Preliminary Fluid Inclusion Study of Quartz Vein and Massive-Banded-Stringer Pyrite Mineralization in the Wells-Barkerville Gold Belt, East-Central British Columbia

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INTRODUCTION

The Wells-Barkerville Gold Belt lies approximately 65 km east of Quesnel, in the Cariboo Mining Division, British Columbia. Gold in this area is hosted by two types of mineralization: quartz-pyrite vein and massive-banded-stringer pyrite ore. Both types are hosted by a lower greenschist facies stratigraphic interval within clastic metasedimentary rocks of the Barkerville subterrane.

This paper is the first publication of fluid inclusion data from the belt. The objectives of this study are to:

- document fluid inclusion characteristics (i.e. temperature, composition) in quartz from both vein and 'massive' pyritic mineralization at the Mosquito Creek and Island Mountain mines, and from quartz vein mineralization at the Cariboo Gold Quartz mine, and the BC, Warspite and Perkins vein occurrences (Figure 1).
- compare fluid inclusion characteristics of vein and massive-banded-stringer ore within and between deposits in the belt.
- compare fluid inclusion data from the Wells-Barkerville Belt with data from other gold districts hosted in low metamorphic-grade rocks.
- discuss the use of fluid inclusion data as a tool to determine the depositional environment of deposits in the Wells-Barkerville Belt.

GEOLOGICAL SETTING

The Wells-Barkerville Belt is within the Barkerville subterrane of the Late Proterozoic and Paleozoic Kootenay Terrane. The Barkerville subterrane comprises metamorphosed grit, quartzite, phyllite, lesser limestone and volcanioclastic rocks of the Snowshoe Group (Struik, 1988). Quartz-pyrite vein and massive, banded and stringer pyritic mineralization in the Wells-Barkerville Belt are confined to a lower greenschist facies stratigraphic interval within the upper Snowshoe Group variably termed the ‘Baker and Rainbow Members” (Hansen, 1935), Snowshoe Formation (Sutherland-Brown, 1957) and Downey and Hardscrabble successions (Struik, 1988).

Isoclinal to tight folds and shear zones record conditions of early ductile flow in the Barkerville Subterrane (Struik et al., in Gabrielse, 1991). Open folds and faults characteristic of brittle conditions are superimposed on the ductile structures (Struik op. cit.). A progressive sequence of vein mineralization at the Cariboo Gold Quartz, Island Mountain and Mosquito mines spans early veins formed during the dominant phase of ductile deformation and later least strained veins that contain most of the gold (Rhys and Ross, 2000; Rhys, 2000).

MINERAL DEPOSITS

Two types of gold-bearing ore occur in the Wells-Barkerville Belt: quartz-pyrite veins and massive-banded-stringer pyrite (Johnson and Uglow, 1926; Hanson, 1935; Benedict, 1945; Skerl, 1948; Richards, 1948; Sutherland-Brown, 1957; Aldrick, 1983; Robert and Taylor, 1989). McTaggart and Knight (1993) suggest that gold from the ‘massive’ pyritic ore at Island Mountain and Mosquito Creek mines (average fineness of 870) differs from gold in quartz veins at the Cariboo Gold Quartz mine (fineness of 945). Production figures from the Island Mountain mine indicate that gold grades in the ‘massive’ ore are higher than grades in the ‘vein’ ore (Benedict, 1945).

Vein ore typically comprises dominantly massive, white to translucent quartz, lesser dolomite/ankerite, muscovite (as sericite) and pyrite and rarely minor arsenopyrite, galena, sphalerite and/or scheelite (cf. Skerl, 1948). Pyrrhotite and chalcopyrite have been reported as accessory minerals (Skerl, op. cit.; International Wayside Gold Mines Ltd., 2000). Wide veins, such as the BC Vein, can be greater than 15 metres in width and may have sheared graphitic margins. Sericite from quartz veins in the Cariboo Gold Quartz mine, Mosquito Creek Gold mine and Cariboo Hudson mine have been dated using the

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Vein textures in the Wells-Barkerville Belt are highly variable. Massive, white to translucent ‘bull’ quartz veins comprise subhedral to anhedral crystals from less than 0.5 mm to approximately 2 mm in size. Sutured grain boundaries have been noted in some samples. Many of the massive veins are highly fractured (Photo 1) and in some cases the abundance of microfractures results in a texture described by Reynolds (1991) as ‘wispy quartz’ (Photo 2). Reynolds (op. cit.) suggests that this texture is characteristic of deep vein environments (> 4 km and possibly > 8 km). In contrast, breccia textures indicative of brittle crushing reflecting higher level emplacement are observed in other veins (Photos 3 and 4). Skerl (1948) reports that approximately 1 percent of the veins at the Cariboo Gold Quartz deposit have vugs containing well terminated quartz crystals. These vugs indicate open-space filling late in the vein history. They have been noted in veins elsewhere in the Wells-Barkerville Belt (eg. Mosquito Creek, Warspite, Perkins). The quartz crystal terminations are typically translucent whereas most of the massive quartz is white due to abundant fluid inclusions along microfractures. Even fractured and wispy quartz veins have vugs (cf. Photo 2 - centre). Differences in temperature and composition between the late (?), open-space fill quartz and the earlier massive quartz are described below.

Four distinct, structurally-controlled vein orientations occur in the Wells-Barkerville Belt: strike, bedding-parallel veins (NW-SE/45-70NE), northerly (N-S/40-70E), orthogonal (030-040/70SE) and diagonal (070-090/subvertical) (Hanson, 1935; Benedict, 1945; Richards, 1948; Skerl, 1948; Robert and Taylor, 1989). Orthogonal veins are most abundant and these contain the highest concentrations of gold (Benedict, 1945, Robert and Taylor, 1989, International Wayside Gold Mines Ltd., 2000).

Two distinct styles of pyritic ore mineralization are evident in the belt. At Mosquito Creek and Island Mountain mines the pyritic orebodies occur within or adjacent to limestone units (Benedict, 1945; Alldrick, 1983), but at Bonanza Ledge in carbonaceous metasedimentary units and limestone (Rhys and Ross, 2000; Rhys, 2000). Pyrite orebodies at Mosquito Creek and Island Mountain mines tend to be commonly associated with fold hinges. Stope dimensions for these orebodies in fold hinges are commonly less than 10 metres thick and several hundred metres in the down plunge direction (Benedict, 1945, Robert and Taylor, op. cit.). Pyrite lenses at Mosquito
Creek can either be parallel to the strong foliation or parallel to the bedding (Robert and Taylor, 1989). At the Bonanza Ledge zone, Rhys (2000) describes folded high-grade pyrite mineralization that is discordant to stratigraphy and locally more than 30 metres thick over a strike length of 130 metres.

Pyritic ore at Bonanza Ledge comprises veinlets, concordant laminations and massive bands of pyrite, often with trace chalcopyrite and galena, in a gangue of muscovite, dolomite/ankerite and quartz (Rhys and Ross, 2000; Rhys, 2000). Pyrite orebodies at Mosquito Creek typically comprise fine to medium-grained crystalline pyrite forming individual or stacked lenses (Robert and Taylor, 1989). At the Cariboo Gold Quartz mine, massive crystalline pyrite orebodies contain little or no quartz but grey and white carbonates, galena, sphalerite and scheelite are reported around the margins of the ore (Skerl, 1948). Examples of the massive and banded pyrite ore from the Island Mountain mine in a gangue of...
fine-grained quartz, sericite and minor carbonate are in Photos 5 and 6.

Quartz in the massive pyritic Bonanza Ledge ore occurs as subhedral to anhedral crystals from about 0.25 mm to 1.5 mm in size, or as finer-grained, possibly recrystallized crystals that are mostly <0.15 mm in diameter, with sutured grain boundaries (C. Leitch, written communication to G.E. Ray, October 2000). Undulose extinction indicative of strain is common in the larger crystals (C. Leitch, op. cit.). Similar quartz textures are evident in a limited number of samples collected from Mosquito Creek and Island Mountain deposits.

Most workers in the Wells-Barkerville Belt (Hanson, 1935; Benedict, 1945; Skerl, 1948; Sutherland-Brown, 1957; Alldrick, 1983; Rhys and Ross, 2000; Rhys, 2000) believe that the pyrite lenses formed by replacement of carbonate units. A syn-sedimentary origin has also been proposed by Robert and Taylor (1989).

**FLUID INCLUSION DATA**

This preliminary paper describes fluid inclusions in quartz in the quartz-pyrite veins and in the massive-banded-stringer pyrite. Samples were examined from the Warspite, Cariboo Gold Quartz, Island Mountain, Mosquito Creek, and Perkins properties (Figure 1). The former Cariboo Gold Quartz, Island Mountain and Mosquito Creek mines were the principal lode gold producers in the belt. Description of the geology of the deposits have been given by Hanson (1935), Benedict (1945), Holland (1948), Johnson and Uglow (1926), Skerl (1948), Richards (1948) and Sutherland-Brown (1957). Where possible, samples were taken from surface outcrops, underground exposures and drillcore. However, as some mine workings are inaccessible, a number of samples were collected from dumps adjacent to portals. Over 30 ‘quick plates’ were prepared for fluid inclusion petrography. Quick plates are thick sections, 80 to 100 microns thick, mounted on glass slides with epoxy and polished on the top surface only. Of these, 12 samples, 2 from each of the 5 properties listed above and 2 from the BC Vein were selected for fluid inclusion microthermometry and re-prepared as doubly-polished sections. Samples were selected to give broad representation of both types of mineralization and, for veins, to give representation of some of the four vein orientations (Table 1).

Quartz was used for microthermometry because it has high tensile strength and is relatively translucent. Sphalerite is another high tensile strength mineral and is preferable to quartz because it is a sulphide mineral. Sphalerite is present in the BC Vein in the hanging-wall of the Bonanza Ledge zone (Ray et al., 2001, this volume) but unfortunately the mineral in the sample (GR-00-91) is too opaque for fluid inclusion study. Future work in the belt should focus on the potential of sphalerite and scheelite for fluid inclusion microthermometry.

Fluid inclusions were evaluated using the concept of fluid inclusion assemblages (FIA’s). This ensures that the data was not biased by samples containing large numbers of fluid inclusions and helps to eliminate inconsistent data caused by changes in mass, volume or shape of inclusions after entrapment (i.e. eliminate non-representative inclusions that are the result of diffusion, stretching, or necking-down processes). A fluid inclusion assemblage (FIA) is a petrographically-associated group of inclusions such as those aligned along primary growth zones or secondary fracture planes. One representative data point, rather than several data points is used for each FIA.

**Petrography**

Fluid inclusions in quartz from both vein and ‘massive’ ore in our Wells-Barkerville samples are typically less than 15 microns in longest dimension with inclusions in ‘massive’ ore usually less than 6 microns in longest dimension. Inclusions in some vein samples reach 30 microns in longest dimension. They vary in shape from irregular to smooth and in some cases they mimic the host crystal form and are ‘negative-crystal’-shaped.

Fluid inclusions in our vein samples are classified as secondary or indeterminate. Secondary inclusions are aligned along fractures that crosscut grain boundaries.
Interpretation of secondary fluid inclusions reflects the conditions of formation of post-crystal formation fluids trapped in fractures after crystal growth ceased. No gold particles were seen with any fluid inclusions in this study but gold is reported to be directly associated with secondary fluid inclusions in quartz veins at the Sigma Mine in Quebec (Robert and Kelly, 1987). Further detailed petrographic work is required to evaluate the occurrence of gold with respect to fluid inclusion chronology in the quartz veins of the Wells-Barkerville Belt.

Fluid inclusions noted in our ‘massive’ pyrite ore samples are classified as primary, secondary, pseudosecondary or indeterminate, based on the criteria of Roedder (1984) and Bodnar et al. (1985). Primary fluid inclusions are aligned along growth zones in quartz proximal to sulphide grains in ‘massive’ ore from the Mosquito Creek deposit (Photos 7 and 8). Unfortunately, these primary inclusions are less than 1-2 microns long and are too small for heating-freezing work. However, slightly larger primary and pseudosecondary fluid inclusions trapped in quartz in recrystallized zones around pyrite in ‘massive’ ore from the Island Mountain and Mosquito Creek deposits have been observed and measured (Photos 5, 9, 10 and 11). Pseudosecondary fluid inclusions (Photos 11 & 12) are aligned along fractures that do not crosscut grain boundaries and are presumed to represent fluids trapped in fractures at the time the crystal was growing (Roedder, 1984).

The occurrence of primary and pseudosecondary fluid inclusions in our samples is unusual because typically, in deposits hosted by metamorphosed and deformed rocks, significant deformation of quartz leads to recrystallization and expulsion of inclusions as well as cracking and trapping of secondaries, which may be subsequently annealed out (cf. Yardley, 1999). However, some studies report that the quartz grains are not completely recrystallized. For example, Garba and Akande (1992) document primary fluid inclusions in vein quartz hosted by metasediments in the Zuru Schist Belt of northwestern Nigeria. Primary fluid inclusions have also been documented in euhedral quartz encapsulated in sulphide grains at the Sigma mine in Quebec (Guha et al., 1991).

The primary and pseudosecondary fluid inclusions documented in this study have relatively consistent liquid-to-vapour ratios but moderately variable homogenization temperatures. The variability in homogenization temperature data may be due to thermal re-equilibration as suggested by Smith and Yardley (1999), undetectable necking down (post-entrapment change in inclusion shape) or real variability in the FIA’s. Further petrographic work on additional ‘massive’ ore samples at a number of deposits in the Wells-Barkerville Belt is required to assess whether the primary inclusions represent fluids formed syn-crystallization or whether the primary inclusions show the effects of leakage or decrepitation.

In the Wells-Barkerville Belt, four compositional types of fluid inclusions have been identified in quartz from both vein and ‘massive’ ore in the Wells-Barkerville Belt through observation of phases present and volume percent of phases at room temperature. For each measured fluid inclusion type within a fluid inclusion assem-

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### Table 1

**SUMMARY DESCRIPTIONS OF SAMPLES USED FOR FLUID INCLUSION MICROThERMOMETRIC ANALYSES, WELLS-BARKERVILLE GOLD BELT**

<table>
<thead>
<tr>
<th>DEPOSIT NAME</th>
<th>SAMPLE NUMBER</th>
<th>ORE TYPE</th>
<th>STRUCTURE TYPE</th>
<th>LOCATION IN VEIN</th>
<th>VEIN TEXTURES</th>
<th>MINERALS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cariboo Gold Quartz (mine)</td>
<td>CGQ-FI-3</td>
<td>vein</td>
<td>orthogonal?</td>
<td>whole vein</td>
<td>bull qz qz</td>
<td>qz</td>
</tr>
<tr>
<td></td>
<td>CGQ-FI-4</td>
<td>vein</td>
<td>?</td>
<td>?</td>
<td>bull qz qz</td>
<td>qz</td>
</tr>
<tr>
<td>BC Vein (Bonanza Ledge)</td>
<td>GR-00-91</td>
<td>vein</td>
<td>strike</td>
<td>footwall</td>
<td>massive qz</td>
<td>sph qz</td>
</tr>
<tr>
<td>BC Vein</td>
<td>GR-00-46</td>
<td>vein</td>
<td>strike</td>
<td>margin</td>
<td>bx, vugs qz</td>
<td>qz</td>
</tr>
<tr>
<td>Island Mountain (mine)</td>
<td>GR-00-85</td>
<td>massive</td>
<td>vein</td>
<td>diagonal</td>
<td>massive/banded recry. qz</td>
<td>py, qz, ser gal, qz</td>
</tr>
<tr>
<td></td>
<td>GR-00-94</td>
<td>vein</td>
<td>diagonal</td>
<td>?</td>
<td>bulq qz</td>
<td></td>
</tr>
<tr>
<td>Mosquito Creek (mine)</td>
<td>GR-00-67</td>
<td>vein</td>
<td>strike</td>
<td>centre of 1 m thick vein</td>
<td>banded/stringer recry. qz</td>
<td>qz</td>
</tr>
<tr>
<td></td>
<td>GR-00-68</td>
<td>vein</td>
<td>diagonal</td>
<td>?</td>
<td>vugs qz</td>
<td>py, qz</td>
</tr>
<tr>
<td>Warspite (veins)</td>
<td>GR-00-81</td>
<td>vein</td>
<td>dump</td>
<td>?</td>
<td>bull qz py, sph, qz</td>
<td></td>
</tr>
<tr>
<td></td>
<td>GR-00-82</td>
<td>vein</td>
<td>dump</td>
<td>?</td>
<td>bull qz gal, qz</td>
<td></td>
</tr>
<tr>
<td>Perkins (veins)</td>
<td>GR-00-49</td>
<td>vein</td>
<td>dump</td>
<td>?</td>
<td>vugs qz</td>
<td>qz</td>
</tr>
<tr>
<td></td>
<td>GR-00-56</td>
<td>vein</td>
<td>orthogonal?</td>
<td>?</td>
<td>vugs qz</td>
<td>qz</td>
</tr>
</tbody>
</table>

1. Mineral abbreviations: qz=quartz, py=pyrite, sph=sphalerite, gal=galena, ser=sericite

(Boedder, 1984).
blage (FIA), the liquid-to-vapour ratios were relatively consistent (±20 volume percent vapour). The compositional types, based on phases present at room temperature (20°C), modified from the nomenclature of Nash (1976) are: two-phase aqueous liquid-rich (Type I), multiphase (Type III), two and three-phase mixed aqueous and CO₂-rich (Type IV) and monophase vapour CO₂-CH₄ (Type V).

Type I fluid inclusions are characterised by 2 aqueous phases, liquid and vapour (Photo 12). The vapour phase typically comprises approximately 5 volume percent of the inclusion but rarely 10, 20 and 30 volume percent vapour have been observed. Type I fluid inclusions have been noted in all samples except in quartz from the Perkins occurrence.

Type III inclusions comprise a liquid brine, vapour and one or more solid phases (Photo 13). The vapour phase typically comprises approximately 10 to 30 volume percent of the inclusion. Many of the solid phases are dominantly translucent and cubic and therefore are presumed to be salts. Confirmation of the identity of the solid phases as salts has not been possible as fluid inclusions containing these phases decrepitate prior to solid phase dissolution. In some cases, secondary planes of type III inclusions with comparable phases present have been observed, although some ‘isolated’ type III inclusions may have formed by accidental trapping of the solid phases or post-entrapment changes in the inclusions. Type III inclusions have been noted in quartz veins from the Cariboo Gold Quartz, BC Vein and Perkins mineral occurrences and in quartz associated with ‘massive’ ore at the Mosquito Creek deposit. Limited freezing and subsequent melting behaviour of type III fluid inclusions in quartz from the Perkins occurrence indicates a CO₂-bearing vapour phase (see below).

Type IV inclusions consist of 2 or 3 phases at room temperature. These are either an aqueous liquid and CO₂-bearing liquid (Photo 14) or an outer aqueous liquid, inner CO₂-bearing liquid and a CO₂-bearing vapour (Photo 15). The CO₂ volumetric proportions of Type IV
Photo 9. Recrystallized quartz zone, approximately 0.5 mm wide, with virtually no fluid inclusions, around medium-grained pyrite (black) in massive ore, Mosquito Creek deposit. Note area of enlargement for Photo 11 is right of centre of Photo 9. Sample GR-00-68. Transmitted plane light. Width of photo 2mm.

Photo 10. Recrystallized quartz zone, approximately 0.3 mm wide, around medium-grained crystalline pyrite (black) in 'massive' ore, Island Mountain deposit. Recrystallized zone comprises less than one percent tiny fluid inclusions. Sample GR-00-85. Transmitted plane light. Width of photo 340 μm.

Photo 11. Pseudosecondary fluid inclusions aligned along fractures in recrystallized quartz proximal to pyrite crystals (black), 'massive' ore, Mosquito Creek deposit. Note occurrence of 2 phase liquid-rich and monophase vapour-rich fluid inclusions trapped in the same healed fracture. This photo is an enlargement of area right of centre of Photo 9. Sample GR-00-68. Transmitted plane light. Width of photo 300 μm.

Photo 12. Negative crystal-shaped Type I fluid inclusions characterized by 2 aqueous phases: liquid and vapour in vein quartz, Mosquito Creek deposit. Sample GR-00-67. Transmitted plane light. Width of photo 160 μm.
inclusions range from 5 percent to 90 percent with 20 to 30 percent most typical. Type IV inclusions have been noted in all samples except GR-00-91 (BC Vein) and GR-00-94 (Island Mountain vein).

Type V inclusions are typically very dark and consist of a single vapour phase at room temperature (Photo 14). Freezing and subsequent melting behaviour of these inclusions indicate the presence of CO₂-CH₄±N₂ phases. Type V fluid inclusions in quartz have been noted in all samples except in ‘massive’ pyritic ore from the Island Mountain mine and in veins from the Perkins occurrence.

Two phase liquid-rich Type IV inclusions are coeval with monophase vapour-rich Type V inclusions in sec-

Photo 13. Smooth to negative crystal - shaped Type III fluid inclusions in a massive ‘bull’ quartz vein, Cariboo Gold Quartz deposit. Note solid ‘daughter’ crystals in the fluid inclusions left of centre and far right. Sample CGQ-FI-4. Transmitted plane light. Width of photo 160 µm.

Photo 14. Coexisting monophase vapour-rich Type V inclusions and two phase liquid-rich Type IV inclusions aligned along a secondary fracture plane in quartz from a massive ‘bull’ quartz vein, Cariboo Gold Quartz deposit. Sample CGQ-FI-3. Transmitted plane light. Width of photo 160 µm.

Photo 15. Smooth to negative - crystal shaped Type IV fluid inclusions in quartz from a quartz vein, Mosquito Creek deposit. Note the three CO₂ and H₂O phases present at room temperature (20°C). Sample GR-00-67. Transmitted plane light. Width of photo 160 µm.

ondary and pseudosecondary fracture planes in quartz from both vein and massive ore (Photos 11 and 14). The coexistence of CO₂-bearing liquid-rich inclusions with variable liquid-to-vapour ratios and vapour-rich inclusions in the same fracture plane indicates that local effer-

vescence occurred.

Microthermometric Data

Microthermometric data were obtained using a Fluid Inc. adapted USGS gas-flow heating-freezing stage housed at the Mineral Deposit Research Unit, Department of Earth and Ocean Sciences, University of British Columbia. Calibration of the stage was achieved using commercial Syn Flinc synthetic fluid inclusions and ice with the following accuracies: at -56.6±0.2°C, 374.1±0.6°C and 0.0±0.1°C. Temperatures of phase changes are presented for each fluid inclusion type from lowest to highest. Variation in final aqueous homogenization temperature with respect to fluid inclusion origin, deposit type and comparison between deposits are illustrated.

TYPE I FLUID INCLUSIONS

Temperatures of first melting were obtained on 15 fluid inclusions from 4 samples representing both vein and ‘massive’ styles of mineralization (Figure 2). First melting temperatures range from -28.6°C to -20.0°C, with an average of -23.1°C. No systematic differences were
noted between vein and ‘massive’ styles of mineralization.

First melting temperature approximates the eutectic temperature of the salt-water mixtures. The observation of first melting below -21.2°C, the stable NaCl-H2O eutectic, indicates the addition of small concentrations of K+, Ca2+, Mg2+ or other ions to an H2O-NaCl fluid. For the purposes of this preliminary study, the type I fluid is modelled as an NaCl brine partly because most formation fluids are NaCl-dominant (Goldstein and Reynolds, 1994) and because comparison of the cotectic surfaces where ice melts for various systems (Figure 6, from Crawford, 1981) shows only relatively small variations (< 5 wt.% change).

Temperatures of final ice melting were obtained from 30 fluid inclusions from the same and additional samples as the first melting temperatures (Figure 2). Final melting temperatures range from -9.2°C to -0.2°C, with an average of -3.3°C. Salinities calculated from final melting temperatures and the equation of Bodnar (1993) range from 0.4 to 13.1 weight percent NaCl equivalent (wt. percent NaCl equiv.) and average 5.4 wt. percent NaCl equiv. No systematic differences were noted between vein and ‘massive’ styles of mineralization. Metastable hydrate melting (possible hydrohalite) is observed from 0 to 10°C after ice melting.

Final homogenization temperatures of the inclusions, always to the liquid phase, were obtained on 39 Type I fluid inclusions from the same samples and some additional samples as the freezing data (above). Homogenization temperatures range from 101.1 to 298.8°C and average 168.9°C (Figure 3). Five fluid inclusions in quartz vein samples from the Cariboo Gold Quartz mine and BC Vein exhibited decrepitation of fluid inclusions prior to homogenization at temperatures between 150 and 300°C.

TYPE III FLUID INCLUSIONS

Limited data (4 data points) on freezing and subsequent melting behaviours of Type III fluid inclusions in quartz from the Perkins vein parallel the behaviour of CO2-bearing Type IV fluid inclusions (see below). On heating, the solid phases do not melt prior to decrepitation (leakage) of the fluid inclusions at temperatures ranging from 220 to 258°C. Homogenization of one type III inclusion was achieved at 224°C, within the range for Type IV fluid inclusions (see below), prior to inclusion decrepitation at 250°C.

It is not known whether the Type III inclusions contain minerals that are true ‘daughter’ minerals or if the minerals are trapped accidental solids or are the result of ‘necking down’. If the solids are salts and true ‘daughter’ minerals, this combination of salt-saturated and CO2-bearing fluids trapped within inclusions in quartz veins at the Perkins veins has rarely been documented in fluid inclusion literature.

TYPE IV FLUID INCLUSIONS

On freezing of the inclusions, phase separation of the vapour bubble into CO2-liquid and CO2-vapour phases occurred at about +5 to + 25°C. Further cooling resulted in freezing of the H2O phase at about -35 to -50°C and the CO2 phase at about -90 to -95°C. Temperatures of CO2 melting were obtained on 50 fluid inclusions from both vein and ‘massive’ styles of mineralization. Carbon dioxide-melting temperatures typically range from -61.4 to -56.6°C with an average of -57.5°C (Figure 4). The average CO2 melt temperature of -57.5°C indicates that < 4 mole percent or virtually no CH4 or N2 is dissolved in the CO2. Type IV fluid inclusions can therefore be modelled using an H2O-CO2-NaCl system. Carbon dioxide-melting temperatures in quartz from the Perkins veins are much lower (Figure 3). These inclusions comprise from 0 to 20 mole percent CH4 dissolved in the CO2 using Vx diagrams of Thiery et al., 1994).

Temperatures of clathrate (gas hydrate) melting were obtained on 47 fluid inclusions from the same samples as the CO2-melting temperatures. Clathrate melting, which occurs after ice melting, varies from 0.2 to 9.8°C with an average of 6.6°C (Figure 4). Clathrate melting temperatures less than +10°C are another indication of very low CH4 or N2 presence in Type IV inclusions. Clathrate melting temperatures in excess of +10°C are related to CH4 impurities (Burruss, 1981). Salinities calculated from clathrate melting using the MacFlincor computer program (Brown and Hagemann, 1994) range from 1.4 to 15.7 wt. percent NaCl equiv.

Homogenization temperatures of CO2 liquid and vapour were obtained from 45 fluid inclusions from the same samples as CO2-melting and clathrate melting temperatures. Homogenization of the inclusions (always to the liquid phase) ranges from 5.6 to 30.5°C with an average of 19.7°C (Figure 4) which combined with volume estimates indicate a range in density of 0.54 to 0.84 grams per cubic centimetre for the CO2 component of the inclusions.

Final homogenization temperatures of the inclusions, again always to the aqueous phase, were obtained on 36 Type IV fluid inclusions from the same samples as the freezing data (above). Homogenization temperatures range from 124.7 to 341.9°C and average 241.1°C (Figure 3). A large proportion, approximately one-third, of all Type IV inclusions decrepitate at temperatures ranging from 150 to 300°C prior to homogenization. This large proportion occurred irrespective of reasonable heating rates which were reduced to 5 degrees per minute in an attempt to lower the number of failed homogenization temperatures. Figure 3 shows that overall, Type IV fluid inclusions homogenize at significantly higher temperatures than Type I fluid inclusions for data evaluated in this study.

TYPE V FLUID INCLUSIONS

On freezing the monophase Type V inclusions, phase separation of the vapour bubble into CO2-bearing liquid
Figure 2. Temperatures of first melt and final melt of Type I (aqueous) fluid inclusions from the Cariboo Gold Quartz, Island Mountain, Mosquito Creek mines and BC and Warspite veins, respectively. The first melt approximates the eutectic temperatures of the fluid inclusions. The final melt is used to calculate the equivalent salinity. Note the diagrams share common x axes.
and CO₂-bearing vapour phases occurred at temperatures below 20°C, often below 0°C. Further cooling resulted in freezing of the CO₂ phase at about -90 to -95°C. Rarely, the segregation of a second CO₂-rich liquid occurs at temperatures just below the freezing point. Up to 3 different stable phase transitions and rarely one metastable phase transition are observed on warming to just above room temperature ~22°C. The phase transitions observed were: initial melting (occasionally), final melting, metastable partial liquid homogenization (rarely) and final homogenization.

The first observed melting event is incipient or first melting, termed ‘initial melting’ by Kerkhof and Thiery (1994), which occurs as the formation of a liquid on melting solid CO₂ (but not complete melting of solid CO₂). This melt event which ranges from -94 to -69°C is observed in 6 fluid inclusions in as many samples.

The second observed melting event, observed in 25 fluid inclusions in quartz, is final melting of solid CO₂. Carbon-dioxide melting temperatures typically range from -84 to -56.6°C with an average of -61.1°C (Figure 5) which is significantly lower than the range and average observed for CO₂ melting of Type IV fluid inclusions (Figure 4). Some CO₂-melting temperatures in quartz from the BC Vein and Island Mountain mine are much lower than the average temperature (Figure 5).

Metastable partial liquid homogenization of fluid inclusions that have segregated a second CO₂-rich liquid has been observed in 2 fluid inclusions from separate samples in the BC Vein. This phase transition involves disappearance of the outer meniscus between the two CO₂-rich liquid phases. Fluid inclusions from the BC Vein show metastable partial liquid homogenization at -56.6 and -63.9°C respectively.

Final homogenization temperatures of CO₂ liquid and vapour were obtained from 22 fluid inclusions from the same samples as CO₂-melting temperatures. Homogenization of the inclusions (always to the liquid phase) ranges from -62.8 to 21.3°C with an average of -6.9°C (Figure 5). Final homogenization temperatures in quartz from the BC Vein and Island Mountain mine are much lower than the average temperature (Figure 5) as is the case for CO₂-melting temperatures (see above).

The measured CO₂ melt and homogenization temperatures are used to calculate fluid molar volumes (or the density) and composition of Type V fluid inclusions using VX diagrams of Thiery et al. (1994). The average CO₂ melt temperature of -61.1°C and average CO₂ homogenization temperature of -6.9°C indicates an average molar volume of 51 cubic centimetres per mol and on average <16 mole percent CH₄ dissolved in the CO₂ (Thiery et al., op. cit.). Some CO₂-melting and homogenization temperatures in quartz from the BC Vein and Island Mountain occurrences are much lower than the above calculated averages. These inclusions have molar volumes in the range of 51 to >100 cubic centimetres per mol and comprise from 33 to possibly >90 mole percent CH₄ dissolved in the CO₂ (Thiery et al., op. cit.). The high CH₄ in the Type V fluid inclusions from the BC Vein and Island Mountain occurrences indicate that they are CH₄-dominant and represent CH₄-CO₂ fluids. When the CH₄-CO₂ fluid inclusions are removed from fluid inclusions used in the

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Figure 3. Type I (aqueous) versus Type IV (CO₂-bearing) fluid inclusion final homogenization temperatures, to the aqueous phase, in quartz from all vein and massive pyrite samples evaluated in this study.
Figure 4. Temperatures of final CO₂ melt, clathrate melt and homogenization of CO₂ phases of Type IV (CO₂-bearing) fluid inclusions from the Cariboo Gold Quartz, Island Mountain, Mosquito Creek mines and BC, Warspite and Perkins veins, respectively. The final CO₂ melt temperature is used approximate the proportion of CH₄, N₂ or other volatile phases trapped in the fluid inclusions. The clathrate melt is used to calculated the equivalent salinity. The homogenization temperature of CO₂ is used to calculate the CO₂ density. Note the diagrams share common x axes.
Figure 5. Temperatures of final CO$_2$ melt and CO$_2$ homogenization of Type V (CO$_2$-CH$_4$±N$_2$) fluid inclusions.
average calculation of fluid molar volume and composition for Type V fluid inclusions, the average molar volume and composition of dominantly CO₂-CH₄ fluid inclusions is 50 cubic centimetres per mol and 4 mole percent CH₄.

**Variation in Final Homogenization Temperature**

Fluid inclusion final homogenization temperatures to the aqueous liquid phase for 75 Type I and IV fluid inclusions in quartz collected from quartz veins and massive pyrite mineralization in the 6 mineralized zones studied show virtually no difference between fluid inclusions of primary versus secondary origin (Figure 6). A wide spread in homogenization temperatures for both fluid inclusion origins range from 120 to 300°C. Fluid inclusions of indeterminate origin display a similar homogenization temperature range.

Preliminary comparison of the homogenization temperatures and composition of fluid inclusions in late (?), open-space fill quartz vugs and the earlier massive quartz veins of indeterminate origin display a similar homogenization temperature range.

Fluid inclusion final homogenization temperatures to the aqueous liquid phase for 73 Type I and IV fluid inclusions in quartz collected from quartz veins and massive pyrite samples from the Cariboo Gold Quartz, Island Mountain, Mosquito Creek mines and BC, Warspite and Perkins veins, respectively.

Figure 6. Distribution of primary, pseudo-secondary, secondary and indeterminate fluid inclusion origins with respect to final homogenization temperatures, to the aqueous phase, for Type I and IV fluid inclusions in quartz collected from quartz vein and massive pyrite samples from the Cariboo Gold Quartz, Island Mountain, Mosquito Creek mines and BC, Warspite and Perkins veins, respectively.
is the same for vein and ‘massive’ styles of mineralization as are the homogenization temperature averages: 207 and 204°C, respectively (Figure 7). Additional analyses and comparison of homogenization temperatures for each fluid inclusion Type and direct comparison of secondary fluid inclusion origins are recommended to verify the above preliminary results.

Preliminary comparison of fluid inclusion final homogenization temperatures to the aqueous liquid phase for 75 Type I and IV fluid inclusions in quartz from samples from vein and ‘massive’ styles of mineralization at the Cariboo Gold Quartz, Island Mountain, Mosquito Creek mines and Warspite, Perkins, and BC veins are in Figure 8. Vein mineralization is indicated by fluid inclusion homogenization data represented by white and striped columns, ‘massive’ pyrite style mineralization by black columns. This figure includes homogenization temperatures from primary, secondary, pseudosecondary and intermediate fluid inclusions based on the premise that virtually no difference exists between the homogenization temperatures of fluid inclusions of primary versus secondary origin (Figure 6). There is virtually no difference in the homogenization temperature range of the vein and ‘massive’ styles of mineralization at the Island Mountain and Mosquito Creek mines (Figure 8). Both styles at Mosquito Creek show two distinct populations (100 to 180°C and 240 to 360°C), that may reflect differences due to homogenization temperatures of lower temperature Type I versus higher temperature Type IV fluid inclusions (Figure 3).

Homogenization temperatures from both the vein and ‘massive’ styles of mineralization are averaged in Figure 8 based on the premise that virtually no difference exists between homogenization temperatures from both styles of mineralization (Figure 7). The homogenization temperatures for the Cariboo Gold Quartz and Island Mountain mines and BC vein show remarkably consistent averages (between 180 and 192°C) although the range of homogenization temperatures are similar (approximately 120 to 300°C). Average homogenization temperatures from the Mosquito Creek mine and Warspite veins are considerably higher at 212 and 217°C respectively. Quartz in the Perkins veins have the highest average homogenization temperatures (avg. 253°C). This may reflect the absence of generally lower temperature Type I fluid inclusions (Figure 3) in quartz at the Perkins veins.

Figure 7. Distribution of final homogenization temperatures, to the aqueous phase, for Type I and IV fluid inclusions in quartz veins from the Cariboo Gold Quartz, Island Mountain, Mosquito Creek mines and BC, Warspite and Perkins veins, respectively, versus in quartz from massive-banded-stringer ore at the Island Mountain and Mosquito Creek mines.
Figure 8. Final fluid inclusion homogenization temperatures (range, average and number), to the aqueous phase, for Type I and IV fluid inclusions from the Cariboo Gold Quartz, Island Mountain, Mosquito Creek mines and BC and Warspite veins, respectively. Note the diagrams share common x axes.
DISCUSSION

This discussion focuses on the following: (1) estimated fluid properties of inclusions in quartz from both vein and ‘massive’ ore in the Wells-Barkerville Belt, (2) the relationship of fluid inclusions to metamorphism and the introduction of metals in these types of mineral deposits and (3) proposed analogues to the Wells-Barkerville mineralization from a fluid inclusion standpoint.

Fluid Properties

Petrographic and microthermometric data on primary, pseudosecondary and secondary fluid inclusions in quartz from vein and ‘massive’ ore in the belt indicates there are four compositional types of fluid inclusions. These were identified through observation of phases present and volume percent of phases at room temperature: two-phase aqueous liquid-rich (Type I), multiphase (Type III), two and three-phase mixed aqueous and CO₂-rich (Type IV) and monophase CO₂, CH₄ (Type V). Estimates of average composition, salinity and final homogenization temperature for each fluid inclusion type are in Table 2.

COMPOSITION AND SALINITY

Type I fluid inclusions are H₂O-dominant with low average homogenization temperatures (169°C) compared with Type IV fluid inclusions (241°C). Salinities of Type I fluid inclusions are low, averaging 5.4 wt. percent NaCl equiv. This type of inclusion is commonly found in submetamorphic to subgreenschist facies metamorphic rocks (Marshall et al., 2000). Marshall (op. cit.) notes that H₂O dominates in the uppermost continental crust but is progressively diluted by CH₄ and then CO₂ during prograde metamorphism and that CO₂±CH₄±N₂ is typical in inclusions from the lower crust and mantle. Low temperature (< 200°C) aqueous fluid inclusions with H₂O-NaCl-CaCl₂ composition in gold-bearing quartz vein deposits from the southeastern Abitibi Subprovince, Quebec, represent late, post-mineralizing, fresh meteoric waters that percolate downward mixing with brines (Boullier et al., 1998). These deposits may be analogues to gold-bearing veins in the Wells-Barkerville Belt (see below).

Multiphase Type III fluid inclusions appear to be H₂O-dominant and some inclusions contain CO₂ (based on freezing behaviour). At least some of the solid phases appear to be salts which would indicated salt-saturation and minimum salinities of 26.3 wt. percent NaCl equiv. Calculations based on ice melting temperatures give approximate average salinities of 11.8 wt. percent NaCl equiv. Further work using additional analytical techniques is required to resolve the composition of this type of inclusion.

Type IV fluid inclusions fall in the category of High XH₂O (Low XCO₂) compositional type based on compositions in Table 2 (Diamond, 1994). This type is typical of CO₂-H₂O fluid inclusions found in low to medium grade metamorphic rocks and mesothermal to hypothermal ore deposits (Diamond, op. cit.). Marshall et al. (2000) suggest that H₂O-dominant fluid inclusions with only minor

<table>
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<tr>
<th>FI TYPE</th>
<th>ORIGIN</th>
<th>BULK INCLUSION COMPOSITION</th>
<th>SALINITY</th>
<th>HOMOGENIZATION TEMPERATURE</th>
<th>ESTIMATED MINIMUM PRESSURE</th>
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<tr>
<td></td>
<td></td>
<td></td>
<td>wt. percent NaCl equiv.</td>
<td>the aqueous phase, RANGE AND (AVERAGE) in °C</td>
<td>RANGE (bars)</td>
</tr>
<tr>
<td>I</td>
<td>P, S</td>
<td>(H₂O 0.98, NaCl 0.02)</td>
<td>5.4</td>
<td>101.1 to 299 (169)</td>
<td>n = 39</td>
</tr>
<tr>
<td>III</td>
<td>S</td>
<td>(H₂O 0.96, NaCl 0.04?, CO₂?)</td>
<td>11.8</td>
<td>224</td>
<td>n = 1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(H₂O 0.85, CO₂ 0.13, NaCl 0.02)</td>
<td>6.2</td>
<td>178 to 277 (242)</td>
<td>n = 11</td>
</tr>
<tr>
<td>IV</td>
<td>S</td>
<td>(all quartz veins)</td>
<td>4.2</td>
<td>189 to 292 (249)</td>
<td>n = 3</td>
</tr>
<tr>
<td></td>
<td>P</td>
<td>(massive pyrite from IIm)</td>
<td>0</td>
<td>1910 to 3412</td>
<td>n = 3</td>
</tr>
<tr>
<td>V</td>
<td>S</td>
<td>(CO₂ 0.96, CH₄ 0.04) and(CH₄ 0.7, CO₂ 0.3)</td>
<td>0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1. Fluid inclusion origins: P = primary, S = secondary (see text for explanation)
2. Salinity given as weight percent NaCl equivalent, n = number of analyses
3. Number of analyses for average = n
4. Number of analyses for range = n
CO₂ are predominant in greenschist facies metamorphic rocks.

Type V inclusions in this study are classified as homogenization or H-type inclusions (Kerkhof and Thiery, 1994) because the last phase transition observed is characterized by liquid-gas homogenization (always to the liquid phase) rather than solid-gas or solid-liquid homogenization. Type V inclusions are further subdivided into H₁ and H₂ types based on the observed differences in phase behaviour. Fluid inclusions that exhibit initial melting, final melting and final homogenization of CO₂-rich phases are classified as H₁-type (Kerkhof and Thiery, op. cit.); inclusions exhibiting final melting plus or minus metastable phase transitions followed by final homogenization of CO₂-rich phases are classified as H₂-type (Kerkhof and Thiery, op. cit.). Type H₂ behaviour is typical for CO₂-CH₄ mixtures and type H₁ behaviour is typical for CO₂-rich compositions (Kerkhof and Thiery, op. cit.). Fluid inclusions in this study are dominantly H₂-type. Based on the dominance of H₂-type inclusions, the CO₂-CH₄ model system, rather than the CO₂-N₂ model system, is used for Type V inclusions in this study.

The composition of type V inclusions falls in two distinct ranges: high CO₂ - low CH₄ and low CO₂-high CH₄ (Table 2). The latter high CH₄ composition has only been noted in secondary fluid inclusions at the BC Vein and in a vein from the Island Mountain mine.

**MINIMUM PRESSURE ESTIMATES**

Minimum pressure estimates have been calculated for Type IV fluid inclusions using bulk density estimates for the carbonic portion of the inclusions, and projecting isochores calculated using the equation of Kerrick and Jacobs (1981) and the FLINCOR program of Brown and Hagemann (1994) to temperatures of homogenization (minimum trapping temperature estimates). Although this technique assumes binary CO₂-H₂O mixtures, it can be applied to CO₂-H₂O mixtures with the addition of up to 15 wt. percent NaCl equiv. (Diamond, 1994). The range in density for the CO₂ component of the inclusions is 0.54 to 0.84 grams per cubic centimetre (Thiery et al., 1994).

The range of minimum pressures of entrapment for secondary Type IV (H₂O-CO₂-NaCl) fluid inclusions in quartz veins in the belt are 1628 to 3081 bars (Table 2). Entrapment pressures for primary Type IV fluid inclusions in quartz from massive pyritic ore at the Island Mountain mine, are 1910 to 3412 bars (Table 2). Minimum depths of formation for the secondary inclusions in quartz veins are conservatively estimated at about 6 to 12 km. Minimum depths of formation for the primary inclusions in ‘massive’ pyrite at the Island Mountain mine are conservatively estimated at about 7 to 13 km. Both minimum pressure estimates assume lithostatic pressure (greater depths would be inferred for hydrostatic conditions).

**Genetic Models**

As intrusive rocks are extremely rare in the Wells-Barkerville Belt, a magmatic-hydrothermal source for the gold seems unlikely. However, two alternative models have been proposed for mineralization: (1) a synmetamorphic model involving the introduction of metals. In the case of the massive pyritic ore this involved replacement during or just after prograde regional metamorphism (Benedict, 1945, Skerl, 1948, Alldrick, 1983), and (2) a syn-sedimentary model involving metamorphic overprinting of sedimentary-exhalative ore (Robert and Taylor, 1989). As part of their argument, these authors suggest that Wells-Barkerville gold differs from typical mesothermal deposits because they are hosted by a dominantly sedimentary sequence and lack any spatial association with major faults or recognized shear zones.

**Relationship of Fluid Inclusions to Metamorphism**

Petrographic observation indicates that primary and pseudosecondary fluid inclusions with relatively consistent liquid-to-vapour ratios but moderately variable homogenization temperatures formed in recrystallized zones around pyrite in massive-banded-stringer ore at the Mosquito Creek and Island Mountain deposits. The variability in homogenization temperature data may be due to thermal reequilibration, undetectable necking down or real variability in the FIA's. The cause of the variability is difficult to assess given the limited data available. Assuming the real variability in the FIA's and noting that the pyrite also appears to be recrystallized, it is possible that the primary and pseudosecondary inclusions may trap fluids that record metamorphic conditions during or just after peak metamorphism when the sulphides and gold were introduced as massive-banded-stringer ore.

Marshall et al. (2000) suggest that fluid inclusion studies of ores that are potentially metamorphosed or synmetamorphic require identification of: (1) preserved premetamorphic fluid inclusions, (2) inclusions relating to peak metamorphic conditions, and (3) inclusions relating to retrograde remobilization of ore or mineralization overprinting. Such detailed work requires evaluation of structural and metamorphic parageneses in combination with fluid inclusion paragenesis, preferably from a number of gangue and sulphide phases, to derive a fluid history. Ideally, future fluid inclusion work should examine fluid inclusions in sphalerite, scheelite and quartz in each vein set as well as the two styles of ‘massive’ pyritic ore in the belt.

A question to be answered is the relationship of secondary fluid inclusions in the quartz veins in the belt to the synmetamorphic introduction of metals. The similarity in composition, salinity and homogenization temperature range of primary and pseudosecondary fluid inclusions in the ‘massive’ style mineralization and secondary fluid inclusions in the Island Mountain and Mosquito Creek veins may be preliminary evidence that the two fluid inclusion types did trap similar metamorphic fluids. Or, per-
haps the secondary inclusions record microfracture histories that postdate the main vein-filling and mineralizing fluid events. Detailed work as described above is required to resolve this question. McKeag and Craw (1989) report no significant statistical difference between the primary and secondary inclusions at the Macraes shear zone-related gold vein in the Otago Schist Belt of New Zealand. They consider the two fluid inclusion origins to have formed contemporaneously.

Criteria for local effervescence, or unmixing of a primary, homogeneous CO₂-H₂O fluid phase, have been observed in pseudosecondary fluid inclusions in quartz from ‘massive’ ore at the Mosquito Creek deposit and in secondary fluid inclusions from a vein at the Cariboo Gold Quartz deposit. This mechanism coupled with evidence of gold precipitation in secondary fluid inclusion filled fractures is cited as the cause of gold mineralization in veins at the Sigma Mine in Quebec (Robert and Kelly, 1987).

**Analogues**

Gold-bearing mineralization in the Wells-Barkerville Belt is not spatially associated with any plutonic rocks but is hosted by greenschist facies phyllite supracrustal rocks that have undergone early ductile and subsequent brittle deformation. Both the veins and the massive pyrite ore probably formed late in the F₂ ductile deformation history (Ray et al., 2001, this volume).

Veins in the Mosquito Creek and Cariboo Gold Quartz deposits, specifically, have been classified as ‘Au-Quartz veins’ by Ash and Alldrick (1996). This broad classification includes “mesothermal” veins associated with major faults or shear zones such as the Mother Lode district in California (Weir and Kerrick, 1987), the Bralorne-Pioneer system west of Lillooet in British Columbia (Leitch et al., 1988) and Archean lode gold deposits in Ontario and Quebec, for example, at the Sigma mine (Robert and Kelly, 1987).

The Otago Schist Belt of New Zealand includes two types of W-and Au-mineralized veins: (1) ‘syn-metamorphic’ foliation-parallel veins that formed close to the peak metamorphic temperature and post peak-pressure conditions and (2) ‘post-peak metamorphic’ veins which are typically hosted in extension structures (Smith and Yardley, 1999). The main difference in fluid inclusion composition between the two vein types is the presence of CO₂ as a major component in the post-metamorphic vein inclusions and absence of detectable CO₂ in the syn-metamorphic veins (Smith and Yardley, op. cit.). Post-metamorphic veins also tend to have higher salinities (up to > 9 wt. percent NaCl equiv.) rather than salinities equivalent to sea-water or less (< 3.3 wt. percent NaCl equiv.) which were recorded for syn-metamorphic veins (McKeag and Craw, 1989, Smith and Yardley, op. cit.). Fluid inclusions from all the Wells-Barkerville Belt quartz veins evaluated in this study have readily detectable CO₂ and salinities comparable to ‘post-metamorphic lodes’ (Henley et al., 1976) of the Otago Schist Belt in New Zealand. Other potential analogues for Wells-Barkerville Belt veins include the ‘mesothermal’ veins in the Klondike District, Yukon (Rushon et al., 1993), Meguma Terrane, Nova Scotia (Kontak et al., 1988) and the Bendigo Gold Fields, Central Victoria, Australia (Jia et al., 2000).

**SUMMARY**

This preliminary study of fluid inclusions in quartz from vein and ‘massive’ styles of pyritic mineralization provides the following information concerning the nature of fluids that may relate to metamorphism, deformation and deposition of gold and/or late tectonic overprinting in the Wells-Barkerville Gold Belt:

- Some veins in the belt exhibit wispy quartz textures indicating deep (> 4 km) environments and other veins exhibit breccia and open-space filling textures indicating (later?) deposition at more shallow levels (< 1-3 km?) environments. In some veins, both deep and shallow textures are observed.
- Quartz in the quartz-pyrite veins contain fluid inclusions of mostly secondary origin. It is not clear whether some secondary inclusions have trapped metamorphic fluids or whether they record microfracture histories that postdate the main vein-filling and mineralizing fluid events.
- Quartz in the massive-banded-stringer pyrite ore includes variable proportions of very fine-grained, possibly recrystallized or highly strained quartz that contains primary and pseudosecondary fluid inclusions. These fluid inclusions may trap fluids that record symmetamorphic conditions at the time of sulphide and gold deposition.
- The following four compositional types of fluid inclusions are identified in the vein and ‘massive’ styles of mineralization based on phases present at room temperature and microthermometric data: Type I: ‘Aqueous’ H₂O-NaCl, Type III: ‘Multiphase’ H₂O-NaCl (±CO₂), Type IV: ‘CO₂-bearing’ H₂O-CO₂-NaCl and Type V: CO₂·CH₄, CO₂·CH₄ (±N₂) or CH₄·CO₂.
- The dominant fluid inclusion types in both the vein and ‘massive’ mineralization are Type I and Type IV.
- Type I inclusions have average bulk composition (mole percent) of approximately 98% H₂O and 2% NaCl.
- Type IV secondary inclusions from veins have an average bulk composition (mole percent) of about 85% H₂O, 13% CO₂ and 2% NaCl.
- Type IV primary inclusions from ‘massive’ mineralization at the Island Mountain mine have average bulk composition (mole percent) of approximately 93% H₂O, 13% CO₂ and 2% NaCl. This composition is significantly different from the composition of Type IV secondary fluid inclusions in veins.
- Overall, Type IV fluid inclusions homogenize at significantly higher final temperatures (avg. 241°C) than Type I fluid inclusions (avg. 169°C).
• No significant differences are seen between primary and secondary fluid inclusion final homogenization temperatures for Type I and Type IV fluid inclusions.
• No significant differences are seen in final homogenization temperature in the vein and ‘massive’ styles of mineralization, either in the same deposits or between deposits.
• Quartz in the Perkins veins has different fluid inclusion characteristics from other veins in the belt. It is characterized by Type III and IV fluid inclusions that homogenize at significantly higher temperatures (avg. 253°C) than the other vein deposits studied which average < 220°C. Type I and V fluid inclusions are notably absent in the Perkins veins.
• The range of minimum pressures of entrapment for secondary Type IV (H$_2$O-CO$_2$-NaCl) fluid inclusions in veins from the Cariboo Gold Quartz mine and BC, Warspite and Perkins veins are 1628 to 3081 bars. Minimum depths of formation are conservatively estimated at about 6 to 13 km, assuming lithostatic pressure
• The range of minimum pressures of entrapment for primary Type IV (H$_2$O-CO$_2$-NaCl) fluid inclusions in massive ore from the Island Mountain mine are 1910 to 3412 bars. Minimum depths of formation are conservatively estimated at about 7 to 12 km, assuming lithostatic pressure
• This fluid inclusion study suggests that the Wells-Barkerville gold-bearing veins are analogues to the ‘post-metamorphic’ gold-bearing veins in the Otago Schist Belt of New Zealand.

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REFERENCES


Reynolds, T.J. (1991): Short Course on Fluid Inclusions; Mineral Deposit Research Unit, Short Course 6.


Sutherland-Brown, A. (1957): Geology of the Antler Creek Area, Cariboo District, British Columbia; British Columbia Department of Mines, Bulletin 38, 105 pages.


Yardley, B. (1999): Discussion of inclusion survival in sheared quartz; FI Discussion Archives at http://www.geology.wisc.edu/~pbrown/ft.html