and intrusive rocks are fractured and, locally, intensely altered to potassium feldspar, sericite and chlorite. The fractures contain abundant pyrite, lesser chalcopyrite and gold. This style of mineralization has much in common with the Red Mountain Au-Ag deposit, which is in similar rocks on the northern side of the Cambria Icefield.

hosted by

There are no reported dyke swarms underlying the mineral deposits on the east side of the Kitsault River syncline and, although there is some development of a chlorite-pyrite rich stockwork underneath the silver deposits at Dolly Varden and Northstar, the mineralization is low in sulphide (content?). The deposits are composed of quartz, carbonate, barite, traces of pyrite, sphalerite, galena, chalcopyrite, tetrahedrite, pyrargarite and native silver. The Wolf vein is epigenetic in origin, however, there is some dispute as to the origins of the Dolly Varden, Torbrit and Northstar deposits. They may be epigenetic "replacement" deposits, as suggested by Campbell (1959) and others, or exhalative, as proposed by Devlin and Godwin (1986) and Devlin (1987). In the absence of new data, or access to the

old workings, this review is unable to resolve the issue. However, it seems likely that the Wolf, Northstar, Torbrit and Dolly Varden deposits are geochemically related.

The Kit/Sault prospects have a similar geochemical signature and they may also be related. They appear to be exhalative in origin and restricted to small basins or grabens, that formed during the waning stages of Hazelton volcanism. The basins filled with clastic detritus, carbonate, sulphate and trace amounts of sulphide. They appear to have formed in a similar stratigraphic setting to the Eskay Creek Au-Ag deposit.

The mineral prospects in the Upper Kitsault River illustrate potential for several styles of precious-metal bearing mineralization in Hazelton Group strata in the Alice Arm area. In addition to the silver-rich epigenetic or exhalative style of the past producing mines at Dolly Varden and Torbrit, there is potential for Red Mountain and Eskay Creek style deposits.

ACKNOWLEDGMENTS

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