Structural setting and geochemical correlations in bismuth (sulfo) telluride-native gold–bearing veins, CLY Group, British Columbia, Canada: A reduced intrusion-related gold system

William (Bill) R. HOWARD 215 Silver Mead Cres. NW Calgary AB T3B 3W4 Canada
(wm.howard@shaw.ca)

Abstract: New found native gold + native bismuth + bismuthinite + bismuth (sulfo)tellurides occur in fracture-controlled clots in m-plus wide outcropping quartz veins on the CLY Group claims in the historic Nelson Mining Division, southernmost British Colombia. Mineralization has all criteria of the 'Reduced Intrusion-related Gold' model. Veins in three different sets occur over a 1.5 km N-S extent. Some are sheeted (i.e., near parallel and repeated); sulphide content is very low. The Eloise Vein on BiTel Knoll is like the Pogo deposit Liese Zone (3.51 M. oz) in structural-metamorphic setting and Au–Bi–Te mineralogy. The Clarissa Transverse Sheeted Veins and five auriferous Clease quartz veins and shears are analogous to mineralization in the Fort Knox deposit, Alaska (~5.4 M. oz). These are operating mines in the Tintina Gold Province, Alaska and Yukon, northern cordillera. In the Fairbanks district, reduced proximal arsenopyrite-pyrrhotite bearing tungsten + gold skarns occur about Fort Knox. On CLY Group Au(Ag)–Bi–Te–W–Mo ± As bearing quartz veins overprint the proximal Lefevre W + Au skarn. A numerical exploration model objectively ranks the potential of CLY for an economic deposit as high. This impartial analysis is irrespective of the favourable tectonic setting, rare mineralogy and outcrop features of the more than 19 known gold showings.

Key words: gold ores, quartz veins, gold, bismuth, tellurium, bismuthinite, tellurides, British Columbia, Canada

1. REGIONAL TECTONIC SETTING

CLY Group is the name of a Au–Bi–Te prospect situated at the ancestral North American accretionary margin at the maximum point of curvature of the Kootenay Arc, along a since-folded crustal suture zone (Fig. 1). Inboard Kootenay terrane rocks of ancestral North America (blue) include Cambro-Ordovician Index Formation metasediments and –volcanics of the Lardeau Group (Logan and Colpron 2006). Outboard younger Slide Mountain terrane rocks are ophiolitic (grey). The Quesnel Terrane is represented by Lower Jurassic shoshonitic andesites of the Rossland Group (greens and orange). All are intruded by the Salmo and Wallack Creek Stocks. These are part of the Mid-Cretaceous Bayonne magmatic belt granitoids (light red; Logan, 2002a, b) that 'stitch' two major crustal scale structures, the Waneta and Tillicum Creek Faults (Einarsen, 1995; Höy and Dunne, 1999). Concomitant Mid-Cretaceous compression oriented SSW-NNE (arrows on Fig. 1) reactivated all earlier structures. An outlying felsic granitoid of Wallack Creek Stock, named the Bunker Hill Sill [BH Sill] is spatially and genetically related to the Au-Bi-Te mineralization in CLY (Caron, 2006). BH Sill granitoids are I-type felsic biotite ± muscovite ± hornblende granites. They have a reduced petrochemistry with near zero magnetic susceptibility and very low magnetite content (R.G. Anderson, pers. comm., 2006). Abundant sheeted tourmaline veinlets, tourmalinite breccia, quartz crystal-lined fractures and generally coarse grain size is evidence the BH Sill is exposed near its roof (Howard, 2005, 2006b). In form it may be cupola or dyke-like.

2. DISTRICT-SCALE STRUCTURAL SETTING

On the CLY Group property, recently found native gold + bismuth (sulpho)telluride showings are spatially and genetically related to the km-scale BH Sill (Fig. 1). This felsic granitoid intrudes uncertainly correlated Lower Paleozoic to Triassic (?) metasedimentary and –volcanic rocks of the Harcourt Ck Assemblage [HCA] (Einarsen, 1995), a division of the enigmatic CS Unit (Little 1985). Howard (2000, 2005) further subdivides the HCA into three structural units. The structurally upper (and youngest) unit includes metabasalts with MORB petrochemistry (Einarsen, 1995). These correlate with Permian

Kaslo Group metabasalts in the central Kootenay Arc (Roback et al., 1994). Together with fault-bounded slivers of serpentinite and pyroxenite (also Permian?) the HCA is considered an ophiolite, a structural slice or sliver of Slide Mountain terrane. The large age range is mostly Middle to Upper Paleozoic, (?) Devonian to Permian and likely also includes Triassic rocks. At the west intrusive contact of the BH Sill on BiTel Knoll, the HCA argillaceous quartzite is silicic, hornfelsed and well veined (Fig. 2).

Elements and minerals in the showings fit the zonal arrangement of Hart (2005) from Au–Bi–Te in the central granitic pluton to Pb–Zn–Ag distal to the intrusion (Caron et al., 2006). CLY veins are *intrusion-hosted* in the granitoid and *proximal, intermediate and distal-placed* with respect to the BH Sill. CLY meets all exploration criteria for an economic Reduced Intrusion-Related Gold [RIRG] system (McCoy et al., 1997, 2002; McCoy, 2000; Hart et al., 2002; Baker, 2003; Hart 2005; Hart and Goldfarb, 2005; Lefevre and Hart 2005). Comparing bismuth–gold linkages CLY is exemplary (Fig. 3).

3. VEIN MINERALOGY

Base metals and sulphide minerals are generally scarce in auriferous qtz veins and shears; the sulphur content is only tens of ppm. Mineral assemblages include native gold, native bismuth, bismuthinite, ingodite, joséite-A, joséite-B, ikunolite, hedleyite, unnamed Bi_2Te and unidentified secondary bismuth minerals (Cook and Ciobanu, 2006; Part II in Howard 2006a). This is the first report of ingodite Bi(Te,S) in Canada, and the first report of ikunolite $Bi_4(S,Se)_3$ and unnamed Bi_2Te in the Western Hemisphere. In the only two polished sections prepared, Eloise Vein has six of the twelve Bi–Te–S minerals identified in gold ore of the Pogo (3.51 M. oz) deposit, i.e., native bismuth, bismuthinite, ingodite, joséite-A, joséite-B and hedleyite (Rombach et al., 2002).

CLY quartz veins, veinlets, shears and tungsten + gold skarn have high Bi contents to > 2,000 ppm (Fig. 3) and abundant Te to >100 ppm. Both strongly correlate with Au (Ray, 2003; Howard, 2006a). Bi and Te are key pathfinder elements for RIRG deposits in primary (Flanigan et al., 2000) and secondary (Baker, 2003) geochemical media.

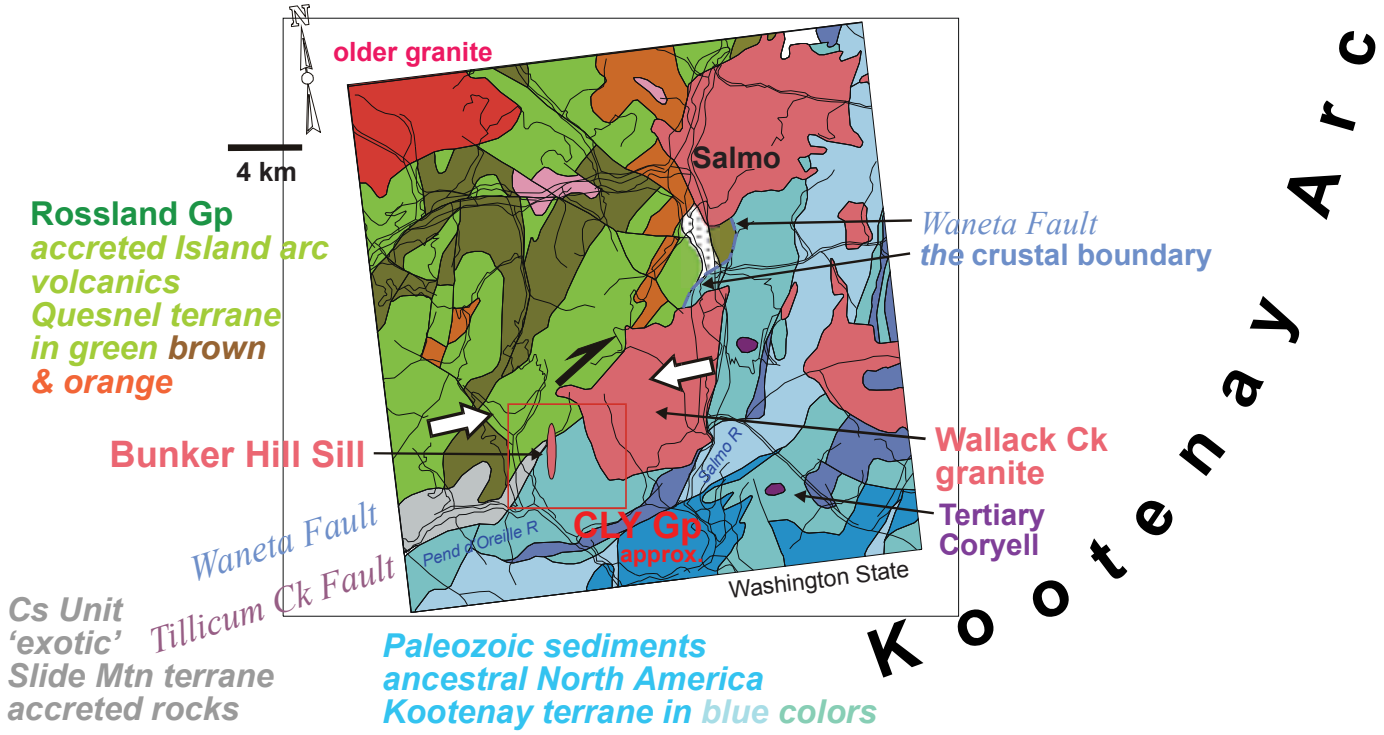

Figure 1. District scale tectonic setting of CLY prospect at the North American accretionary margin. The Kootenay Arc regional structure bends at the Canada-US border. Serpentinite and pyroxenite demarcate the Tillicum Ck Fault.

Figure 2. BiTel Knoll showings, CLY property centre. (Left) Clarissa Transverse Sheeted veins at the BH Sill intrusive contact. Card has cm (top) and inch scales. (Right) Eloise Vein South outcrop. A particular granular silica phase and fractures internal to the vein host clots of gold-associated Bi–Te minerals including ingodite. Vein extends to beyond the left tree.

4. HISTORIC UNDERGROUND MINING AND GOLD CONCENTRATIONS IN VEINS

Small-scale underground mining in the 1930's recovered 3.33 Kg gold (107 oz) and 9,364 Kg silver from three adits of the Bunker Hill Mine, 220 m SW of the central BiTel Knoll showings. For the average 4 foot vein width mined in Adit 2 the gold accumulation value was 13.1 g/t*m at a minimum grade 10.7 g/t. The linear direction of the mined ore shoot is known. Mined veins have low fineness (e.g., 588 for the *intermediate placed* Adit 2 Underhand Stope Vein) compared with the new found BiTel Knoll veins (834 for the *very proximal* Eloise Vein, mean of 10 samples).

Measured gold accumulation values as grade times m width intervals from surface sampling include 9.74 g/t*m for the *intrusion-hosted* Clease 0446-BHCK-13 Shear and 5.1 g/t*m, the mean of six measured samples of the *intermediate placed* Adit 1 Gallery Quartz Vein (Howard 2000, 2006b). This outcrops discontinuously for 46 m.

5. NUMERICAL EXPLORATION MODEL FOR HIGH GOLD POTENTIAL

The numerical exploration model of Flanigan et al. (2000) shows high potential for an *intrusion-hosted to very proximal* subtype of RIRG deposit on CLY Gp (Fig. 3). The model of Flanigan et al. considers three numerical linkages of Bi with Au in mineralized rock in many developed deposits and presently producing mines in the Tintina Gold Belt in the Northern North American Cordillera: the Pearson correlation coefficient $r_{Bi–Au}$, the slope of the best-fit regression line (both using log-transformed data) and the Bi to Au ratio (raw or untransformed data). These linkages measure closeness to the mineralizing intrusive source.

Flanigan et al.'s model is objective as it is arithmetical and irrespective of [1] the favourable outcrop features of the showings, all well drift covered [2] their prospective structural setting near a crustal suture zone [3] crossing vein sets [4] vein density (Lang et. al 2001) sufficient for a RIRG deposit (fig. 2) and [5] the uncommon to very rare gold-associative minerals present (Cook and Ciobanu in Howard, 2006a, b, also 2005).

6. GENETIC CONSIDERATIONS

The Bi-mineral occurrences discussed here support the strong geochemical correlation between Bi and Au, which is typical for intrusion-related Au deposits (Baker et al., 2005). Noting morphologies such as 'droplet' shaped inclusions

and phase assemblages that represent equivalents of eutectic associations in the Au-Te-Bi system, Ciobanu et al. (2004) discussed the formation of Au deposits via Bi-Te-Au melts exsolved from fluids. The Bi-mineral associations found in Clarissa, Eloise and Blue Quartz veins include abundant droplets and patches of Bi-(sulfo) tellurides that are suggestive of deposition in a molten state. All the encountered species have Bi:(Te+Se+S) ratios ≥1 (stable at reducing conditions, i.e., pyrrhotite and magnetite fields). However, the eutectics on the Bi-rich side of the Au-Bi-Te system include maldonite instead of native gold as is observed in the CLY assemblages. Cook et al. (2007, this volume) discuss the textural relationships, Au contents and trends within the Bi-species in more detail. The conclusion is that, even if originally deposited as melts exsolved from a magmatically-derived fluid, the associations record extensive reworking and recrystallization during a subsequent (orogenic?) event that overprint and modify them.

7. EXPLORATION TARGET

CLY Gp targets a near surface, open pittable, M. oz Intrusion-related quartz vein gold deposit with extreme enrichment in both bismuth and tellurium. These elements triply co-associate with gold in over 19 showings on the property.

This large Au–Bi–Te system is little-explored. Sulphide content is low with little potential for acid rock drainage. Mineralization is non-refractory 10-100 µm-sized particulate gold that could be recovered by low-cost gravity separation (McCoy et al., 2002). Local infrastructure is

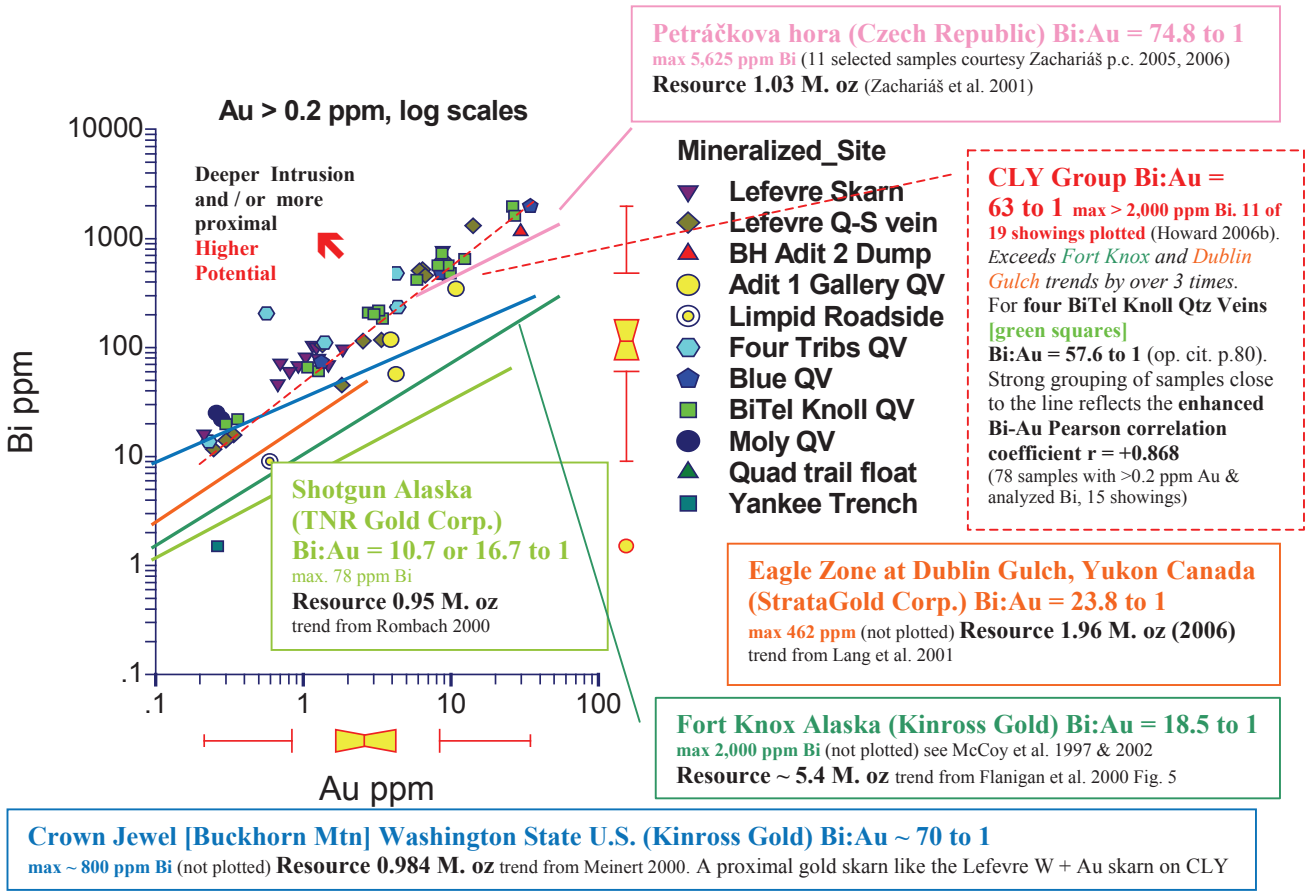

Figure 3. Graph displaying three Bi-Au linkages of CLY Gp rocks. Axes are log scale. Significant explored deposits with mean Bi:Au ratio, max. ppm Bi and gold resource are noted for comparison. The slope of CLY regression line (dashed) is steepest known. Petráčkova hora (Czech Republic; Zachariáš et al., 2001, p.c. 2006 selected samples) is most similar in ratio and Dublin Gulch (Yukon) in slope. Graph axes are logarithmic; thus a slight increase in the slope is a large numerical increase. The mean CLY Bi:Au ratio of 63 to 1 is stable on successively trimming the data by 5, 10 or 15% from each side of the distribution. The last case considers only the central 70% of the ratios (Howard, 2006b, p. 81). The untrimmed ratio is 66.7.

excellent with new logging roads. L. Caron, P. Eng. writes "in my opinion, the property has good potential to host an economic bulk-tonnage intrusion-related gold deposit (April 2007)." She recommends a $600,000 first year exploration programme, half for 1,700 m of large-diameter core drilling and half for further ground surveys. A private company is currently seeking financing for this. Howard (2007) selects six targets for exploratory drilling.

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