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Ministry of Energy, Mines & Petroleum Resources
Mining & Minerals Division
BC Geological Survey

ASSESSMENT REPORT
TITLE PAGE AND SUMMARY

TITLE OF REPORT [type of survey(s)]: Continuing Mineralogical Research on rare to exceptionally rare gold-associated Bi-Te-S-(Se) ore minerals new to Canada...

TOTAL COST: $3950.88

AUTHOR(S): William R Howard N.J. Cook C.L. Ciobanu

SIGNATURE(S): William R Howard

NOTICE OF WORK PERMIT NUMBER(S)/DATE(S): N/A

YEAR OF WORK: 2006-2007

STATEMENT OF WORK - CASH PAYMENT EVENT NUMBER(S)/DATE(S): Event № 4175623 on Oct 18 2007
Work Oct. 20 2006 - Oct. 17 2007

PROPERTY NAME: CLY Group

CLAIM NAME(S) (on which work was done): 516584 (formerly CLY 2)

COMMODITIES SOUGHT: gold, bismuth, silver

MINERAL INVENTORY MINFILE NUMBER(S), IF KNOWN: Bunker Hill 082FSW002

MINING DIVISION: Nelson

NTS: 082F03 W½ BGS 082F.004

LATITUDE: 49° 03' 36" LONGITUDE: 117° 23' 15" (at centre of work)

OWNER(S)
1) Clarke Gold Inc.
c/o William R Howard
2)

MAILING ADDRESS
215 Silver Mead Cres. NW
Calgary AB T3B 3W4

OPERATOR(S) [who paid for the work]
1) Clarke Gold Inc.
2) Natural History Museum, University of Oslo, Norway
and IGCP-486 (see next page)
and South Australian Museum, Adelaide
and Dept. of Earth and Environ. Sciences University of Adelaide Australia

MAILING ADDRESS
as above

PROPERTY GEOLOGY KEYWORDS (lithology, age, stratigraphy, structure, alteration, mineralization, size and attitude): mid Cretaceous Rare bismuth telluride and sulphotelluride minerals ingodite ikunolite unnamed Bi2Te joseite-A joseite-B hedleyite native gold in quartz veins. Intrusion hosted and proximal placed Reduced Intrusion-Related Gold System Type L-02 Bunker Hill Sill native bismuth bismuthinite

REFERENCES TO PREVIOUS ASSESSMENT WORK AND ASSESSMENT REPORT NUMBERS: Howard 2000 # 26,159 Kennedy 2003 # 27,231 Ray 2004 # 27,513 Howard 2005 # 27,893 Howard 2006a # 28,748 Howard 2006b # 28,749

(OVER)

TYPE OF WORK IN THIS REPORT	EXTENT OF WORK (IN METRIC UNITS)	ON WHICH CLAIMS	PROJECT COSTS APPORTIONED (incl. support)
GEOLOGICAL (scale, area)			
Ground, mapping			
Photo interpretation			
GEOPHYSICAL (line-kilometres)	nil		
Ground			
Magnetic	"Note: IGCP-486 is	International Geological	
Electromagnetic	Correlation Programme	Project 486	
Induced Polarization	Au-Ag-telluride-sel	enide deposits.	
Radiometric	Sponsored by UNES	co and the International	
Seismic	Union of Geological	Sciences."	
Other			
Airborne			
GEOCHEMICAL (number of samples analysed for ...)	nil		
Soil			
Silt			
Rock			
Other			
DRILLING (total metres; number of holes, size)	nil		
Core			
Non-core			
RELATED TECHNICAL			
Sampling/assaying			$3950.88
Petrographic		All on claim #516	584:
Mineralographic	electron probe micro analysis	on 11 mineral grains	and
Metallurgic	laser ablation induction coupled	plasma mass spectrometry on 23 spots on various minerals	
PROSPECTING (scale, area)	nil		
PREPARATORY/PHYSICAL	nil		
Line/grid (kilometres)			
Topographic/Photogrammetric (scale, area)			
Legal surveys (scale, area)			
Road, local access (kilometres)/trail			
Trench (metres)			
Underground dev. (metres)			
Other			
		TOTAL COST	$3950.88

Continuing Mineralogical Research on rare to exceptionally rare gold-associated Bi–Te–S–(Se) ore minerals new to Canada: compositions of ingodite ikunolite and unnamed Bi_2Te associated with hedleyite joséite-A joséite-B native gold grains native bismuth bismuthinite molybdenite and scheelite in claim # 516584, central CLY Group, Salmo map sheet NTS 082F03 W1/2, Nelson Mining Division, southernmost British Columbia

2007 Assessment Report – Research on Mineral Compositions

BC Geological Survey
Assessment Report
29864

Claim # 516584 worked on (formerly CLY 2)

Latitude 49° 03' 36'' Longitude 117° 23' 15" or
NAD 83 Zone 11 UTM 471,652 mE / 5,434,400 mN
BGS 082F.004 (1:20,000 scale)

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Date: Jan. 14 2008

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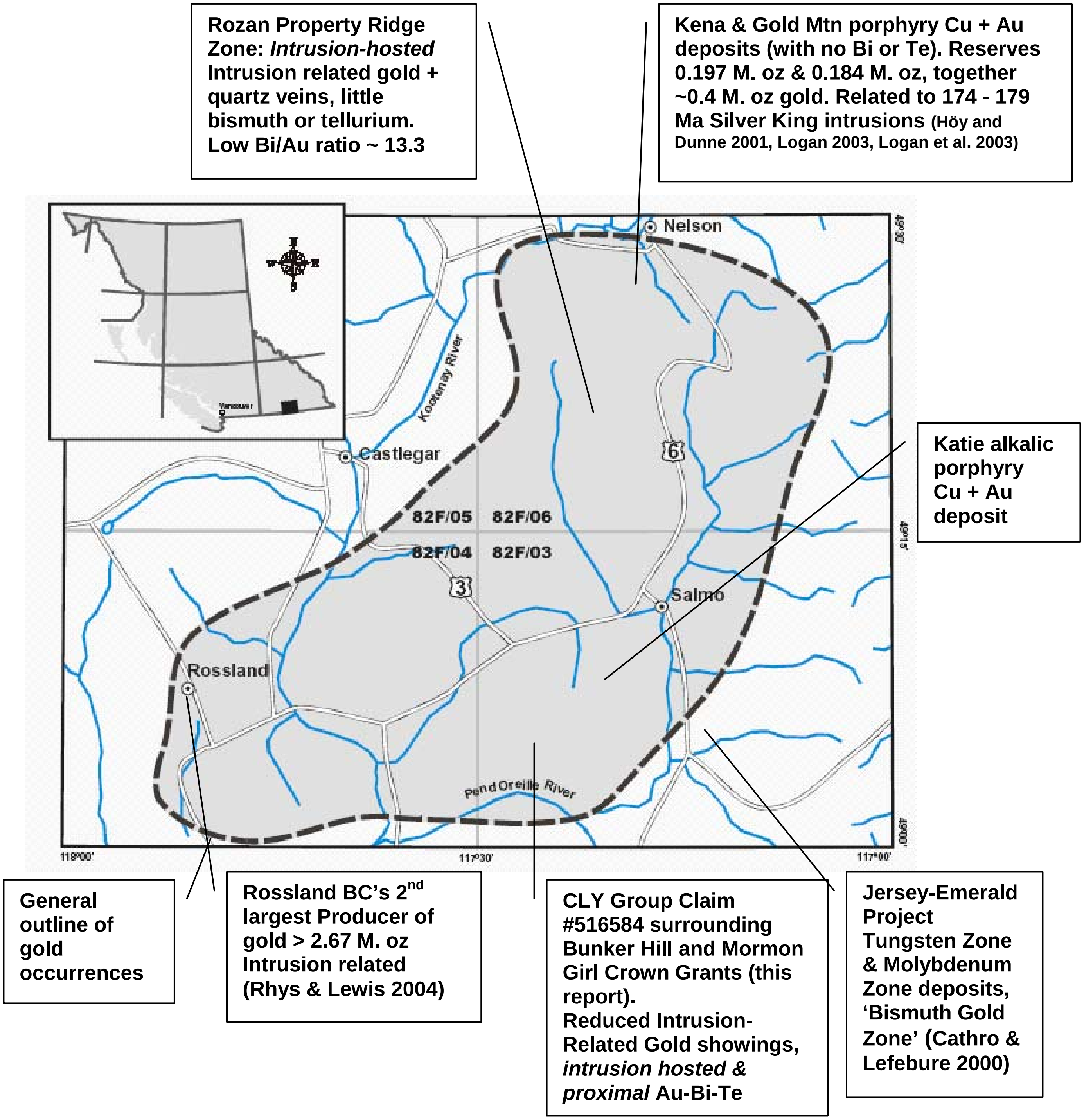


Fig. 1 Location of CLY Gp in the Nelson Mining Division, West Kootenays, southernmost BC, with some mineral deposits in the region (fig. from Jackaman & Höy 2004)

MTO Online Inserts following this page:

Fig. 2A CLY Group Location Map in BC

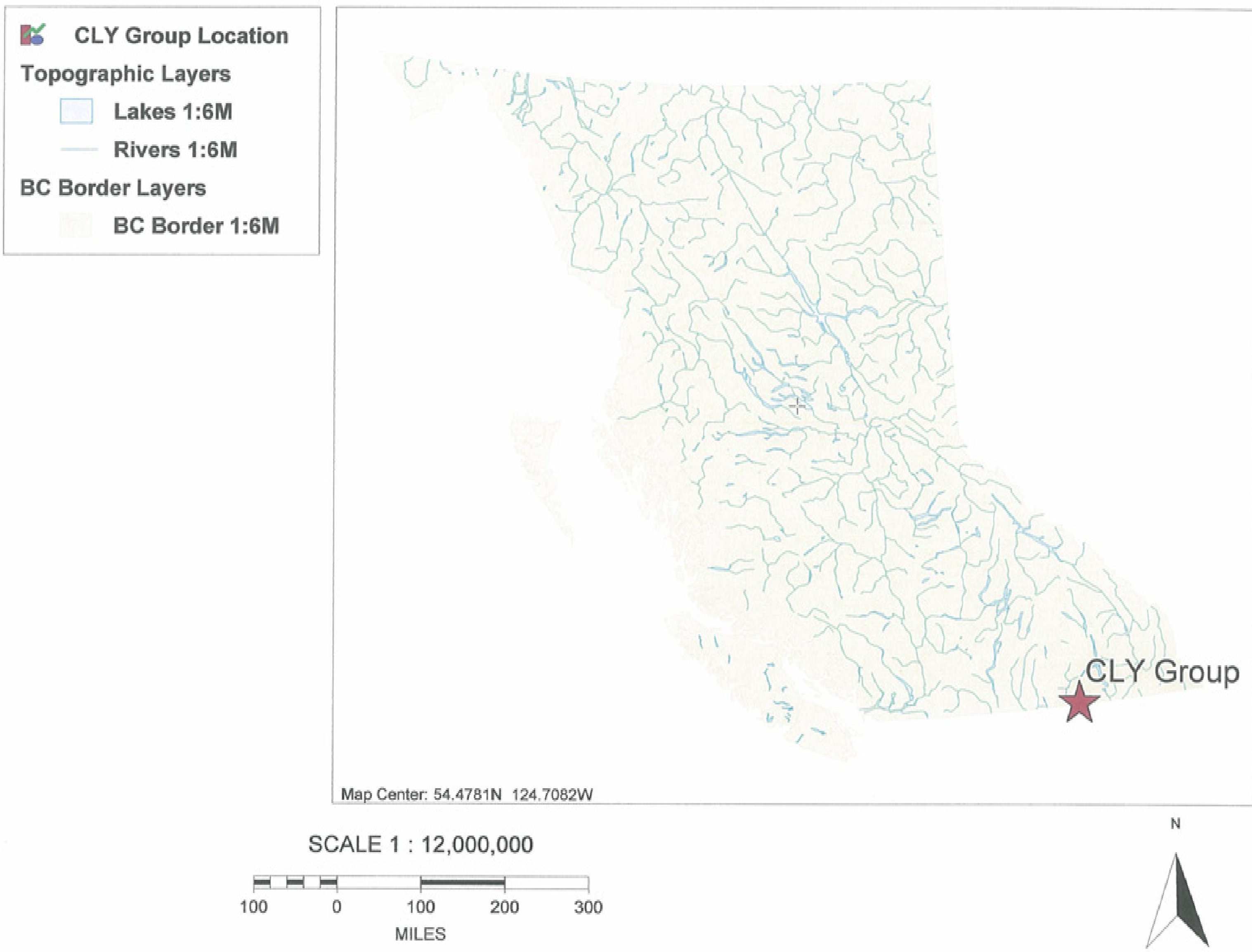
Fig. 2B CLY Group Claim Map with two tenures outlined & roads, 1:50,000 scale

MTO Mineral Claim Exploration and Development Work/Expiry Date Change Confirmation dated Oct. 18 2007

Mineral Titles Online Report with tenure info

See Appendix 2 for further claim info

CLY Group Location Map



CLY Group Claim Map

Mineral Titles Layers

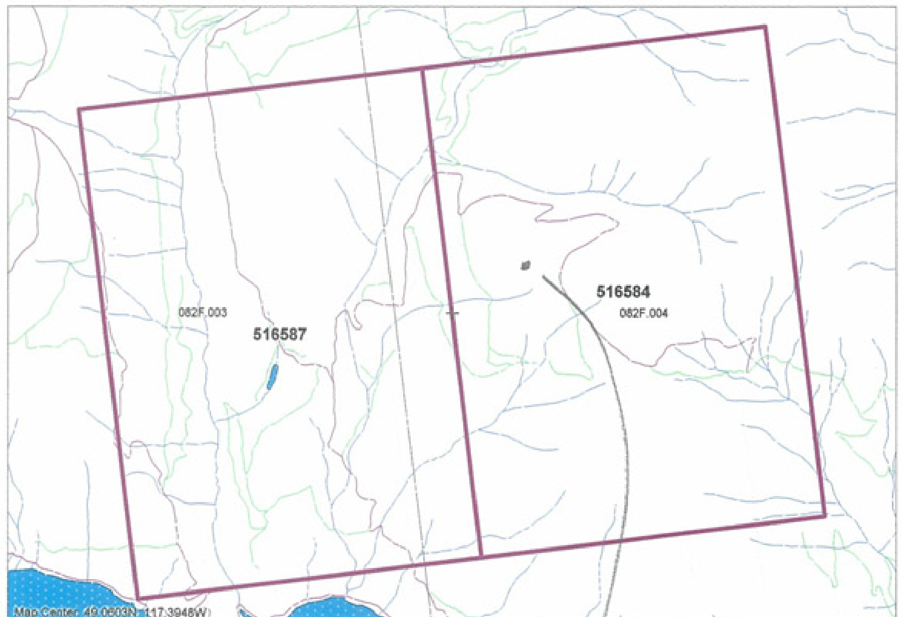
- CLY Group Tenure
- All Mineral Tenures

Topographic Layers

- **Roads 1:20K**
  - Gravel Road
  - Paved Road
  - Rough Road
- **Lakes 1:20K**
- **Rivers 1:20K**

Grid Layers

- **Grid 1:20K - labels**
- **Grid 1:20K - outline**



SCALE 1 : 50,000

5,000 0 5,000 10,000 15,000

FEET

N

BiTel Knoll see Map 1

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Mineral Titles

Mineral Titles Online

Mineral Claim Exploration and Development Work/Expiry Date Change

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Confirmation

Recorder: CLARKE GOLD INC. (210814) **Submitter:** CLARKE GOLD INC. (210814)
Recorded: 2007/OCT/18 **Effective:** 2007/OCT/18
D/E Date: 2007/OCT/18

Your report is due in 90 days. Please attach a copy of this confirmation page to the front of your report.

Event Number: 4175623

Work Start Date: 2006/OCT/20
Work Stop Date: 2007/OCT/17
Total Value of Work: $ 3950.00
Mine Permit No:

Work Type: Technical Work
Technical Items: Geochemical

Summary of the work value:

Tenure #	Claim Name/Property	Issue Date	Good To Date	New Good To Date	# of Days For-ward	Area in Ha	Work Value Due	Sub-mission Fee
516584		2005/jul/10	2009/nov/11	2010/jul/12	243	740.85	$ 3945.80	$ 197.29
516587		2005/jul/10	2009/nov/11	2009/nov/11	0	740.88	$ 0.00	$ 0.00

Total required work value: $ 3945.80

PAC name: Clarke Gold Inc.
Debited PAC amount: $ 0.00
Credited PAC amount: $ 4.20

Total Submission Fees: $ 197.29

Total Paid: $ 197.29

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Mineral Titles Online Report

Click on Tenure Numbers for more information.
Click column headings to sort results.

Download to Excel

Tenure Number	Type	Claim Name	Good Until	Area (ha)
516584	Mineral		20100712	740.853
516587	Mineral		20091111	740.88

Total Area: 1481.733 ha

LIBC Metadata

Mineral Title Online
BC Geological Survey
British Columbia Ministry of Energy, Mines and Petroleum Resources
Last updated in April 2007

1 Summary

Some of the rarest minerals known have been identified in surface samples of the BiTel Knoll quartz veins (Map 1) on claim # 516584 (former name CLY 2): ingodite Bi_2TeS, ikunolite $Bi_4(S,Se)_3$ and unnamed Bi_2Te. These are gold-bearing, and gold-associated, bismuth telluride or sulphotelluride minerals [GBT or Bi-Te minerals]. Other minerals associated with these, less discussed in this report, are native bismuth, native gold, joséite-A Bi_4TeS_2, joséite-B Bi_4Te_2S, hedleyite Bi_7Te_3, bismuthinite and molybdenite. Varying assemblages of these occur in quartz veins in the central part of the CLY Group claims held by Clarke Gold Inc., a private company. The mineral assemblages occur as mm or sub-mm sized silvery-white patches with a brilliantly glistening metallic lustre. They cannot be distinguished by a hand lens.

Significantly Bi-Te minerals characterize *intrusion-hosted* and *(very) proximal* Reduced Intrusion-Related Gold [RIRG] mineralization (Thompson & Newberry 2000, Hart 2005, 2006, 2007). On central CLY they are associated with sparse native gold in large veins near repeated (sheeted) auriferous quartz veins along an intrusive contact with a mid Cretaceous felsic granitoid. This supports applying the RIRG deposit model of Hart (2007). “Due to the large resource and non-refractory nature of the ore, [these] deposits are certainly attractive exploration targets (McCoy 2000).”

CLY Gp is in the extended Boundary–West Kootenay District in south BC, a region that hosts 9 Million oz gold (after Caron 2003, fig. 3).

Electron microprobe analyses of the Au-Bi-Te-S-(Se) -bearing minerals in the BiTel Knoll quartz veins show Bi + trace Pb more abundant than Te + Se + S in their compositional formulae (fig. 8). The minerals are ‘reduced’ phases (Cook et al. 2002) stable with pyrrhotite, arsenopyrite and löllingite[1]. At BiTel Knoll varied Bi-Te mineral assemblages occur generally with native gold, native bismuth and molybdenite. These mineral assemblages formed in the pyrrhotite / magnetite stability fields. In chemical space the concentration of oxygen[2] fO_2 and sulphur fS_2 divides the stability fields of the four common iron sulphide and iron oxide minerals pyrite pyrrhotite hematite and magnetite. That the Bi-Te mineral assemblages are reduced is compatible with their setting in quartz veins in reduced graphitic metasediments near intrusive contacts with reduced ilmenite-bearing felsic granitoids.

Mineralogical research suggests gold-bearing blebs or patches of native bismuth + Bi-Te-S minerals in the BiTel Knoll quartz veins exsolved (crystallized) from gold-bearing Bi + Te (+S) melts. These formed in cooling Bunker Hill Sill felsic granitic magma and solidified at temperatures ~ 277°C (after Ciobanu et al. 2003).

[1] Easily mistaken for arsenopyrite, a common associate which it closely resembles in hand specimen. They are difficult to distinguish; crystal forms, color, luster, streak and fracture are all very similar. Löllingite is somewhat softer and denser. It is steel-gray to silver-white with metallic luster; streak is gray black; hardness 5-5 1/2; specific gravity approx. 7.1-7.5; a basal cleavage is rarely distinct. Habits are brittle with uneven fracture - flat surfaces (not cleavages) fractured in an uneven pattern; massive to granular, a common texture observed in granite and other igneous rock; prismatic. Crystals are usually twinned and commonly striated lengthwise. (from webmineral.com & www.galleries.com/minerals/sulfides/lollingi/lollingi.htm)

[2] *f* is fugacity or standard chemical activity

The mineralogy infers BiTel Knoll Au-Bi-Te mineralization formed early at high temperatures in 'reduced' conditions of very low fS_2. Similar conditions formed the Alaskan Fort Knox [5.4 M. oz] & Pogo [3.51] deposits and the **Petráčkova hora** [1.01] & **Mokrsko** [3.08] deposits SW of Prague in the Czech Republic, discussed below.
In Hart's deposit model (2007) these are all classed as *intrusion-hosted* and *proximal-placed* RIRG gold deposits. Low Sb content of all analyzed bismuthinite grains is additional evidence for early stage mineralization – in Fort Knox later bismuthinite grains are Sb-bearing (McCoy 2000).

On CLY it is hypothesized that along with accumulation of auriferous bismuth-tellurium melts and their subsequent freezing, increased chemical activity of sulphur fS_2 in cooling hydrothermal solutions is a mechanism of gold deposition. This is late stage sulphidation. In CLY, as in both the **Fort Knox and Pogo** (section 16.3) deposits the

> "Bi-Te mineralogy changes in kind with the gold composition and the sulphide-alteration assemblages. In general paragenetically early, high temperature, and very low fS_2 (löllingite–pyrrhotite stable) native bismuth, bismuth telluride and S-poor sulphotelluride assemblages [e.g. early formed ingodite in Eloise Vein, ikunolite in the Blue Quartz Vein] yield to late, lower temperature, higher relative fS_2 (pyrite stable) S-rich sulphotelluride [e.g. joséite-A in both veins], Sb-bearing bismuthinite and sulphosalt assemblages (Rombach et al. 2004)."

Ingodite in Eloise Vein is only the third occurrence in North America. Very comparably of 13 Bi-Te minerals in the Liese Zone of the 3.51 M. oz **Pogo deposit in Alaska** (Rombach et al. 2002, 2004) 7 occur five microscopic mounts of the only eight prepared. Mineralogical research infers conditions of formation are markedly similar. Fig. 7 is a typical hand specimen.

Microprobe analyses show the Bi-Te minerals are near stoichiometric, meaning the mineral formulae have atomic proportions close to integer numbers. Lead is near absent except for ikunolite in the Blue Quartz Vein. Because bismuth contents are high other rare Bi-Te minerals may be expected, e.g. jonassonite $Au(Bi,Pb)_5S_4$ (Paar et al. 2006). This is identified in the **Petráčkova hora** deposit (Zachariáš et al. 2001).

LA-ICP-MS microanalysis shows "Au contents [of four Bi-Te minerals from Eloise Vein North] are higher [than five minerals from Eloise Vein South] by at least one order of magnitude[3]. Gold content in bismuthinite is comparable to that in coexisting tellurides. The highest Au concentrations do not appear to be restricted to one bismuth telluride species in particular. For example, ingodite can be the most and least Au-enriched within individual patches (Cook et al. 2007c)." This is similar to the 'gold nugget effect' at a macroscopic or hand specimen-scale: for CLY on the microscopic scale varying gold is due to 'blebby bismuth' – individual blebs (patches) of Bi-Te melt scavenged varying amounts of gold. These are now patches of native gold, native bismuth, bismuthinite and Bi-Te minerals, notably variably auriferous ingodite.

Ingodite in Eloise Vein South caries submicroscopic 'dissolved' gold to 57 g/t. In some grains this has nucleated forming coronas of native gold at unnamed Bi_2Te / ingodite boundaries. The 'gold corona' texture displaying this is quite pronounced (fig. 8). Thus some ingodite must be early formed at relatively high temperatures. Eloise ingodite is not plumbian ingodite like that found in the Tyrnyauz W + Mo deposit or the Mazowe gold mine.

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[3] this also roughly concurs with Acme Analytical metallic screen fire assay analyses on ~500 g samples, 8.6 vs. 26 g/t Au see table 1

In the Blue Quartz Vein early formed native bismuth is replaced by any of the assemblages: ikunolite / ikunolite + joséite-A / bismuthinite / unnamed Bi_2Te + joséite-B.

"Preserved textures in the ores are interpreted as a primary Au-Bi-Te assemblage that may have been deposited in the molten state and *overprinted* during a later orogenic episode that led to significant recrystallization and redistribution of gold (Kojonen et al. 2007)." Outcrops and hand specimens of BiTel Knoll and other CLY auriferous quartz veins generally have pervasive cm-spaced healed fractures - pages-of-a-book texture (photos fig. 4, 5). This overprinting younger event may be Eocene age. This advantageously may re- concentrate gold and form an economic gold deposit on CLY. Quartz veins are expected to have discrete Au-rich parts (Ciobanu et al. 2006b).

The phrase "gold-telluride mineralization" poorly describes CLY. The occurrences are better termed gold-bearing bismuth telluride mineralization or more briefly gold + bismuth deposits (Ren et al. 2005). Gold-telluride deposits generally formed in the shallow epithermal environment (<5 km); an example is Cripple Ck in Colorado (Cook et al. 2007d). CLY formed at paleodepths of 5 - 8 km, an estimate of the present level now exposed (section 3.11.7 in Howard 2006a).

The 1.03 M. oz **Petráčkova hora deposit in Czech Republic** (Zachariáš et al. 2001, 2006, p.c. 2006) **has Bi-Te mineralogy similar to CLY** with minor ingodite and trace unnamed Bi_2Te. There quartz veins are "characterized by low sulfide content, native gold with auriferous Bi-Te minerals and no visible alteration (Zachariáš et al. 2006)." Petráčkova hora has all criteria of an *Intrusion-hosted* RIRG gold deposit. The Bi:Au ratio of 74.8 to 1, a very high Bi-Au correlation of +0.892 with max 5,625 ppm Bi[4] is much like CLY at ~ 76 to 1, +0.969 and > 2,000 ppm Bi. This is >0.2%, ore grade for bismuth.

BiTel Knoll has Bi-Te mineral assemblages similar to the 3.08 M. oz **Mokrsko deposit**[5]**,** also in the **Czech Republic**. In this RIRG deposit unnamed Bi_2Te is "younger than maldonite or native gold and older than tetradymite, joséite-A, joséite-B or bismuthinite (Zachariáš et al. 2006)." Maldonite or tetradymite is not identified on CLY but microphotos of the Blue Quartz Vein infer unnamed Bi_2Te is younger or the same age as native gold (fig. 8) and older than joséite-A, joséite-B or bismuthinite (fig. 2E in Cook et al. 2007c).

Large gold concentrations forming economic deposits are about as uncommon as the gold-associated Bi-Te minerals in the BiTel Knoll quartz veins on central CLY Gp described herein and by Cook & Ciobanu 2006 in Howard 2006a, Part II. These gold showings are greatly enriched in the uncommon element bismuth and the very rare element tellurium.

Trace ingodite, ikunolite and unnamed Bi_2Te also occur very sparsely in some researched intrusion-linked 'contact metasomatic' polymetallic deposits of any of Sn Mo W Bi Pb Zn Ag worldwide. Intriguingly three of these occurrences are in very large ore bodies (ikunolite in Vysokogorsk tin deposit and Vostok-2 skarn scheelite–sulphide tungsten deposit, ingodite in Tyrnyauz tungsten + molybdenum deposit, all in Russia). Why do these peculiar minerals denote high prospectivity for very large polymetallic mineral deposits, as well as well-endowed gold deposits?

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[4] **11 selected grab samples from J. Zachariáš p.c. 2005 & 2006**
[5] **Bi-Au numerical systematics not available**

It is surprising that these especially rare minerals occur in 5 of the polished sections (Table 1) of the only 8 prepared from surface samples of two partly outcropping quartz veins. The area is generally well covered.

The goal of exploration is to find concentrations of auriferous Bi or Bi-Te minerals on the property; the present mineralogical research confirms these would be gold-bearing. Geochemical surveys would be effective. Further mineralogical research is suggested.

2 Preface

This report follows the previous Assessment Report "Rare to exceptionally rare Gold-associated Bi–Te–S–(Se) ore minerals new to Canada…" by Howard (2006a). That report details preliminary mineralogical research on opaque ore minerals from surface samples of the BiTel Knoll quartz veins on claim # 516584 (formerly CLY 2). This is the best-exposed part of a newly identified, potentially economic, Reduced Intrusion-Related Gold system [RIRG] (Hart 2006, 2007) on part of Clarke Gold Inc.'s CLY Group claims in southernmost British Columbia. The bismuth telluride or sulphotelluride minerals occur in the apparently barren quartz veins as mm or sub-mm sized silvery-white patches with brilliantly glistening metallic lustre. They cannot be distinguished by a hand lens.

In 2005 R. Goldfarb of the USGS in Denver reported the first occurrence in Canada of ingodite in a hand specimen of Eloise Vein South: an X Ray Diffraction pattern gave "a very distinct Bi-Te-S signature with no trace of other species. The XRD analysis indicated ingodite, bismuthinite and …native bismuth. Also, although not 100% certain, there is likely a trace of tetradymite (p.c. Nov. 2005)".

The former report qualitatively identifies three bismuth telluride or sulphotelluride mineral species new to Canada by reflected light ore microscopy and scanning electron microscopy (SEM). Microphotographs show native gold grains with blebs of several of the bismuth (sulpho)telluride minerals - 'Bi-Te minerals'. These occur in various assemblages, also with native bismuth and bismuthinite. Several microphotos show textures that suggest sub-microscopic 'dissolved' gold in ingodite Bi_2TeS grains is released to form native gold particles. Fig. 8A & 7B well display this corona texture.

Importantly Bi-Te minerals "control the distribution and impact on the overall gold balance in … ores (Ciobanu et al. 2006b)". They are direct associates of gold and study of them is quite relevant.

One objective of this report is to quantify the elemental chemistry of the Bi-Te minerals, giving empirical mineral formulae[6]. Bismuth telluride and sulphotelluride minerals are only ideally stoichiometric, meaning the constituent atoms Bi Te and S have integer values in the formulae. Compositions of these rare minerals are compared to other localities, mostly past or presently producing deposits. In Russia some polymetallic deposits with these are very large (sections 15 & 16). This report also notes research work on other occurrences of similar rare Bi-Te mineral assemblages to advance understanding the ore genesis, meaning the conditions of formation of the gold in the BiTel Knoll veins. Certain Bi-Te minerals carry substantial amounts of sub microscopic 'dissolved' gold.

The continuing mineralogical work detailed herein includes electron probe microanalysis and Laser Ablation - Induction Coupled Plasma - Mass Spectrometry [LA-ICP-MS] analysis conducted on polished blocks (polished thick sections or microscope mounts) of opaque ore mineral specimens from claim # 516584. The research paper 'Bi-tellurides in gold veins, BiTel Knoll (CLY prospect), southeastern British Columbia, Canada' by N.J. Cook, C.L. Ciobanu & W. Howard published Aug. 2007 by the Geological Survey of Finland [GTK] details this work. Part II of this report includes this and a preliminary Nov. 2006 letter 'Short report on electron probe microanalysis on samples'.

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[6] **the minerals include other elements in their formulae, notably Pb Cd & Sb**

Part III includes a short abstract 'Telluride Assemblages in a Reduced Intrusion-Related Gold (RIRG) deposit, CLY Group Prospect, southeastern British Columbia Canada', paper #72-5 presented at the 2007 Geological Society of America [GSA] Denver Annual Meeting October 28–31 2007 (Howard et al. 2007). This was part of a topical session[7] 'Au-Ag-Te Se Deposits and other Precious Metal Deposits' sponsored by the Society of Economic Geologists and the International Geological Correlation Programme IGCP - 486.

The reader might note that work on two sections of sample 0414 from the Blue Quartz Vein is not itemized in Appendix 3, even though it is from claim 516584. Sections labelled • are very similar in 2008 reports describing 2007 work.

2.1 Bismuth •

Bismuth is a silver-gray, reddish-tinged, brittle and heavy metallic element atomic number 83. It is usually produced as a by-product of processing of lead ores. Bismuth melts at 271.4 °C and unusually for a liquid expands on solidifying. "Bismuth, at an estimated **8 parts per billion** by weight, is the 69th element in order of abundance in the Earth's crust, **about twice as abundant as gold**. World reserves of bismuth are usually based on bismuth content of lead resources because bismuth production is most often a by-product of processing lead ores; in China, bismuth production is a by-product of tungsten and other metal ore processing. Bismuth minerals rarely occur in sufficient quantities to be mined as principal products; the Tasna Mine in Bolivia and a mine in China are the only mines that produced bismuth from a bismuth ore. ... Several bismuth-containing deposits are in varying stages of mining feasibility review. These polymetallic deposits include NICO in Canada, Nui Phao in Vietnam, and Bonfim in Brazil (USGS 2006)." Its insoluble compounds are non-poisonous and used in medicine.

2.2 Tellurium •

Tellurium was discovered in gold ores in Transylvania Romania in 1782. It is a rare element, 73rd in order of crustal abundance, **1 to 2 parts per billion.** "Estimates of the mean Te content of the Earth's crust range from 0.36 to 10 ppb, with 1 to 2 ppb [0.001-0.002 ppm] being the most commonly cited estimates of mean content (see refs in Hein et al. 2003, Brown et al. 2000)." "Tellurium is enriched more than any other element (up to about 50,000 times) relative to its Earth's crustal mean …" in ocean floor Fe-Mn crusts (Hein et al. 2003). Tellurium is about as rare as platinum and **about four times rarer than gold**.

Crystalline tellurium is silvery-white with a metallic luster but industrial tellurium is usually a dark gray powder. It is brittle and a p-type semiconductor. Many telluride-bearing minerals occur with sulfides of the chalcophile metals Cu Ag Au Zn Cd Hg Fe Co Ni Pb As & Bi. The mineral native tellurium is very rare. Tellurium is obtained from anode slime as a byproduct of electrolytic copper refining (Klapotke & Crawford 2004). It has an affinity to gold in nature as shown by the existence of several gold telluride minerals. Tellurium and bismuth are specific geochemical pathfinders for gold concentrations (Boyle 1979).

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[7] **"…papers dealing with the geology, mineralogy and/or geochemistry of precious metal telluride and/or selenide deposits, which are among the largest sources of gold and silver in the world."**

3 Introduction & Rationale

This report is lengthy as it is comprehensive. Following are reasons to use state-of-the-art mineralogical research to objectively characterize the BiTel Knoll Au(Ag)-Bi-Te-Mo-W bearing quartz veins on central CLY Group (Map 1, Howard 2006a, 2006b, 2005). These and other occurrences on CLY are part of a new found *intrusion hosted* to *very proximal* sub-type of RIRG system. “Due to both the large resource and the non-refractory nature of the ore, these are certainly attractive targets (McCoy 2000)”. A concentration of auriferous Bi-Te bearing quartz veins on CLY may be a significant gold resource in a historic district of known production and reserves (fig. 3):

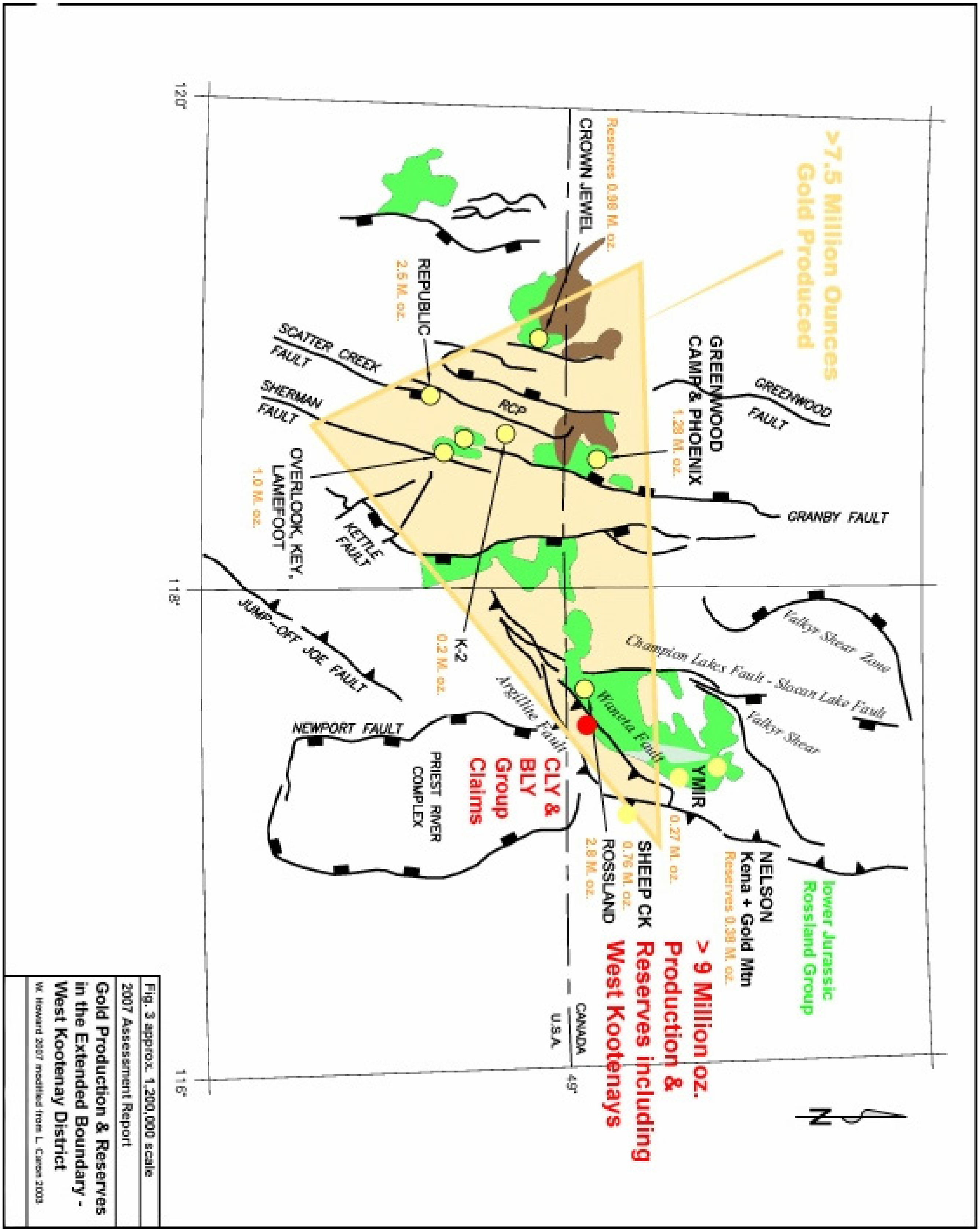

Fig. 3 approx. 1,200,000 scale
2007 Assessment Report
Gold Production & Reserves in the Extended Boundary - West Kootenay District
W. Howard 2007 modified from L. Caron 2003

3.1 Regional Setting in an area with 9 Million ounce gold •

CLY property is an exploration stage prospect, with no known mineral reserves. It is located "within the highly mineralized Boundary District. The Boundary District includes the Republic, Belcher, Rossland and Greenwood Mining Camps in southern British Columbia and northern Washington State, and has total past production exceeding 7.5 Million ounces of gold (Caron 2003)". Fig. 3 extends the gold mineralized area slightly N & E to include West Kootenays production and reserves: Sheep Ck camp produced 0.76 M. oz and Ymir 0.27. Near Nelson the Kena and Gold Mtn deposits (Logan 2003, Logan et al. 2003) together have known reserves 0.38 M. oz (Giroux & Dandy 2004). Conservatively the extended Boundary–West Kootenay District hosts 9 Million oz gold (fig. 3).

"Important gold deposits within the Boundary District can be broadly classified into six deposit types, including skarns, epithermal and mesothermal veins, mineralization associated with Jurassic alkalic intrusives, mineralization associated with serpentinite, and gold-bearing volcanogenic magnetite-sulfide deposits (Caron 2003)."

3.2 CLY - a newly identified Au-Bi-Te-W-Mo bearing, deeply formed Reduced Intrusion Related Gold [RIRG] system •

CLY is an example of a mineral deposit type presently unknown in the extended Boundary–West Kootenay District (fig. 3). It is a new discovery of possibly economic Reduced Intrusion-Related Gold [RIRG] mineralization (Howard 2007). A very good visual summary of this deposit model is the 2 page poster 'Tombstone Gold Belt' by Hart 2006. Hart 2007 is a very thorough current review. Cathro & Lefebure (2000) review some RIRG occurrences genetically related to the mid Cretaceous Bayonne suite in the West Kootenay region. Plotting the analytical results (the geochemistry) of 19 showings on a Au vs. Bi graph shows the central CLY area hosts the exemplar (the prime or best example) of a Au-Bi-Te -bearing, deeply formed RIRG system (see graph Howard 2006b p.82 or Howard 2007). The advantage of this approach is that it is entirely objective (that is rational and arithmetical) in judging the economic potential of a RIRG system (Flanigan et al. 2000) and not subject to personal opinion.

3.3 Synopsis of the RIRG deposit model and key criteria of this present on CLY •

In the most recent review of this mineral deposit model C. Hart (2007) writes

> “Areas of High Potential in Canada
>
> …In southeastern British Columbia, most effort has been directed towards large solitary veins, but potential also exists in targeting bulk tonnage deposits in pluton cupolas. The greatest potential in BC exists with the Bayonne plutonic suites… [in] smaller stocks or apophyses…”

Multiple criteria are used for identification of this deposit type (Hart 2005, 2006, 2007, Lefebure & Hart 2005). “There is controversy about the most appropriate model for many Au deposits (Hart 2007)”. Confusingly some criteria (meaning key points or attributes) of this ore deposit model are subjective, that is they depend on the observer’s personal field experience and knowledge. On central CLY Group the presence of both

[1] specific, rare auriferous bismuth tellurides (Thompson & Newberry 2000) with high-fineness, micron to sub mm-sized particulate gold including gold-associated Bi-Te minerals (very rare ingodite Bi_2TeS for one), and
[2] the excellent triple correlation (co-association) of Au-Bi-Te. Geochemical analyses of mineralized rocks from over 13 showings have these elements strongly co-varying (Howard 2006c). In support of this mathematical relationship very fine grained Bi-Te minerals are intimately associated as blebs / patches or irregular laminae in the quartz veins (fig. 4, fig. 5);

are considered two of several key criteria of the RIRG mineral deposit model present on CLY. These objectively confirm *intrusion-hosted* to *very proximal-placed* RIRG on CLY. Note “…a Bi-Au association is not reported from orogenic gold deposits. …low fs_2 minerals [native bismuth, bismuthinite and bismuth tellurides] are rare to absent in classic orogenic gold deposits (Thompson & Newberry 2000)”.

In RIRG systems “*Intrusion-hosted* ores are dominated by a Au-W-Bi-Te signature with Au correlating well with Bi and Te, but not at all with W (Hart 2007, fig. 11)”. The first two have pronounced correlations on CLY; the W-Au association has not been investigated.

CLY occurrences can also be termed gold-bearing bismuth telluride mineralization or more briefly gold + bismuth deposits (Ren et al. 2005). Previous to development of the RIRG model gold deposits were known to be associated with Bi-Te minerals and reduced granitoids. For example gold-skarn and gold-greisen deposits in northeast Russia have native gold associated with native bismuth, bismuthinite, ikunolite, tellurides and sulphotellurides (Gamyanin et al. 1998). These are genetically related to late Mesozoic granitoids; like in the CLY 2 occurrences the native gold is tiny, “90% less than 0.1 mm. Its fineness varies (400-950 fine). The distribution of gold in ores is irregular, often a bonanza one in the lode type. Geological, mineralogical-geochemical, and P, T geochemical data show the genetic relation … with I-type granitoids of the ilmenite and magnetite series in collisional and marginal-continental magmatic arc environments (op. cit.).”

3.4 Bismuth telluride minerals indicate local conditions of ore formation in the central CLY area

The bismuth telluride minerals in the examined showings occur as trace minerals associated with particulate native gold. Specific minerals can be expected if ore forming conditions are known: "…telluride speciation can be readily predicted from the local redox environment at the time of crystallisation, as reflected by the observed host minerals. Modelling of trace mineralogy can therefore assist in identifying formation conditions and deposition during processes characterised by abrupt changes in physical-chemical fluid parameters (Ciobanu & Cook 2003)". Active changes are expected in the hydrothermal fluids that deposit gold and associated minerals.

Knowing what minerals are present is useful as "Telluride speciation[8] respects regional and temporal trends … [atomic] Bi / (Te + S + Se) ratios of bismuth tellurides-selenides indicate reduced (>1) or oxidised (<1) fluids (Ciobanu et al. 2004)." Thus understanding ore formation conditions can allow for better exploration practise. This is useful both on regional scales considering the entire Boundary–West Kootenay District and exploring at a local property-scale.

Telluride mineralogy is a practical tool in understanding gold deposits (Cook & Ciobanu 2003). Confirming its usefulness, mineralogic observations suggested an overprinting deformation before it was seen by the main researchers in the field in Oct. 2007: auriferous veins generally have pervasive cm-spaced healed fractures like pages-of-a-book texture (in outcrop, fig. 4 photo of Adit 1 Gallery Quartz Vein, fig. 5 the multiply fractured Blue Quartz Vein). This is entirely consistent with latter, overprinting Eocene extensional normal faulting described in the region. "The highly variable gold contents in the Bi-tellurides from one location to another along Eloise Vein, as well as between patches in the same sample, indicates the impact of the overprinting event that assisted Au redistribution and is beneficial for nucleation of native Au (Cook et al. 2007c)." Fig. 7 shows these fractures in a hand sample of Eloise Vein North.

Nekrasov 1996 p. 186 finds "Phase relations among [Pb-Sb-Zn] sulphosalts themselves and also with gold, bismuthinite, maldonite, native bismuth and galena in such cases are extremely complex…"
Very low base metal content in the mineral assemblages of the BiTel Knoll veins simplifies understanding of their formation conditions.

[8] The telluride or selenide mineral present

Fig. 4 Outcrop photo of Adit 1 Gallery Quartz Vein with pages-of-a book texture. View to N of the dug out north (left) wall. Note blue-grey Bi-Te laminae trend to the middle of the left side of the photo (blue grey lines). This differs from the strike of the silicified near-vertical cm-spaced fractures (orange lines). Both do not follow the vein orientation 031 46 SE. Eloise Vein has this same Set 2 orientation. It is about on trend ~ 180 m NE. A conservative estimate of the mean gold accumulation value of the 1.0-1.35 m thick Adit 1 Gallery Quartz Vein is 5.1 g/t * m (Howard 2006b). UTM 471,490 mE / 5,434,280 mN

3.5 Process metallurgy that could recover gold is economical •

Aside from identifying which more abundant bismuth telluride mineral(s) are associated with gold, the mineral assemblages (parageneses) present importantly affect methods used to recover gold if an economic ore body is outlined by drilling on CLY. McCoy et al. 2002 “suggest that a high Bi-Au correlation, together with a low arsenic content, may be predictive of ore that is more easily beneficiated.”

The mineral phases present have an effect on the processing and extraction procedures of metals and ultimately on the economic viability of the deposit. The ore minerals, their physical properties and inter-granular relationships and grain size play an important role in whether a deposit would be worth mining. All these factors influence the ease of liberation of ore minerals from gangue and / or other ore minerals.

This is ‘process metallurgy’ or ‘ore beneficiation’. Thus before mining the economics of extracting gold from CLY can be appraised.

It is favourable: with fine grinding of mineralized quartz or skarn some native gold could be recovered by simple gravity separation. CLY occurrences have ‘free-milling’ gold ore. The mineralogy, the high Bi-Au correlation and bismuthian (bismuth-rich) geochemistry (Howard 2006b) indicates non-refractory gold ore on CLY, amenable to low-cost extraction.

4 Work Performed

Table 1 Microanalytical work by two methods on polished microscopic mounts prepared from three occurrences on claim #516584, CLY Group

				Wet chemical analyses by Acme Analytical Labs Vancouver				
Occurrence, sample ID, [# of microscopic mounts analyzed]	**>electron probe micro-analysis**	**LA-ICP-MS microanalysis 11 isotopes monitored in these minerals:**	**Total ablated (analyzed) spots:**	**Au by ICP-MS, Fire Assay**	**Bi**	**Te**	**Pb**	**Fineness**
***Blue Quartz Vein 0414 [2]**	**formulae for 5 minerals**	**nil**	**nil**	**7.636 ¤8.65**	**478**	**23.2**	**13.0**	**880**
Eloise Vein South 0441a & 0441b [2]	**formulae for 6 minerals**	**bismuthinite ingodite joséite-B & -A**	**11 2 2**	**7.969 ◙8.17**	**564**	**33.0**	**4.8**	**851**
'Eloise' meaning Eloise Vein North 0412 [1]	**formulae for 5 minerals**	**unnamed Bi_2Te ingodite joséite-B & -A**	**4 2 2**	**23.095 †27.03**	**1,601**	**95.4**	**84.1**	**867**

*Work on sample 0414 from the Blue Quartz Vein is not itemized in Appendix 3, even though it is from claim 516584. Formerly the site was thought to be on the Mormon Girl Crown Grant.
> in addition, fineness of native gold grains in all three veins, expressed as values of the atomic ratios of Au & Ag
¤ Fire Assay & metallic screen procedure on 490 g sample
◙ FA on 2 assay ton sample = 2 * 29 1/6 g = 58.333 g sample
† FA & metallic screen procedure on 500 g

The electron probe microanalysis was carried out on a CAMECA SX-51 instrument at Adelaide Microscopy, Adelaide, South Australia at an operating voltage of 20 kV and beam current of 20 microamperes. The physical address is Adelaide Microscopy Basement Level Medical School North Building The University of Adelaide, Frome Road Adelaide SA 5005. The postal address is Adelaide Microscopy The University of Adelaide Adelaide South Australia 5005. 16 mineral formulae were obtained, 11 on claim #516584

Laser Ablation - Induction Coupled Plasma - Mass Spectrometry 'LA-ICP-MS' analysis was carried out using the Agilent HP4500 Quadripole ICP-MS instrument at CODES, University of Tasmania in Australia with operating conditions as noted in the report in Part II. 23 spots on different mineral grains (table) from claim #516584 were ablated. Total analysis time was 90 seconds [s]: (30s pre-ablation and 60s ablation time). Calibration was performed on a doped pyrite standard; pure Bi served as the internal standard for the tellurides and bismuthinite. Detection limits for gold were 0.01 to 0.05 ppm. The physical address is CODES, University of Tasmania, Hobart Campus, Geography-Geology Building, room 356 and postal address CODES, Private Bag 79, Hobart Tasmania 7001 Australia.

Element values are Acme Analytical Vancouver ultra trace ICP-MS geochem analyses from Howard 2006b. Gold is repeated by Fire Assay and the metallic screen procedure using two-mesh sizes (in Howard 2005). For all As < 2.2 ppm.

5 Claims •

New Tenure claims # 516584 (formerly named CLY 2) and # 516587 (formerly CLY 1) are located in Nelson Mining Division, southeastern British Columbia in the southern Bonnington Mtns (Index map fig. 2A). These surround two 'freehold', fee-simple Crown Granted claims Bunker Hill Lot 2939 and Mormon Girl Lot 1949 (Tables A & B in Appendix 2, fig. 2B Claim map, Map 1). In this report 'CLY Group' refers to all. Claims are 100% owned by Clarke Gold Inc.

6 Location •

CLY Group is approximately 16 km southwest of the town of Salmo and 6 km north of the Canada-US border. CLY 1 & CLY 2, 35 cell units each, surround two Crown Granted claims Bunker Hill Lot 2939 and Mormon Girl Lot 1949. The National Topographic System map is NTS 082F03 W ½, Salmo sheet. The 1:20,000 BGS sheets are 082F.004 and 082F.003 (fig. 2B). CLY Group's centre at a position just south of the Lefevre Skarn workings is latitude 49° 03' 36'' longitude 117° 23' 15" or NAD 83 UTM Zone 11 471,620 mE / 5,434,080 mN. Sample site 0441 of Eloise Vein North is at UTM 471,652 mE / 5,434,400 mN (Map 1).

Adjusting the site of the BiTel Knoll occurrences with new, more precise GPS readings locates most all the sampled vein exposures on tenure claim # 516584, formerly CLY 2 (Map 1). Thus it is very conservative in the previous report and the present one not to include costs of microanalytical work on polished sections from the Blue Quartz Vein, even though the sample is on new tenure claim # 516584 (CLY 2), see Map 1. BiTel Knoll is part of the well mineralized central vicinity referred to as the Bunker Hill mine - central CLY area.

7 Software used •

This report is written using Microsoft® Word 2002 SP3 software. Map 1 was composed with MapInfo Professional Software V4.1.2 1997 using the software add-on Discover V3.0 ©Encom Technology Pty. Limited Australia (1999). Inserted maps figs. 2A & 2B were from ARIS MapBuilder at 'The MapPlace' online. The triangular plot fig. 8 was made by CSpace (Composition Space) V. 1.0 "non-commercial freeware", software © Djinn Works 2000 (Torres-Roldan et al. 2000). For the LA-ICP-MS analyses MEOLaser 213 software was used.

8 Access •

Road access to BiTel Knoll on CLY 2 is by driving S of Salmo on Hiway #6 to the Nelway customs station, then W (right turn) on the paved, then gravel, Pend d'Oreille Road. Continue north and north-westerly (right) for approx. 4 km uphill on the 4x4 Limpid Creek Forest Service Road [LCFS Rd] to just before a logging landing. The LCFS Rd is maintained by the Ministry of Forests (road is in purple on fig. 2B).

After parking at a side pull out at UTM 471,910 mE / 5,434,450 mN access to the BiTel Knoll veins is by a short hike due W downhill (inset map on Map 1) then slightly uphill to the height of land. After about 200 m the land rises near the W intrusive contact of the granitic Bunker Hill Sill. On the Knoll hiking is easy as the under brush is comparatively light.

9 Physiography, vegetation, exposure and climate •

The CLY property is in the rounded southern Bonnington Mountains north of the Pend d'Oreille River valley. The Pend d'Oreille River (fig. 3, fig. 2B) is a reservoir for hydroelectric power generation with two major power stations south of Trail. Generally the relief is moderate ranging from 600 to 1,700 meters above sea level. Areas have recently been clear cut including parts of the two Crown Grants. The east edge of the BiTel Knoll site on CLY 2 is a cut block boundary. Forest cover is merchantable Douglas fir and lodge pole pine with some stands of mature cedar. Some slopes have dense alder brush growing downhill, bushy and almost impassable.

The forest is thick second growth forest, with dense undergrowth. Alders grow thickly on old logging road beds. GPS equipment may not read under thick forest cover. Recent logging benefits mineral exploration as foot and road access is considerably easier.

Glacial drift especially ablation till covers most all; in valleys there are bedded glaciofluvial deposits[9]. Thin soil is well development on this. Rock exposure is better than usual about BiTel Knoll (about 20%) as it is a height of land and well drained due to the resistant hornfels bedrock. All is drift covered tens of meters away.

The climate is moderately dry with hot summers and only minor rainfall. The property is generally snow free from mid April to early November.

[9] **Material moved by glaciers and subsequently sorted and deposited by melt water streams. Glaciofluvial deposits are stratified - outwash plains, deltas, kame eskers, and kame terraces.**

10 Brief economic assessment and property history •

Assessment reports investigating the gold potential are by Kaufman 1984 #12,758, Pratico 1999; Howard 2000 #26,159; Kennedy 2003 #27,231; Ray 2004 #27,513; Howard 2005 #27,893 and Howard 2006a & 2006b. In 2007 an integrated exploration program of magnetic and VLF-EM ground geophysics and soil, rock & drainage geochemistry was conducted. This was modified after L. Caron's 2007 recommendations. In addition, irrespective of the surface surveys, Caron recommends 1,700 m of large-diameter core drilling in about 6 targets. Three short holes drilled underground in 1936 (Waneta Gold Mines Ltd. 1936a & 1936b, Minister of Mines 1936) were misdirected.

Minor production of silver & gold is recorded (tabled in Howard 2005). The ore was from pyrite-marcasite + pyrrhotite + trace galena + gold ± cosalite -bearing quartz veins (Howard 2006a Part II) mined from Adit 1 & Adit 2 on the Mormon Girl Crown Grant (locales on inset of Map 1). Recovery in 6 years from 1933 to 1942 was 3,332 grams gold = 3.33 kg and 9,639 g silver from 309 tonnes at 8.479 g/t Au, 24.526 g/t Ag [in imperial units 107.1 oz Au and 309.8 oz silver from 356.5 tons = 0.30 oz/ton Au and 0.87 oz/ton Ag]. This corrects Bunker Hill MINFILE 082FSW002 by referring to the original Annual Reports.

Briefly CLY Group hosts various types (or styles) of variably placed, Au(Ag)-Bi-Te-Mo-W ± As bearing mineralization and is a reduced Intrusion related gold [RIRG] system (Howard 2005). More than fifteen gold showings are known. These are spatially and likely genetically related to the Bunker Hill Sill, a Bayonne magmatic suite felsic granitoid (Logan 2000, 2001, 2002a, 2002b), considered mid Cretaceous age(?). Confusingly this mineral deposit model has also been called 'gold porphyry' (Bakke 1995, Hitchens & Orssich 1995) 'Plutonic-Related Gold' (McCoy et al. 1997) or 'Plutonic-Related Au Quartz Veins & Veinlets' (Lefebure & Hart 2005 type L-02). The designation 'Intrusion-related Au-(Ag-Cu) pyrrhotite veins' type 'I02' (Alldrick 1996) may be applicable but it is little used and refers to only one mineralization style in RIRG *systems*.
Hart (2005) reviews the nomenclature. RIRG deposits are quite distinct from oxidized porphyry copper ± gold deposits (Hart 2007 schematic plot fig. 14) like the Katie alkalic porphyry copper ± gold deposit just north. These are also intrusion related.

> ★"The reduced IRGS model is among the best classified of intrusion-related models and is easily differentiated from other gold deposit classifications by a set of distinguishing characteristics…" (Hart 2005)

Targets considered most prospective are clusters of *intrusion hosted to proximal placed* sheeted quartz veins derived from magmatic-sourced Bunker Hill Sill granitoids. This sub-type of RIRG system can form high value but low grade deposits ~1 g/t gold with large tonnages.

MINFILE 082FSW002 names all mineralization collectively as 'Bunker Hill'. Howard (2005) details the development and exploration history of the Bunker Hill mine and CLY Group. Clarke Gold Inc. is the current operator and owns 100% of CLY Group comprising CLY 1, CLY 2 and the two Crown Grants subject to a low NSR royalty. Exploratory drilling is contemplated on several identified targets (Howard 2006c, Caron 2007).

11 Geology at Regional to District Scale •

CLY prospect covers a compressional fold and thrust belt, thereafter faulted and intruded by at least two plutonic suites. It is within the Omineca Belt, the region of overlap between volcanic and sedimentary strata of the Intermontane Belt to the west and sedimentary rocks of the Foreland Belt, ancestral North America to the east. The tectonic divisions Quesnellia (also named Quesnel), Slide Mountain and Kootenay Terranes are arranged from NW to SE on the property. Corresponding litho units are the well-mineralized Rossland Group Elise & Hall Formations (Höy & Andrew 1990a, 1990b, Höy & Dunne 2001), the Cs Unit of H. Little (1965, 1985) divided into the Charbonneau Ck Assemblage & Harcourt Ck Assemblage [HCA] by Einarsen (1995) and the unconformably underlying Cambrian age Lardeau Group Index Formation. This contact is not known on the property.

Einarsen (1995) describes regional stratigraphy, district scale structural assemblages and provides a structural-tectonic synthesis. In summary rocks on CLY become older to the SE, in order of the above named terranes. This is also the proposed direction of aging of the three HCA Units (Howard 2000, 2005).

The colour map of Höy & Dunne 1999 requires updating over the prospect area. H. Little’s 1960 map outlines larger areas of drift; this is the best map of the project area.

Howard (2005) details the nature of the layered rocks and this is not repeated herein. North of CLY Gp Höy & Andrew (1990a, 1990b) detail polyphase structures in the Mount Kelly - Hellroaring Creek Map Area. They mapped only to Swift Ck headwaters several km north of central CLY area.

12 Local Scale Geology (1) Layered rocks •

Uncertainly correlated metasediments and metavolcanics host the mineralized showings in the Bunker Hill mine - central CLY area. H. Little (1965, 1985) names these layered rocks Carboniferous sediments the 'Cs Unit'. Ages are now ascribed to a longer range.

J. Einarsen from district-scale structural-geologic mapping divides the Cs Unit into two structural divisions, the Harcourt Ck Assemblage [HCA] & Charbonneau Ck Assemblage [CCA] (1995). These structural divisions are fault-bounded lithologic assemblages, not stratigraphic formations. The *Tillicum Ck Fault* 340 m NW of BiTel Knoll separates the structurally higher CCA from the underlying HCA to the east and southeast. CCA exposures are unknown in the Bunker Hill mine - central CLY area.

Howard (2000) subdivides the HCA into three recognizable lithologic assemblages or Units. These are only defined W of the Bunker Hill Sill. The HCA Units are thought to be internally fault-bounded and thus likely discontinuous along trend. Country rock underlying BiTel Knoll is argillaceous metaquartzite of the HCA Quartzite + Tuff Unit, the structurally lowest tripartite division. It is considered the oldest. "In the Bunker Hill mine [central] area rocks strike mainly N to NNE and dip mostly E to ESE (Ray 2004)". See Howard (2000) for description of the HCA Units; this is not repeated herein.

In the region Eocene age, extensional high angle NNE to NNW -striking normal faults offset and transect earlier folds and thrusts but these are not firmly identified on the property. Lensing and fracturing of the BiTel Knoll quartz veins as shown in figs. 4 & 5 and more importantly nucleation of gold grains in the BI-Te assemblages may be due to this Eocene orogenic event (section 16.7).

13 Local Scale Geology (2) Intruding Bunker Hill Sill granitoids •

H. Little (1965) and M. Kaufman (1984) map a sill or dyke-like body of granite in the central part of CLY Group. This felsic granitoid is named the 'Bunker Hill Sill.' It intrudes the HCA country rocks close to the investigated showings. It is considered an outlier of the Wallack Ck stock[10]. The Bunker Hill Sill is at least 2.5 km long N-S and 0.5 - 1.5 km wide; it is named a sill after its elongate shape (though this pluton may be dyke-form). Two 'granite dykes' mapped underground in the Bunker Hill Mine (Minister of Mines 1934 p. E24, 1936 p. E18) are probably related.

13.1 Description of Bunker Hill Sill granitoids •

Bunker Hill Sill outcrops are mafic-poor, off white to speckled grey, medium to very coarse crystalline biotite ± hornblende felsic (leucocratic) granitoids. They are variably feldspar porphyritic and generally always hydrothermally altered. Ray (2004) notes "sporadic sericite and hornblende" and trace disseminated pyrite and lesser pyrrhotite (?). Uncommonly muscovite may be primary; detailed petrographic descriptions are lacking.

Bunker Hill Sill granitoids have variable grain sizes, textures and mafic mineral contents, evidence for fractionation (igneous differentiation). More felsic phases may be younger. Magnetic susceptibility measurements with a hand held Kappa meter (ZH Instruments Brno, Czech Republic) are very low (R.G. Anderson, p.c. Sept. 19 2006). This indicates the Bunker Hill Sill is a gold-favourable, 'reduced' ilmenite- or titanite-bearing granitoid.

Importantly in some 'reduced' ilmenite-bearing granitic melts

> "gold and other metals become enriched during fractional crystallization … no gold-enriched precursor melt is required [to] enrich gold concentration to economic levels (Mustard et al. 2006)."

Examples are the Vogl stock of the Fort Knox Alaska deposit (McCoy et al. 1997) and the Stanthorpe leucocratic monzogranite of the Timbarra NSW Australia deposit (Mustard 2001). This model of gold concentration is much like the 'liquid bismuth gold collector' model of Douglas et al. 2000, Cook et al. 2002, Ciobanu et al. 2003, Ciobanu et al. 2006a & 2006b and Tooth et al. 2007.

It is easy to visual this process. Blobs of metallic bismuth ± incorporated tellurium would stay liquid to low temperatures in a granitic magma body. This fluid dissolves any gold present – sequestering or scavenging it from dilute hydrothermal solutions – on moving about any irregularities in the networks of silicate crystals, that is the meshes of nearly-solidified rock. Bismuth is about 70 times as abundant as gold in central CLY 2 claim mineralization (Howard 2006b), in ample amounts for this perceived process "the liquid bismuth gold collector model" of Douglas et al. 2000, also explained by Ciobanu et al. 2005, researched by Tooth et al. 2007.

[10] Howard (2000) mistakenly refers to the Bunker Hill Sill as the Wallack Ck granitic pluton or granitoid.

14 General Economic Assessment: a little explored Reduced Intrusion Related Gold [RIRG] System

14.1 Mineral Deposits in the Region •

The region is exceptionally well mineralized. BC GSB Bulletin 109 outlines features of the many past producing polymetallic mineral deposits (Hoy & Dunne 2001).

Near Nelson the Sultan Minerals Inc. **Kena and Gold Mountain Zones are two significant porphyry Au-Cu deposits** (Höy & Dunne 2001, Logan 2003, Logan et al. 2003) with gold reserves (Giroux & Dandy 2004):

Kena Gold Zone
  Measured plus Indicated 6,330,000 tonnes at 0.969 g/t (197,000 ounces gold)
  Inferred 1,440,000 tonnes at 1.216 g/t (56,000 ounces gold)
Gold Mountain Zone
  Measured plus Indicated 5,490,000 tonnes at 1.040 g/t (184,000 ounces gold)
  Inferred 10,710,000 tonnes at 0.967 g/t (333,000 ounces gold)

Together the resource is 0.381 or ~0.4 M. ounces. Sultan plans to drill at depth the extension of the Gold Mountain Zone (Nov. 7 2007 news release).

On the **Jersey-Emerald property** of Sultan Minerals Inc. 13 km E of CLY Gp centre the Tungsten and Molybdenum Zones have advanced exploration. “Within the tungsten zones, using a cut-off grade of 0.15% WO_3, the results show 2.51 M. tons averaging 0.37% WO_3 classed as measured plus indicated, with an additional 1.21 M. tons averaging 0.40% WO_3 classed as inferred. In the molybdenum zone the results at a 0.05% Mo cut-off show 28,000 tons averaging 0.098% Mo classed as indicated, with a further 481,000 tons averaging 0.103% Mo classed as inferred” (Giroux & Grunenberg 2006). There is “excellent exploration potential in both the historically mined areas and the surrounding terrain. A preliminary scoping study by Wardrop Engineering Inc. of the Invincible and Dodger Tungsten Zones “has identified a potentially commercial operation at current prices” (May 23 2007 Sultan Minerals Inc. news release).

14.2 Mineral Deposits in the District •

Noranda Exploration Company Ltd. & Yellowjack Resources Ltd. extensively drilled **Katie** an alkalic copper-gold porphyry 10 km northeast of CLY Gp in the 1990’s (MINFILE 082FSW290, Naciuk & Hawkins 1995). Katie has a ‘geological potential’ of 200 M tonnes at estimated 0.17% Cu & 0.17 g/t Au (Schroeter et al. 2004). On July 21, 2006 Valterra Resource Corp. of Vancouver acquired the option to earn up to a 100% interest in Katie MINFILE 082FSW290 and Swift 082FSW215. In Fall 2007 Phase I exploration estimated at $450,000 may proceed with geophysical surveys and approximate 1,200 m of drilling.

Just 5 km S the former Reeves MacDonald zinc-lead-silver-cadmium mine is a “Kootenay Arc-type sedimentary exhalative deposit hosted by a dolomitized envelope of Reeves Member limestone of the Lower Cambrian Laib Formation. Production from the various ore bodies for the period 1949 to 1971 inclusive totalled 5,848,021 tonnes. From this 19,842 kg of silver, 203,616,006 kg of zinc, 57,692,784 kg of lead, 1,215,665 kg of cadmium and 27,584 kg of copper were recovered

(MINFILE 082FSW026).” ReMac Zinc Corp. (TSX-V ‘RMZ’) plans to complete a 13,000 m drill program in 2008 targeting the depth and strike extensions of the Reeves Limestone.

14.3 Property scale metallogeny •

14.3.1 CLY: *intrusion-hosted* and *proximal* placed RIRG showings and comparable deposits worldwide •

Lefebure et al. (1999 map), Lefebure & Cathro (1999) and Cathro & Lefebure (2000) class the Bunker Hill quartz veins as Intrusion-related gold–tungsten–bismuth mineralization. Logan describes Intrusion-related occurrences in BC (2000, 2001, 2002a, 2002b).

CLY Group’s tectonic - geologic - structural setting, opaque ore mineralogy and geochemistry is much the **same as mid Cretaceous age *intrusion-hosted and / or proximal* placed, reduced Intrusion related gold [RIRG] deposit systems in the Tintina Gold Province in Alaska and Yukon.** Specifically Pogo, 4021 Prospect, Fort Knox, Dublin Gulch, Scheelite Dome (only a small part) and Shotgun are well explored or developed comparable examples (McCoy et al. 1997, Maloof et al. 2001, Rombach, et al. 2002, Mair et al. 2006, Howard 2006b see fig. 22 & Table 9). The Bunker Hill Sill is thought petrogenetically comparable to a Tombstone Gold Belt Mayo Suite intrusion - “… characteristically gold-enriched, with associated As, Bi, Te and W (Hart et al. 2005)”.

RIRG deposits occur sparsely worldwide (Baker et al. 2005). In NSW Australia the Timbarra deposit is entirely *intrusion (granite) -hosted*. Similar well researched deposits in Europe known to the writer are Mokrsko [3.08 M. oz][11] and Petráčkova hora [1.03 M. oz] both in the Czech Republic (Morávek et al. 1989, Hollister 1992, Morávek 1996, Zachariáš et al. 2001 & 2006; Zachariáš p.c. 2005-2006). In July 2006 the writer toured these with J. Zachariáš. Howard 2006b discusses CLY’s Bi–Au numerical linkages: CLY is the exemplar or <u>best example</u> of the exploration model by B. Flanigan and four authorities (2000). This objectively (arithmetically) indicates its high prospectivity.

14.3.2 RIRG systems have variable mineralization styles, variably placed •

In RIRG systems a host of **varying styles**[12] **(spatial forms) of mineralization may occur** in any one system (discussed by Lefebure & Cathro 1999, Lang et al. 2000, Thompson & Newberry 2000, McCoy 2000, Lang et al. 2001, Lang & Baker 2001, Hart et al. 2002, Hart & Burke 2003, Baker 2003a short course, Baker 2003b, Ebert et al. 2003, Dilworth et al. 2003, Rhys & Lewis 2004 short course, Hart 2005, Hart et al. 2005, Hart & Goldfarb 2005 short course, Hart 2006, Mair et al. 2006, Hart 2007). These are variably placed (zoned) with respect to a causative intrusion. Styles include

- dispersed Au in certain granite phases, e.g. in the Timbarra deposit, NSW Australia 0.4 M. oz was recovered from disseminated mineralization within a pervasively altered medium - coarse grained granite, in an areally extensive roof zone (Mustard 2001). Timbarra has “no discernible vein, joint, or fracture control at the outcrop or hand specimen scale (op. cit.).”
- extensional quartz veins ✓ or veinlet swarms or ‘sheeted’ veins ✓
- shear hosted veins ✓
- mineralized discrete shears ✓

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[11] Mokrsko has a resource 66 Mt @ 1.5 g/t = 99 tonnes gold = 3.08 M. oz

[12] Style is used in a spatial or geometric sense, type as used by this writer has a *genetic sense* referring to geochemistry

- ❖ intrusive hydrothermal sulphidic breccias
- ❖ replacement bodies or mantos – is the Reeves-MacDonald Pb–Zn–Ag–Cd deposit overprinted?
- ❖ *proximal* skarn ✓ *to distal* skarn

Those checked occur on CLY Group. Reduced pyrrhotite + arsenopyrite -bearing tungsten ± gold skarns are generally found in a RIRG district (McCoy et al. 1997, Newberry et al. 1997, Jensen et al. 2003, Mair et al. 2006). The Lefevre W + Au skarn on CLY Group is located between the BiTel Knoll and Clease showings. L. Meinert (1998a, 1998b, 2000) relates gold skarns to causative ‘epizonal’ intrusions; more generally tungsten ± gold skarns (Meinert et al. 2005) are simply parts of larger RIRG *systems.* This model more encompasses descriptive features and thus has more utility for exploration; this assessment report uses it. Differing mineral assemblages and widely variable element geochemistry complicate description but these may be systematically zoned about a causative pluton (figs. in Hart & Burke 2003, Hart 2006 and 2007).

14.3.3 RIRG on CLY is the *Intrusion-hosted and/or Proximal* placed sub-type•

Central CLY Gp hosts ‘sheeted’ subparallel extensional quartz veins, to 2 m-plus thick, quartz veinlets, shear veins and *proximal* skarn along the west granitic intrusive contact of the Bunker Hill Sill and within the granitoid Sill. Specifically this is the *intrusion-hosted and/or proximal* placed sub-type of RIRG mineralization (Ray 2004, Hart 2005, Hart & Goldfarb 2005 short course, Lefebure & Hart 2005 type L-02, detail in Howard 2005, Hart 2006, Howard 2006b, Hart 2007). This sub-type can have a large gold resource of high value.

“The success of the property depends on identifying a large enough area with sufficiently close-spaced veins carrying adequate gold mineralization. None of these conditions has been proven by work to date, however there are indications that each could exist. Quartz veins, with good gold values, are known to occur intermittently over an area of approximately 400 x 1500 meters. Favourable geological conditions continue on-strike in both directions and the system may continue beyond this area. The system is untested at depth. Numerous other veins are known in outcrop and in float outside of the main corridor, which have also returned elevated gold values. Rock exposure is poor and the density of veining is unknown, however at the BiTel Knoll showing, multiple close-spaced veins are seen in outcrop and suggest the potential for a sufficient density of veining (Caron 2006).”

On BiTel Knoll Eloise Vein is a 2 m thick *very proximal* Au(Ag)–Bi–Te–Mo–W bearing vein (Map 1). Clarissa Main Vein is anomalous and shallowly dipping; *Intrusion-hosted* Clarissa Transverse Sheeted Veining has many subparallel extensional quartz veins. Cm-sized blue grey quartz veins are gold anomalous and also sheeted. Clarissa veins are superficially barren and easily overlooked.

East and south of the Knoll drift covers all the veins. Here exposure and topographic relief of the host granitoids is much less than for the adjacent hornfelsed HCA at the intrusive contact. At the property scale some parts of the Bunker Hill Sill are surprisingly low in elevation (Map 1 in Howard 2006b). E of BiTel Knoll there is evidence of a N-S shear zone with softer rocks due to pervasive alteration and quartz veining (section 11.3, op. cit.).

In the Lefevre workings *proximal* pyrite + Bi-Te mineral gold-bearing vuggy quartz veins overprint the Lefevre W + Au skarn (Howard 2000, Ray 2004, photo in Howard 2006b). Sulphidic skarn has potassium feldspar-actinolite-pyrrhotite-pyrite-arsenopyrite-scheelite. Garnet is not firmly identified. Overprinting veins to 0.9 m thick in at least two orientations upgrade the skarn in trench #5.

The Lefevre workings and the buried Domain 5 VLF-EM positive dip angle anomaly are coincident with multi-element soil anomalies (section 13.2 in Howard 2005). Both have geochemical signatures characteristic of gold skarns and are considered such.

The *intrusion-hosted* Clease Sheeted Quartz Veins and Shears (Howard 2006b) may be younger than the BiTel Knoll veins. These Bi + Te auriferous semi-brittle shears have sericitic alteration + pyrite. This overprints feldspathic alteration. Silver and arsenic are more abundant and bulk gold fineness values are lower, with a larger range, than in Eloise Vein.

Microscopic examination of a sample from the *intermediate placed* Bunker Hill mine Adit 2 Underhand Stope Vein (Cook & Ciobanu Aug. 2006) shows pyrrhotite altering to pyrite and marcasite with native gold formed. This is the same change of chemical conditions for the Pogo deposit in Alaska [3.51 M. oz]: "data indicate a change from very low fS_2 and/or high T (loellingite-pyrrhotite stable) to higher fS_2 and/or lower T (pyrite stable) over time (Rombach et al. 2002)." Minimum *in-place* gold grade of the Underhand Stope Vein is 10.7 g/t (~ ⅓ oz / ton) and 7.5 g/t Ag (AR 1936 p. E20). Its gold accumulation value is 13.1 g/t * m over the average 4 foot width mined (Howard 2006b).

Gold showings on the central part of CLY Gp are greatly enriched in the uncommon element bismuth and the very rare element tellurium.

15 The rare minerals - Ikunolite $Bi_4(S,Se)_3$

15.1 Ikunolite in general and the type locality

"Ikunolite has only been recognized from a relatively small number of localities (e.g., Kato 1959, Markham 1962, Nechelyustov et al. 1978, Finashin et al. 1979, Bortnikov et al. 1982, Imai & Chung 1986 [also Lawrence & Markham 1962, Dobosi & Nagy 1989, Gamyanin et al. 1998]). Although appreciably less common than bismuthinite, the mineral is nevertheless stable in several telluride- and selenide bearing deposits. In our experience, it is most stable where pyrrhotite is the stable Fe-sulfide. Ikunolite may occur together with laitakarite, joséite-A or joséite-B, hedleyite, native bismuth and bismuthinite… Compositional data show a range of compositions from end-member Bi_4S_3 to $Bi_4S_{2.5}Se_{0.5}$. … [there is] very limited Te-for-(Se,S) substitution in most natural specimens (Cook et al. 2007b and Fig. 9 therein)". Solid solution between laitakarite Bi_4Se_3 is limited as most ikunolite compositions are near Bi_4S_3.

The type mineral from the Ikuno mine, Hyôgo Prefecture Japan is

> "lead-grey platy crystals, ranging from microscopic to about 1 mm diameter (although multi-cm plates are also alleged), very flexible, showing only (0001) faces and cleavages, usually coated with bismuthinite (or the reverse, ikunolite coating Bi minerals) and intimately associated with bismuth, ferberite, chalcopyrite, pyrite, secondary Bi minerals and sporadic cassiterite in a high-temperature vein of fine-grained massive grey quartz in the Kanagase orebody … the type locality for this rare bismuth sulfide of the tetradymite group. The host rock for these polymetallic veins is Cretaceous pyroclastic rhyolite. Contains 1.98% Se, corresponding to the formula $Bi_{3.90}(S_{2.84}Se_{0.26})sum_{3.10}$. Streak is dark grey; Hardness 2; Density 7.8; stains grey in conc. HNO_3 acid, bluish grey in 1:1 HNO_3. Cleavages to 2.5 cm (!) across have come from the Akenobe mine (Petrov 2006-2007)."

The Ikuno mine is a tin-bearing cassiterite sulphide deposit with a few tens of g/t Au (Kato 1959, Nekrasov 1996).

Regarding the sequence of mineralization (paragenetic sequence) in typical Au-Bi-Te-S deposits, Nekrasov (1996) finds "In the early stage, high grade gold was deposited … mainly with bismuthinite and native bismuth … and maldonite, tetradymite, ikunolite, tsumoite, hedleyite and joséites -A, -B, -E and –K crystallized in association with gold of the first generation."

15.2 Ikunolite localities with compositional formulae

Also in Japan ikunolite occurs in the **Ashio copper mine, Ashio, Kamitsuga, Tochigi Prefecture** with composition $(Bi_{4.33})(S_{2.38}Se_{0.62})sum_{3.00}$. 0.7 Mt copper were produced to 1973. Rhyolite-associated veins and massive sulphides ("Kajika") formed in high to mid temperatures. Deposits are zoned:
Central upper zone: Sn W Bi Cu
Middle zone: Cu As Zn
Marginal zone: Zn Pb Cu As
Reported are native gold, copper, and bismuth; chalcopyrite marcasite arsenopyrite pyrrhotite sphalerite galena bismuthinite stannite stannoidite mawsonite cosalite ludlamite chalcocite cassiterite and wolframite.

From the **Şoimuş Ilii vein**, a copper prospect in the **Highiş Massif, Western Apuseni Mtns of Romania**, a representative analysis of ikunolite [n=8] is $(Bi_{3.19}Pb_{0.78})sum_{3.96}(S_{2.83}Se_{0.17}Te_{0.04})sum_{3.04}$ (Ciobanu et al. 2006a).

Ikunolite occurs in the **Ortosa 'reduced' gold skarn in the Río Narcea Gold Belt, Asturias Spain** (Cepedal et al. 2006). This is a proximal Intrusion-related calcic skarn developed in impure limestones at the top of a Silurian siliciclastics. In one polished section ikunolite is adjacent to native gold on one side and native bismuth on the other in an interstitial patch in fluorapatite (op. cit., Fig. 6e). **A typical gold content is 0.28 wt % or 2,800 ppm Au** (op. cit., Table 5). "… the typical assemblage (native bismuth–gold–hedleyite–joséite-B) limits conditions … within the pyrrhotite stability field. …The occurrence of hessite, bismuthinite and joséite-A may indicate an increase in fS_2 as suggested by the replacement of pyrrhotite by pyrite. …This fact is confirmed by … Bi-tellurides and selenides (hedleyite, joséite-B, joséite-A, ikunolite–laitakarite) with Bi / Te + (Se + S) ≥ 1 (op. cit.)." The mean of three ikunolite analyses is $Bi_{3.95}(S_{3.04}Se_{0.02})sum_{3.06}$ with very significant 0.28 wt % gold and 0.18 wt % Ag is unaccounted for in the structure.

At **Kingsgate New South Wales Australia**, irregular pipe-like bismuth-molybdenite deposits are localized along a granite intrusive contact (Markham 1962):

> "Molybdenite, bismuth and bismuthinite are the three principal metallic minerals with galenobismutite, cosalite, ikunolite, joséite-A, joséite-B, pyrrhotite, pyrite, arsenopyrite, galena, chalcopyrite, sphalerite, wolframite and cassiterite present in minor to trace amounts (Lawrence and Markham, 1962). Ikunolite … occurs as well developed plates and foliated masses up to 3 cm in dimension associated particularly with native bismuth and molybdenite. It shows the perfect {0001} cleavage and splendent lead-gray color characteristic of all minerals of the tetradymite-joséite group. Polished section study reveals that ikunolite is associated with bismuth, bismuthinite, joséite A, molybdenite and gold. The most common assemblages recorded are:
>
> 1. Ikunolite-bismuth
> 2. Ikunolite-bismuth-bismuthinite
> 3. Ikunolite-bismuthinite
> 4. Ikunolite-bismuth-bismuthinite-joséite-A
>
> though any combination of the above four minerals may be present… The assemblages noted above give no clear-cut textural evidence of disequilibrium. Ikunolite and bismuthinite are commonly intergrown."

Kingsgate ikunolite has 5.49% Pb and 0.78% Te in the analysis; Imai & Chung 1986 give the formula as $(Bi_{3.58}Pb_{0.24}Fe_{0.01})sum_{3.83}(S_{2.92}Se_{0.03}Te_{0.05})sum_{3.00}$. "The rarity of ikunolite and the commonly reported association of bismuth with bismuthinite suggest that very special conditions are necessary for its formation. Ikunolite may, perhaps, be stable over a limited P-T range or form only in the presence of significant amounts of selenium and tellurium (Markham 1962)."

In the **Vysokogorsk** (alternate sp. Vysokogora) **cassiterite-silicate-sulfide tin deposit in Primor'ye Russian Federation**, Sikhote Alin, Russian Far East (Finashin et al. 1979, Roberts et al. 1990) the mean composition is $(Bi_{3.47}Pb_{0.30})sum_{3.77}(S_{2.77}Se_{0.15}Te_{0.08})sum_{3.00}$ (Imai & Chung 1986). Ikunolite is associated with cosalite and cannizzarite. Vysokogorsk is a vein and stockwork deposit mined since the 1960's with medium tonnage and grade 1.0% Sn (Ariunbileg et al. 2003).

From the **Wolam Zn Pb Ag skarn** deposit of the Yeonhwa 1 mine, then the largest producer of lead and zinc in South Korea, the mean composition of 9 ikunolite grains is $(Bi_{3.76}Pb_{0.22}Ag_{0.01})sum_{3.99}(S_{2.99}Se_{nil}Te_{0.01})sum_{3.00}$ (Imai & Chung 1986). Pb variably substitutes for Bi from grain to grain. Galena, galenobismutite, bismuthinite, native bismuth, gustavite and pyrrhotite are associates in sphalerite and pyrrhotite-bearing clinopyroxene skarn.

Inclusions of native bismuth, ikunolite and bismuthinite occur in the new mineral jonassonite, ideally $Au(Bi,Pb)_5S_4$. This occurs as anhedral grains of up to 500 x 150 µm in drill core of the former gold-producing **Nagybörzsöny deposit in Hungary** (Dobosi & Nagy 1989, Paar et al. 2006). Other associated phases are bismuthinite, marcasite and chalcopyrite (Paar et al. 2006, their Fig. 2).

15.3 Ikunolite – additional localities without compositional formulae

The second paragenetic mineral stage at the **Cobar New South Wales Australia** deposits is "A sulfur-poor assemblage of extremely fine-grained and high fineness (>950 fineness) gold, maldonite (Au_2Bi), native bismuth, ikunolite (Bi_4Se_3-Bi_4S_3 solid solution series), clausthalite-galena (PbSe-PbS solid solution series) and other rare bismuth minerals in early-stage colloform quartz veins and quartz vein breccias associated with Fe-rich chlorite alteration (Stegman 2001)".

In addition to sites referred to in Howard 2006a, ikunolite occurs in the **Jähnichen quarry**, Königshain, Lausitz, **Saxony in Germany** (T. Witzke http://tw.strahlen.org/indengl.html).

Aside from in the Maiskoe deposit (reviewed in Howard 2006a), ikunolite also occurs in **Ukraine in the Sergeevske gold deposit.** This Archean age 3.5-3.1 Ga deposit is hosted in Middle Dnieprian block tonalite-greenstones (Stein et al. 1998). "It is associated with an astonishingly well preserved volcanoplutonic complex with a Au-Cu-Mo core and a Au-Ag-Bi-Te peripheral zone of mineralization". See the microphoto fig. 6 below.

Ikunolite occurs in the **Tuguchak-2 deposit in northeast Yakutia, Russia.** This is a granitoid-related Au deposit with W, Bi & Te. Grade is up to 10 g/t Au, to 0.25% Bi and to 0.08% Te. Steeply-dipping, cross-cutting quartz veins have tourmaline, muscovite, arsenopyrite, wolframite, bismuth, ikunolite, bismuthinite, hedleyite, joséite-A, joséite-B and gold (fineness 400-1000). The gold-quartz veins range up to 1 m thick, to 100 m long and strike north-south. These cut earlier molybdenite-quartz veins that form the Tuguchak-1 deposit. Tuguchak-2 is hosted in the Early Cretaceous Ulakhan-Tass granodiorite pluton. Beresite alteration is associated (Bakharev et al. 1988, Nokleberg et al. 1997). In C. Hart's (2007) current categorization the Tuguchak deposits are *intrusion-hosted* and / or *very proximal* RIRG deposits. Gamyanin et al. 1998 note ikunolite with native bismuth, bismuthinite and Bi-Te minerals in NE Russian gold skarn and gold greisen deposits.

The **Vostok-2 skarn scheelite–sulphide deposit in northern Primorye, Russia** mined by Primorsky GOK was recently Russia's leading tungsten producer (Shedd 2004). The average grade is 0.65% Cu, 1.64% W_2O_3; it has been mined since 1980's (Ariunbileg et al. 2003). Bismuth, lead, silver, gold, tellurium, and selenium are extracted from ore with galena, native Bi and Au, kobellite, Bi-containing jamesonite, tetradymite, and other minerals (Gvozdev & Tsepin 2005). Ikunolite, jaskolskiite, and cosalite with a high Sb content were found by electron microprobe analysis. Permian to Triassic metaseds are intruded by granitoids.

In some deposits of the **Khingan-Olonoi tin district in Russia** these minerals occur: "molybdenite, native gold, siliceous indium, … bismuth- and silver-bearing galena, native bismuth, aikinite, hedleiite, joséite B, hessite, wittinchenite, miharaite, native silver, ikunolite, benjaminite and bismuthinite… (Korostelev et al., no date)." The Khingan tin greisen deposit "consists of over 15 ore zones that range from 10 to 50 m across and 100 to 400 to 500 m depth that occur in an symmetrical breccia zone about 250-300 m across. Breccia zone is traced to depths of over 1200 m. At the upper levels … breccia is replaced by chlorite, and at depths of 700 to 800 m, the breccia is replaced by quartz-muscovite (sericite)-topaz greisen. Ore assemblage is quartz-fluorite-cassiterite. Arsenopyrite, marcasite, loellingite, chalcopyrite, and bismuth minerals are subordinate. The deposit occurs in pipe-shaped ore bodies of hydrothermal explosion breccia cutting felsic volcanic rocks. The deposit is … related to a 80-90 Ma subalkaline potassium granite (ref. Ognyanov 1986), Nokleberg et al. 1997". The deposit has medium tonnage with 0.6-0.7% tin mined since the 1960's.

Zabytoye in Amgu valley **Primorye, Rusia** is a greisen tin deposit with pyrite pyrrhotite cassiterite arsenopyrite galena molybdenite sphalerite bertrandite cosalite hubnerite wolframite ikunolite ingodite and topaz (de Graff 2007, http://www.mindat.org/loc-25400.html). Small stocks of specialized lithium-flourine granite occur.

Ikunolite is identified in the **Kara-Obo Mo–W deposit, Bet-Pak-Dal Desert, central Kazakhstan** (Nechelyustov et al. 1978). This is a large greisen W-Mo (Sn,Bi) porphyry deposit with 0.07% Mo and 0.20% W, age 292 Ma (Kotlyar et al. 1995, Mutschler et al. 1999).

Ikunolite is identified in bismuthian gold ore in the Baocun and/or Chaoshan skarn in the **Tongling area, south China** (Ren et al. 2005). Native bismuth and bismuthinite are dominant, montanite, pavonite, hedleyite wehrlite, emplectite, galenobismutite, gustavite and maldonite are minor to trace ore minerals. At Baocun 1-25 mm wide quartz veins with native bismuth, bismuthinite, native gold and chalcopyrite crosscut copper + gold skarn. Gold correlates with Ag Cu and Bi: a "correlation coefficient matrix of 8 trace elements in 41 pieces of gold ore [has] correlation coefficients Au-Bi 0.6916, Cu-Bi 0.5030 and Ag-Bi 0.5836. There is a prominent positive correlation of gold, copper and silver with bismuth. …gold and bismuth minerals synchronously developed … [with] copper and silver (op. cit)".

The grade of the Baocun copper-gold skarn is 0.63% Cu & 7 g/t Au with production 5 tons gold (Chen et al. 2007). Opaque minerals include magnetite, pyrrhotite, pyrite, chalcopyrite, native bismuth, bismuthinite, molybdenite, gold, electrum, sphalerite, bornite, arsenopyrite and galena (Zhao et al. 1999).

The arsenical **Osikonmäki (Osikko) gold prospect in Finland** has minor ikunolite. This shear-zone hosted orogenic or 'mesothermal- style' deposit has reserves of 2.2 Mt @ 3.1 ppm Au = 7,330 kg = 7.33 t Au with 0.77% arsenic at a 1 ppm Au cut-off grade. "Native gold and electrum, with a set of Bi-Se-Te minerals, occur as inclusions and at grain boundaries within and between arsenopyrite, quartz and plagioclase. Native gold is more abundant towards the centres of early crystallised loellingite-arsenopyrite grains. Major opaque minerals are pyrrhotite, arsenopyrite, loellingite, chalcopyrite; marcasite, sphalerite, galena, ilmenite, rutile, cubanite, covellite, molybdenite, native gold, electrum, native bismuth, native antimony, maldonite, ikunolite, hedleyite, kawazulite, pilsenite, dyscrasite, tetrahedrite and stannite are minor.

"Gold was precipitated by the sulphidation of the host rock in structurally favourable locations [with] ... arsenopyrite, löllingite and pyrrhotite … the formation of certain Te- and Bi-bearing minor ore minerals took place during the fall of temperature, between 300-100 °C. Gold is geochemically associated with Bi and Te..." (http://www.gsf.fi/explor/gold/osikonmaki.htm).

Iilijarvi also **in Finland** has abundant Bi-Te-Se-S phases within galena: "hedleyite, joséite-B, joséite-A, and ikunolite with intergrowths between these phases (Ciobanu et al. 2002)."

Ikunolite is also found in the dumps of the former **North Devon United Mine at Devon U.K.** with a complex assemblage of minerals including arsenopyrite, cobaltite, chalcopyrite, scheelite, bismuth, erythrite, quartz, fluorite, stannite, bismuth, bismuthinite, aikinite, cosalite, gersdorffite and various bismuth-bearing supergene minerals (Rumsey & Savage 2005).

At **Rędziny in Poland** dolomitic marbles in schist, intruded by Hercynian granites, have "… aikinite [as] large grains reaching 1 mm and associated with … chalcopyrite, bismuth, Bi sulphides. In the outer parts of such aikinite grains as well as in their fractures were found tiny inclusions of bismuthinite, ikunolite and bismuth with sizes not exceeding 10 µm (Golebiowska et al. 2005)".

Ikunolite also occurs with gold mineralization in **central Vietnam** with "tellurides, bismuthinite, native bismuth, rossvietite (AuBiS), scheelite and molybdenite (Borisenko et al. 2006)."

15.4 Interpretation: Significance of Ikunolite and other Bi-Te assemblages in the Blue Quartz Vein and the texturally-indicated alteration processes

In the Blue Quartz Vein both bismuth minerals and gold occur as micron-sized blebs along fractures in the quartz. In sample 0414 (Map 1) "…the Bi-mineral assemblage is dominated by joséite-A (Bi_4S_2Te), together with bismuthinite and native bismuth as major components … and lesser amounts of joséite-B (Bi_4Te_2S), hedleyite (Bi_7Te_3) and close-to-end-member ikunolite (Bi_4S_3) (Cook & Ciobanu Aug. 2006)". The trace molybdenite present is not spatially associated with native gold nor the Bi-Te minerals.

In one of the two, several relatively coarse (50-100 µm) patches of Bi-minerals (<50% remain non-weathered) occur in the vein as larger masses interconnected by a fine network of filled fractures (Fig. 2a, bright). The patches consist mainly of (i) ingodite, Bi(Te,S), and unnamed Bi_2Te (Fig. 2b, c) and (ii) ingodite and coarse symplectites of joséite-A and joséite-B. Bismuthinite may be part of the assemblages. Native gold is present in (i) as a rim at the contact between the two Bi-minerals (Fig. 2c, d). It also forms separate grains, tens of µm in size, at the margins of assemblage (i), connected by veinlets to the Bi-mineral mass. Ingodite is enveloped by unnamed Bi_2Te. The latter contains irregular µm-sized inclusions of joséite-B (Fig. 2e).

Samples from the second location, on the northern side of the vein, contain mm-sized patches of bismuthinite (<50% remain non-weathered). Tellurides, such as ingodite, joséite-A and joséite-B occur either as 10-20 µm-sized inclusions, or as larger (100-500 µm) masses at the margin of bismuthinite. The inclusions can be euhedral or are slightly deformed. A comparable deformation is observed along the cleavage planes of host bismuthinite. Scarce native gold is present as <10 µm-sized inclusions in bismuthinite, sometimes combined with tellurides (Fig. 2f). The same coarse symplectites between joséite-A and –B as in samples from the other location described above are observed in the larger patches at the margins of bismuthinite.

ELECTRON MICROPROBE DATA

A CAMECA SX-51 instrument at Adelaide Microscopy, Adelaide, South Australia was used, at an operating voltage of 20 kV and beam current of 20 a.

Microprobe data for identified species are presented in Tables 1-3. Data for unnamed Bi_2Te and hedleyite in the Blue Quartz Vein were obtained by EDAX and are not included in the table. We point to the variable contents of Pb in joséite-A and -B and that Pb is preferentially enriched in joséite-A in the Eloise vein. In the Blue Quartz vein, neither joséite-A nor -B contain Pb, which is actually higher in the coexisting ikunolite.

Table 1. Mean analyses of Bi-minerals in Blue Quartz Vein sample 0414.

	Jo-A	**Jo-B**	**Iku**	**Bism**
	n=13	n=2	n=2	n=3
Cu	0.00	0.00	0.00	0.06
Pb	0.17	0.06	4.15	0.10
Cd	0.22	0.17	0.26	0.17
Bi	80.00	74.15	83.66	80.16
Sb	0.11	0.13	0.02	0.15
Te	11.97	21.84	0.97	0.04
Se	0.12	0.06	0.15	0.02
S	6.36	2.98	10.33	18.52
Total	99.09	99.37	99.56	99.53

Empirical formulae:
Joséite-A: $(Bi_{3.95}Pb_{0.02}Sb_{0.01})_{3.98}Te_{0.97}S_{2.05}Se_{0.02}$
Joséite-B: $(Bi_{4.00}Sb_{0.01})_{4.01}Te_{1.93}S_{1.05}Se_{0.01}$
Ikunolite: $(Bi_{3.72}Pb_{0.19})_{3.91}(S_{3.09}Te_{0.07}Se_{0.01})_{3.17}$
Bismuthinite: $(Pb_{0.01}Cu_{0.01}Bi_{1.97}Sb_{nil})_{1.99}S_{3.01}Se_{nil}$

Table 2. Mean analyses of Bi-minerals in Eloise Vein South' 0441a & 0441b samples.

	Jo-A	**Jo-B**	**Ing**	**Bi_2Te**	**Bism**
	n=8	n=6	n=10	n=12	representative
Cu	0.00	0.00	0.00	0.00	0.23
Pb	3.03	0.68	1.74	0.79	1.03
Cd	0.32	0.27	0.18	0.25	0.04
Bi	75.34	74.99	68.54	76.78	78.73
Sb	0.11	0.17	0.15	0.32	0.46
Te	14.39	21.49	23.54	22.09	0.02
Se	0.10	0.11	0.15	0.21	0.17
S	6.29	2.88	5.57	0.34	18.31
Total	100.59	99.58	99.87	100.77	98.99

Empirical formulae:
Joséite-A: $(Bi_{3.68}Pb_{0.15}Sb_{0.01})_{3.84}Te_{1.15}S_{2.00}Se_{0.01}$
Joséite-B: $(Bi_{4.03}Pb_{0.04}Sb_{0.02})_{4.08}Te_{1.89}S_{1.01}Se_{0.02}$
Ingodite: $(Bi_{0.94}Pb_{0.02})_{0.97}Te_{0.53}S_{0.50}Se_{0.01}$
Unnamed Bi_2Te: $(Bi_{1.97}Pb_{0.02}Sb_{0.01})_{2.00}(Te_{0.93}S_{0.06}Se_{0.01})_{1.00}$
Bismuthinite: $(Bi_{1.96}Pb_{0.03}Cu_{0.02}Sb_{0.02})_{2.03}S_{2.98}Se_{0.01}$

Table 3. Mean analyses of Bi-minerals in Eloise Vein North samples 0412.

	Jo-A	**Jo-B**	**Ing**	**Bism**
	n=9	n=7	n=16	representative
Cu	0.00	0.00	0.00	0.34
Pb	2.89	0.42	3.29	0.73
Cd	0.20	0.27	0.30	0.00
Bi	75.57	74.13	66.96	79.04
Sb	0.11	0.14	0.16	0.41
Te	13.99	21.09	21.65	0.11
Se	0.10	0.07	0.06	0.03
S	6.31	3.24	5.81	18.83
Total	99.17	99.37	98.24	99.53

Empirical formulae:
Joséite-A: $(Bi_{3.70}Pb_{0.14}Sb_{0.01})_{3.85}Te_{1.12}S_{2.01}Se_{0.01}$
Joséite-B: $(Bi_{3.97}Pb_{0.02}Sb_{0.01})_{4.01}Te_{1.85}S_{1.13}Se_{0.01}$
Ingodite: $(Bi_{0.93}Pb_{0.05})_{0.98}Te_{0.49}S_{0.53}$
Bismuthinite: $(Bi_{1.95}Pb_{0.02}Cu_{0.03}Sb_{0.02})_{2.02}S_{2.98}Se_{nil}$ (corrected)

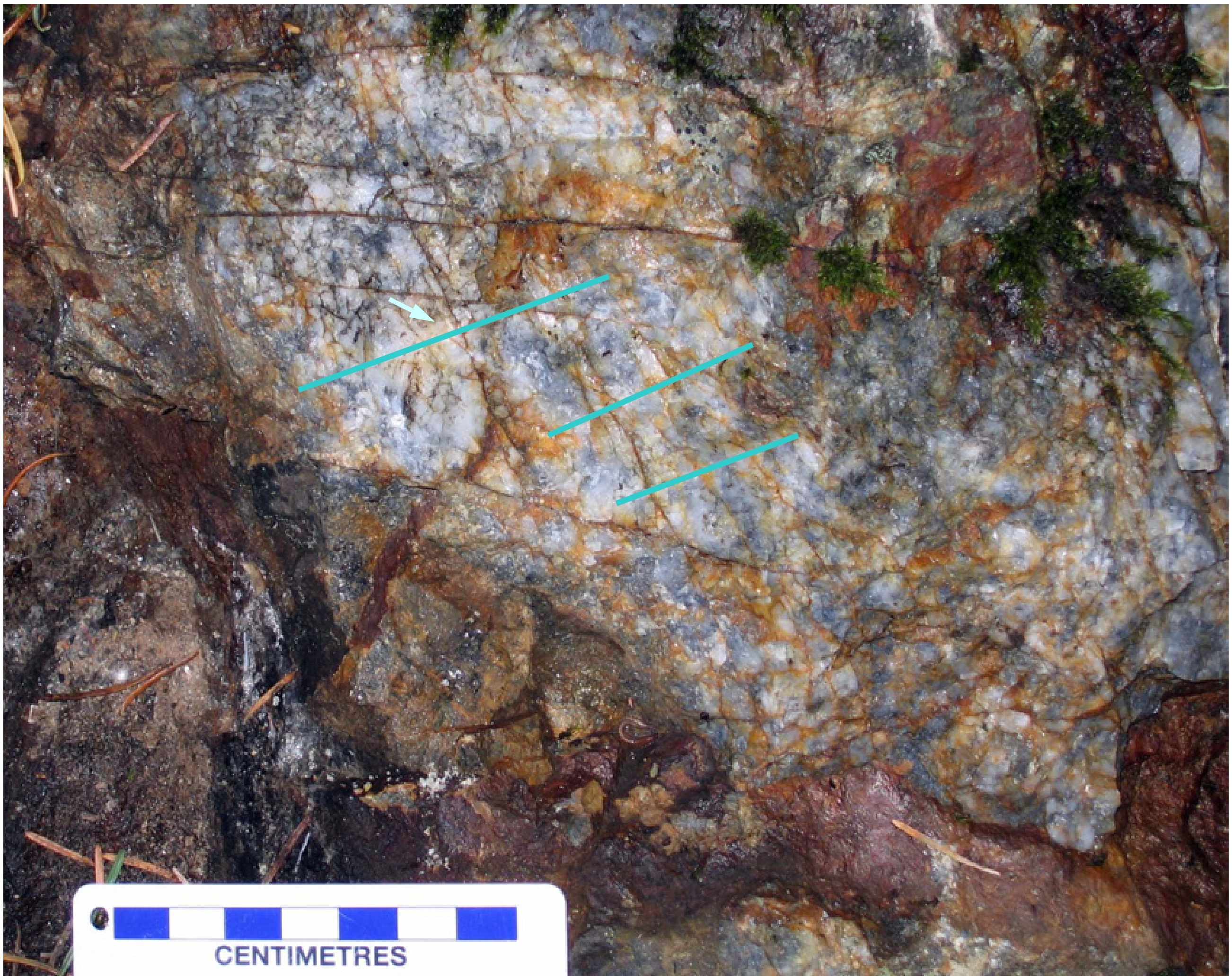

Fig. 5 Close-up photo of the Blue Quartz Vein sample site 0414 at the top of the N wall of the trench. View to about NE. Two, most likely three, fracture sets splinter the vein. Fractures are strongly silicified and healed. Color lines outline disrupted and indistinct quartz laminae with varying concentrations of grey-blue Bi-Te minerals. Arrow marks top of a barren quartz band. Bottom of photo is the metaquartzite footwall of this fault-hosted vein.

The former report Howard 2006a discusses some textural relationships apparent in twelve microphotos of Bi-Te minerals in sample 0414 from the Blue Quartz Vein, Fig. 2 of Cook & Ciobanu 2006. Some of the grains labelled hedleyite may actually be unnamed Bi_2Te; they are optically similar with reflected light microscopy (p.c.). Reprising the textures, in Fig. 2A joséite-B surrounds a grain of hedleyite (or unnamed Bi_2Te?). Fig. 2E shows two native bismuth cores surrounded by both ikunolite + joséite-A on both sides. *This replacing mineral pair is younger.* Figs. 2I & 2K show interstitial blebs of ikunolite + joséite-A. This mineral pair stably coexists as the grain boundaries are smooth and curve at low angles. In Fig. 2G both unnamed Bi_2Te and joséite-B corrode native bismuth; in Fig. 2F bismuthinite envelopes and corrodes native bismuth.

There are too many Bi-Te mineral phases in the Blue Quartz Vein for all to be an equilibrium assemblage in the Bi-Te-S-(Se) system. Textures infer native bismuth is early; it is partially replaced by any of the assemblages

ikunolite
ikunolite + joséite-A
bismuthinite
unnamed Bi_2Te + joséite-B.

The processes are sulphidation and increase in tellurium chemical activity. One of these replacing textures noted above is also well displayed in:

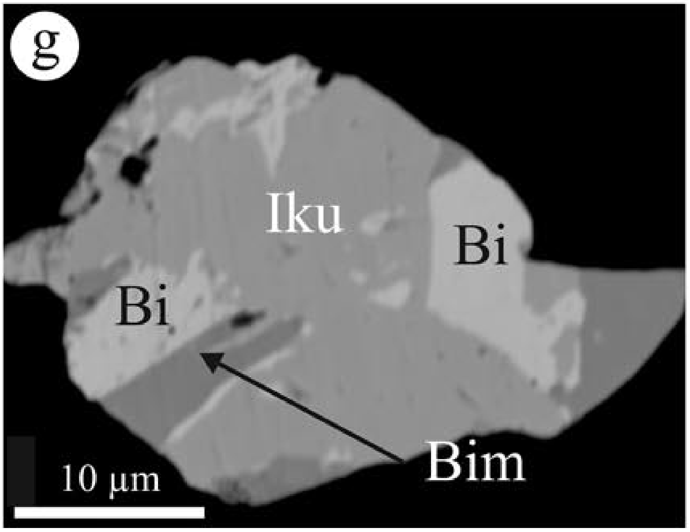

Fig. 6 Microphotograph of a bismuth sulphosalt mineral assemblage consisting of native bismuth (Bi), ikunolite (Iku) and bismuthinite (Bim) from the Sergeevske (alternate sp. Sergiivske) gold deposit in Ukraine. Fig. 11 (g) from Cook et al. 2007b. Textures clearly indicate ikunolite corrodes first-formed native bismuth as in microphotos 2E & 2F from the Blue Quartz Vein, discussed above. There is slight indication of bismuthinite replacing native Bi. The process is sulphidation.

15.5 Formation conditions of the Blue Quartz Vein inferred from the mineral formula of ikunolite & its associated minerals

The above described Bi-Te minerals in sample 0414 from the Blue Quartz Vein (Map 1) 1have atomic ratios Bi (+ Pb) / Te + S (+Se) ≥ 1 (see fig. 8, Ciobanu & Cook 2003, Ciobanu et al. 2003). Both the Blue Qtz Vein and the Maiskoe deposit include hedleyite + joséite-B and native bismuth + ikunolite assemblages. Thus, as also proposed for the Maiskoe gold deposit in Ukraine,

> "Scavenging of Au by Bi melt above 271°C (the Bi melting point) is evident. [Estimated formation] temperatures ~266°C are indicated by paired Bi–telluride associations with Bi / (Te + S) > 1[13], representing binary eutectics in the Bi–Te–(S) system. …An increase in fS_2 triggered Bi-Au-Te droplet precipitation (Mudrovska et al. 2004)."

Similar formation conditions are proposed for two other gold deposits with ikunolite - Ilijarvi in Finland (Ciobanu et al. 2002) and the Ortosa gold skarn in Spain (Cepedal et al. 2006).

[13] **This is just an abbreviated formula**

Ikunolite in the Blue Quartz Vein concentrates the minor lead present; there is very little in coexisting joséite-A and joséite-B (Cook et al. 2007c). The average of two analyses is $(Bi_{3.72}Pb_{0.19})sum_{3.91}(S_{3.09}Se_{0.01}Te_{0.07})sum_{3.17}$. This amount of Pb substitution is in the linear range for other occurrences (fig. 9, Cook et al. 2007b). As in most other natural specimens Te-for-(Se,S) substitution is very limited with Te 0.97 wt % and Se 0.15% (op. cit.).

Associated native gold has high fineness with atomic ratios between $Au_{76}Ag_{24}$ and $Au_{80}Ag_{20}$ in sample 0414b (Cook & Ciobanu Nov. 2006).

Argillaceous metaquartzite adjacent to the Blue Quartz Vein has rusty-weathering skarn-like alteration (photo in Howard 2005). Ore microscopy shows the "…Bi-rich associations are similar to those typically reported from gold skarns (Cook et al. 2007c)." Bi-Te mineral assemblages in the Blue Quartz Vein formed under 'reduced' conditions of low fS_2 and low fO_2. As in other worldwide occurrences ikunolite "… is most stable where pyrrhotite is the stable Fe-sulfide (Cook et al. 2007b)".

16 Ingodite Bi_2TeS

16.1 Ingodite in general

Ingodite is a rarely reported mineral (Shin et al. 2005). "Zav'yalov & Begizov (1981a) formally described ingodite as Bi(Te,S) (ideally Bi_2TeS)[14], although the existence of the phase had been mentioned in several earlier studies (Zav'yalov & Begizov 1978). Their data and subsequent information from other occurrences (e.g., Ren 1986a, Ren 1986b, Shimizu et al. 1999) illustrate a degree of nonstoichiometry [atomic (Bi / (S + Te + Se) ranges between 0.95 and 1.08] and also variable but roughly equal Te and S contents… (Cook et al. 2007b)." Pb may be essential to the ingodite structure, with ~0.05 atoms per formula unit (op. cit. fig. 12). Fleischer et al. 1982 and Dunn et al. 1985 review the work of Zav'yalov & Begizov. Ingodite in Pogo gold ore is discussed in section 16.4.

16.2 Ingodite localities with compositional formulae

From the type locality the **Verkhne-Ingodinskoye Sn Deposit,** near the source of the Ingoda River, Transbaikalia (Zabaykalye), Eastern-Siberian Region in **Russia,** ingodite formulae range from "$(Bi_{2.00}Pb_{0.02})sum_{2.02}(S_{1.12}Te_{0.86}\ Se_{0.02})sum_{2.00}$ to $(Bi_{1.38}Pb_{0.24})sum_{1.64}(S_{0.95}Te_{1.42}Se_{nil})sum_{2.37}$ with quite variable Te / (Se + S) = 0.75 to 1.49 (Shin et al. 2005)". This is a cassiterite-sulfide-silicate vein and stockwork deposit in volcanic complexes and replacements.

Ingodite occurs in the important **Tyrnyauz W + Mo deposit**, left bank of the Baksan River Valley, northern Caucasus Mountains, Kabardino-Balkaria Republic, **Russian Federation** (©2001-2005 Mineral Data Publishing, version 1, Jambor et al. 1997, Bindi & Cipriani 2003). This was "…the former Soviet Union's largest producer of tungsten from tungsten skarns (0.14% WO_3), with an original annual capacity of 42,000 t of tungsten concentrate. At Tyrnyauz mining began in 1940, and surface mining was stopped in 1995. Only underground mining of the deepest and richest deposits (with an average WO_3 content of 0.19%) remained profitable in the second half of the 1990s (Bindi & Cipriani 2003)". Tyrnyauz is Russia's largest tungsten producer with "low-grade reserves estimated at containing 375 million tonnes ore (Nokleberg et al. 2005)."

At Tyrnyauz baksanite occurs in altered magnetite-andradite skarn among voids in aggregates of andradite, calcite, chlorite, and stilpnomelane. "Associated minerals are bismuthinite, tetradymite, joséite-A and ingodite… gangue minerals are calcite and andradite.
The mineral occurs as anhedral grains up to 0.5 mm across, closely associated with bismuthinite (Bindi & Cipriani 2003)." Baksanite contains inclusions of native gold and, rarely, intergrowths of ingodite and joséite-A; all are separated from the host aggregates by a thin lining of bismuthinite. Baksanite is ideally $Bi_6Te_2S_3$; "electron-microprobe analyses gives the formula $(Bi_{4.94}Pb_{0.96})sum_{5.90}Te_{2.03}S_{3.06}$ …

Chemical analyses of the ingodite and joséite-A associated with plumbian baksanite yielded the following formulae (means of 5 analyses):
ingodite $(Bi_{1.78}Pb_{0.32})sum_{2.10}(S_{1.01}Te_{0.95})sum_{1.96}$
joséite-A $Bi_{3.64}Pb_{0.40})sum_{4.04}Te_{0.91}S_{1.94}$,
thus indicating a Pb-rich environment of formation for the baksanite (op. cit.)."

[14] Bi(Te,S) means 1 atom of Bi with equal halves of Te & S atoms, better $Bi_2(TeS)$

EDAX {Energy Dispersive Analysis} identifies ingodite as a minor phase in the **Petráčkova hora deposit, Bohemian Massif, SW of Prague in Czech Republic** (Fig. 5 in Zachariáš et al. 2001, 2006, p.c. 2006). This *Intrusion-hosted* RIRG gold deposit has 1.03 M. oz reserves.

Petráčkova hora quartz veins are "characterized by low sulfide content, native gold with auriferous bismuth telluride minerals and no visible alteration (Zachariáš et al. 2006)." It is hosted in a Variscan age porphyritic biotite-hornblende granodiorite stock as "sheeted arrays of quartz veins and veinlets. Sulphides and other ore minerals form <5 volume % of the quartz veins... The most common sulphide minerals are pyrrhotite and chalcopyrite. …Pyrite, arsenopyrite and molybdenite are present, but are relatively rare.

…Gold within and associated with quartz veins occurs mainly as free grains ≤ 80 microns in size or as intergrowths with Bi–Te–S [younger] or Bi–S [older] minerals. … Traces of electrum and Cu-Au alloy are present. Gold minerals, including maldonite, aurostibite, an unnamed $AuBi_5S_4$ phase [jonassonite see section 18], and Au-Hg amalgam are rare and intimately intergrown with native gold or Bi–Te–S minerals.

Native bismuth, bismuthinite and hedleyite (Bi_7Te_3) are the most common bismuth-bearing minerals. Many other Bi-Te-S minerals were identified qualitatively (Zachariáš et al. 2001)". EDAX identifies ingodite (fig. 5). … In one case a veinlet of unnamed $Bi_2(Te,Se)$ cuts bismuthinite [see section 17.3]

Shin et al. (2005) quote a formula for ingodite from the **Pangushan W + Bi vein-form deposit,** Jiangxi Province, Ganzhou Prefecture in **China** studied by Ren (1986b) as "$(Bi_{2.00}Pb_{0.04})sum_{2.04}(S_{0.95}Te_{1.05})sum_{2.00}$ with Te / S = 1.11, which is close to the ideal composition." Ren et al. 1986 discuss mineral and element zonation.

Ingodite in the **Suehiro vein of the Otome Deposit, Yamanashi Prefecture, Japan** is found enclosed in cosalite in Stage II quartz veining formed at 330-150 °C with pyrrhotite, less pyrite, bismuthinite, native bismuth, sphalerite, galena, cosalite, galenobismutite, Bi-bearing boulangerite and molybdenite (Tsunoda & Shimizu 1995). It has significant Pb, e.g. an analysis in their Table 3 is $(Bi_{1.77}Pb_{0.23})sum_{2.00}(S_{0.99}Te_{1.01})sum_{2.00}$.

Ingodite from the Precambrian **Mazowe mine**, **Zimbabwe** [0.99 M. oz] is lead-rich at $(Bi_{1.476}Pb_{0.319}Fe_{0.215})sum_{2.009}(S_{1.100}Te_{0.885})sum_{1.985}$ (Oberthür et al. 2000). "A late association of a number of Bi-minerals is notable in the ores, namely native bismuth, bismuthinite, tetradymite (Bi_2Te_2S), cosalite ($Pb_2Bi_2S_5$) with distinct Ag contents (0.49-1.95 wt % Ag, n=10), joséite-A (Bi_4TeS_2) and ingodite".

"Ingodite is described as the second most abundant Bi–Te–(S) phase after tetradymite in the **Băița Bihor skarn deposit, Romania**, as well as others in the Upper Cretaceous 'banatitic' province (Ilinca & Makovicky 1999). Compositional ranges [of] the entire population varies … with Bi / (S + Te) from ~0.7 to 1.25 and Te/S from ~0.4 to 0.6. Ilinca & Makovicky (1999) state their compositions contain Pb and plot along the same line as reported by Zav'yalov et al. (1984), i.e., from $(Bi_{2.00}Pb_{0.02})sum_{2.02}(S_{1.12}Te_{0.86})sum_{1.98}$ to $(Bi_{1.38}Pb_{0.24})sum_{1.62}(S_{0.95}Te_{1.42})sum$ (Cook et al. 2007b)."

At the **Highiş Romania** copper prospect "Ingodite, the most abundant sulfotelluride, displays a limited spread of compositions, with the (Te + Se) / (Te + S + Se) ratio varying from 0.42 to 0.54 and (Bi + Pb) / (S + Te + Se) ranging from 0.9 to 1.06 (Ciobanu et al. 2006a)." The later is the metal to chalcogenide ratio, near 1. Mean analysis of ingodite [n=8] from Highiş is $(Bi_{1.92}Pb_{0.06})sum_{1.98}(S_{1.06}Te_{0.72}Se_{0.24})sum_{2.02}$ (on the basis of 10 atoms per formula unit) (op. cit.).

"Ingodite from **Carrock Fell**[15]**, Cumbria, U.K.** … is intimately associated with joséite-A, joséite-B, tetradymite, bismuthinite and hedleyite. Microanalytical data illustrate the variation in Bi / (Te + S) from 0.88 to 1.08 [between ~$Bi_5(S,Te)_6$ and ~$Bi_6(S,Te)_5$] and significant differences also in Te:S value. The Se contents in ingodite are negligible (Cook et al. 2007b)." The mineral baksanite $Bi_6Te_2S_3$ may be present. In one section the mean of 8 is $(Bi_{3.09}Pb_{nil})sum_{3.09}(S_{1.66}Te_{1.23}Se_{0.01})sum_{2.91}$, in another section the mean of 12 is $(Bi_{2.82}Pb_{0.04})sum_{2.86}(S_{1.55}Te_{1.59}Se_{0.01})sum_{3.14}$.

16.3 Ingodite localities without compositional formulae

Ingodite occurs at **Sácárîmb** [2.7 M. oz.] (formerly Nagyag) in the Metaliferi Mtns, **Romania**. This epithermal gold-telluride deposit has pilsenite, galena, chalcopyrite (Simon & Alderton 1995, Shimizu et al. 1999b). Pilsenite replaces Pb-rich ingodite along cleavage planes or surrounds ingodite blebs. No formula is available.

Ingodite also occurs in mesothermal Cu-Zn-Pb-Bi-Mo-W veins at the **Ohisawa mine** (Oizawa) Tochigi Prefecture, **Japan** (Shimizu et al. 1999). Minor Pb may be essential to the structure.

There is an occurrence in **Arizona** in Cochise Co. in the Little Dragoon Mts on the Primos group of claims (Primos Mine) aka **Bluebird Mine** (Anthony et al. 1995). Ingodite occurs as small silver-gray cleavable crystals with a tabular habitat in scheelite-bearing garnetite. Mineralization is hübnerite with minor scheelite, pyrite and chalcopyrite in irregular quartz veins in a fractured and altered Laramide age quartz monzonite intrusion.

Ingodite occurs with other bismuthian minerals in gold-bearing mineralization at **Kasejovice, southwest Bohemia, Czech Republic** (Litochleb et al. 1990) in the gold-bearing stage with quartz, muscovite, chlorite, pyrite-2, pyrrhotite, chalcopyrite-1, molybdenite, native bismuth, bismuthinite, various other Bi-Te-S phases and gold-1.

[15] This is a historic locality with minimal production.

16.4 Compare ingodite in the Pogo Alaska deposit and conditions of formation of the Bi-Te mineral assemblages in Fort Knox and Pogo

At the **Pogo Alaska** RIRG deposit [3.51 M. oz] ingodite is sixth in abundance of twelve gold-associated bismuth and bismuth telluride minerals (Rombach et al. 2002). The formula is stated BiTeS; no analyses are given. In only five microscopic sections the BiTel Knoll veins have 7 of 13 GBT minerals identified in a thorough research study of the Liese Zone at Pogo (see Rombach et al. 2002 in the refs. comparing the two occurrences). Ingodite is in all three Bi-Te mineral assemblages defined by Rombach et al. 2004.

In both the Fort Knox and Pogo deposits

> "Bi-Te mineralogy changes in kind with the gold composition and the sulphide-alteration assemblages. In general paragenetically early, high temperature, and very low fS_2 (loellingite[16]–pyrrhotite stable) native bismuth, bismuth telluride and S-poor sulphotelluride [e.g. ingodite bearing] assemblages yield to late, lower temperature, higher relative fS_2 (pyrite stable) S-rich sulphotelluride [e.g. joséite-A], Sb-bearing bismuthinite and sulphosalt assemblages (Rombach et al. 2004)."

With increased chemical activity of sulphur fS_2 late stage sulphidation is a key mechanism of gold deposition. Low Sb content of all analyzed bismuthinite grains in the BiTel Knoll quartz veins is supporting evidence that central CLY mineralization is paragenetically early, like at Fort Knox and Pogo. See the full abstracts of Rombach et al. 2002 and 2004 in the references.

16.5 Compare: Ingodite carries gold and silver in solid solution in the Nakdong South Korea As + Bi deposit

In the **Nakdong South Korea As + Bi deposit** ingodite has general composition $(Bi_{1.94}Sb_{0.01}Ag_{0.04})sum_{1.99}(S_{1.08}Te_{1.03}Se_{0.03})sum_{2.14}$ "regarded as Te-rich ingodite" (Shin et al. 2005). **Importantly ingodite in this deposit may carry considerable gold to about ⅓ weight percent:** three of nine microprobe analyses have gold in solid solution 0.16, 0.29 and 0.31 wt % or 1,600 2,900 and 3,100 ppm Au (op. cit., Table 1 p. 295). **The maximum recorded 3,100 ppm is 3.1 Kg/t = 90.5 oz/ton Au).** The highest silver value is even greater at near 1 weight %.

Nakdong is obviously an intrusion-related deposit with some precious metals. See Appendix 7 for further information on Nakdong mineralogy.

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[16] Easily mistaken for arsenopyrite, a common associate which it closely resembles in hand specimen. They are difficult to distinguish; crystal forms, color, luster, streak and fracture are all very similar. Loellingite is somewhat softer and denser. Loellingite is steel-gray to silver-white, luster metallic; streak is gray black; hardness 5-5 1/2; specific gravity approx. 7.1-7.5; a basal cleavage is rarely distinct. Habits: Brittle with uneven fracture - flat surfaces (not cleavage) fractured in an uneven pattern; massive to granular, a common texture observed in granite and other igneous rock; prismatic; crystals are usually twinned and commonly striated lengthwise. (from webmineral.com & www.galleries.com/minerals/sulfides/lollingi/lollingi.htm)

16.6 Composition of Ingodite in Eloise Vein

In samples 0441a & 0441b of Eloise Vein South (Map 1) the given ingodite formula is based on Bi(Te,S): $(Bi_{0.94}Pb_{0.02})sum_{0.97}(Te_{0.53}S_{0.50}Se_{0.01})sum_{1.04}$. On doubling the units to use the Bi_2TeS formula the composition is $(Bi_{1.88}Pb_{0.04})sum_{1.92}(Te_{1.06}S_{1.00}Se_{0.02})sum_{2.08}$. In sample 0412 of Eloise Vein North the composition based on Bi(Te,S) is $(Bi_{0.93}Pb_{0.05})sum_{0.98}(Te_{0.49}S_{0.53}Se_{nil})sum_{1.02}$ or $(Bi_{1.86}Pb_{0.10})sum_{1.96}(Te_{0.98}S_{1.06}Se_{nil})sum_{2.04}$ based on Bi_2TeS. Eloise ingodite is not plumbian ingodite with Pb about 0.30 formula units like that found in the Tyrnyauz W + Mo deposit and the Mazowe gold deposit.

Fig. 7 Typical hand specimen of Eloise Vein North with mm-sized seams of dark blue-grey Bi-Te minerals, slightly weathered. Above 3 cm mark are traces of very pale yellow-green secondary Bi minerals along recently broken fractures. Orange-yellow limonite is common on weathered fractures. With a 14X lens trace native gold is infrequently seen in the patches of the Bi-Te minerals. Site 0424 with 9.94 g/t Au (on Map 1), also EL-05 site.

16.7 Conclusion: Eloise Vein ingodite grains carry gold and silver

The conclusion of laser ablation analysis of both Eloise Vein North and South samples is that "The highest Au concentrations do not appear to be restricted to one telluride species in particular. Ingodite can be the most and least Au-enriched within individual patches (Cook et al. 2007c.)", see their figs. 4 & 10. In Eloise Vein some ingodite grains carry gold: auriferous ingodite is partly replaced by unnamed Bi_2Te and native gold (discussed below, see section 17.5 and Fig. 7).

Gold grains have high fineness; atomic ratios are $Au_{74}Ag_{26}$ in sample 0412 of Eloise Vein North and $Au_{75}Ag_{25}$ in sample 0412a of Eloise Vein South (Cook & Ciobanu Nov. 2006).

Ingodite is also Au + Ag bearing in the Nakdong As + Bi deposit (section 16.5).

17 Unnamed Bi_2Te

17.1 Unnamed Bi_2Te - especially rare

Unnamed Bi_2Te is especially rare occurring in about 7 places. "Bi_2Te has been reported by Gamyanin et al. (1980, 1982), Goncharov et al. (1984), Huang et al. (1991), Luukkonen (1994) and Gu et al. (2001) [also Shin et al. 2005 and Zachariáš et al. 2006, see below]. …In the case of Bi_2Te, the observations of Gu et al. (2001) are to be noted: '….the consistent "2:1" stoichiometry and slight difference in optical properties compared to hedleyite, joséite-B or pilsenite, lead us to infer that this may be an independent mineral.' …Our own observations are similar: Bi_2Te is conspicuous within several of the Romanian skarn deposits, and in numerous other reduced gold deposits, but it rarely exceeds a few mm in diameter. We would further reason that the incidence of Bi_2Te in nature and in synthetic studies (Abrikosov & Bankina 1958, Okamoto & Tanner 1990) is sufficiently great to suggest that a discrete mineral with this composition exists (Cook et al. 2007b, see quoted refs. within)".

17.2 Unnamed Bi_2Te localities with compositional formulae

In the **Ergelyakh deposit**, Indigirka River Basin, Saha (sp. Sakha) Republic, **Eastern-Siberian Region of Russia** "The mineral Bi_2Te was found associated with wehrlite, tellurobismuthite, and joséite-A (Fleischer & Pabst 1981)." As the ratio Bi/Te = 2.07, 2.11 the formulae are approx. $Bi_{2.07}Te_{1.0}$ and $Bi_{2.11}Te_{1.0}$.

Ergelyakh is a RIRG deposit, classed as 'Granitoid-related Au' by Nokleberg et al. 1997. The size is 'small' with average grade 0.1-90 g/t Au, 0.02-0.8% WO_3, locally up to 1.37% Bi, to 0.4% Te, and to 2% As. Variously-oriented quartz veins and stringers occur along the contact of an Early Cretaceous granodiorite and Upper Triassic metasediments (op. cit.). "Quartz constitutes 90% of the veins, which also include tourmaline, muscovite, wolframite, arsenopyrite, cobaltite, niccolite, bismuth, bismuthinite, gold, joséite, and other Te and Bi minerals. Ore bodies are cut by [later] crush belts that contain comb quartz, galena, sphalerite, Ag-tetrahedrite, and pyrargyrite that are part of epithermal veins with high Ag grades, up to 200 g/t Ag (op. cit)." The latter compare to younger phase II Pb-Ag-Mo mineralization on central CLY.

Gu et al. 2001 studied Bi-Te(S,Se) minerals from various ore deposits genetically related to Jurassic granites, notably the large-scale **Huangshaping polymetallic Pb-Zn-W-Mo deposit … Hunan Province**, **south China.** This is a skarn - magmatic hydrothermal type deposit in Carboniferous sedimentary rocks about small Jurassic plugs of felsic porphyries. It is operated by Hunan Nonferrous Metals Corp. Ltd. with significant reserves. "One of three listed electron microprobe analyses of unnamed Bi_2Te has wt percents Bi 75.60, Sb 0.16, Ag 0.03, Fe 0.01, Te 24.01, sum 99.81 wt %, giving Bi / (Te + S) = 1.93; for the other two analyses, the ratio is 2.09 and 2.11, ideally Bi_2Te. Grains are 2-10 µm in size, occurring as veinlets along the grain boundaries of pilsenite and joséite-B (Jambor 2002)".

In the **Nagkdong South Korea As-Bi deposit** five analyses of unnamed Bi_2Te have a compositional range $(Bi_{1.95-1.97}Sb_{0.02-0.03})sum_{\sim 1.97}(Te_{0.79-0.86}Se_{0.11-0.13})sum_{\sim 0.90}$ (Shin et al. 2005). The mineral has "a relatively constant Bi / (Te + Se + S) ration close to 2 (1.99-2.11) but a variable Te/ (Se + S) ratio from 5.68-8.18 with Se contents 1.6-1.9 wt %. …unnamed Bi_2Te is "placed in the intermediate compositional range between Bi_2Te and $Bi_2(Te,Se)$ (op. cit.)."

Three microprobe analyses of unnamed Bi_2Te grains from the intrusion-hosted **Mokrsko deposit in Czech Republic** [3.08 M. oz], samples Mo-10, Mo-13/1 & Mo-11/1, give the formula $Bi_{2.02}Te_{0.98}$ for the first two and $Bi_{2.03}Te_{0.97}$ for the third (Zachariáš p.c. 2006). Sb and S are nil. Bi_2Te is "younger than maldonite or native gold and older than tetradymite, joséite-A, joséite-B or bismuthinite. Joséite-A and -B are always younger than tetradymite. Bismuthinite is younger than both gold and bismuth telluride or bismuth sulphotelluride minerals (Zachariáš et al. 2006)."

At Mokrsko "The gold concentration reaches economically important tonnages (several tons of gold) with grades from 0.2 to 30 g/t and averaging 2 g/t in the whole mineralised block. Minerals of Bi (bismuth, bismuthinite, Te (hedleyite and joséite-B) and Au (native gold, maldonite $AuBi_2$ and aurostibite $AuSb_2$) occur as very small particles … observed by scanning electron microscope (Boiron et al. 2001).

In the 1.03 M. oz **Petráčkova hora deposit, Czech Republic** (Zachariáš et al. 2001 and p.c. 2006) in one polished section "a veinlet of an [unnamed] $Bi_2(Te,Se)$ cuts bismuthinite (their fig. 7C). The formula is given as $Bi_{2.3}Te$ (?). Jonassonite $Au(Bi,Pb)_5S_4$ (Paar et al. 2006) also occurs (op. cit. p. 524).

17.3 Unnamed Bi_2Te localities without compositional formulae

Trace unnamed Bi_2Te occurs in the high grade zinc and gold **Caijiaying mine in Hebei Province, China** (Huang et al. 1991). In Zone III, one of five identified mineralized zones, the current Zn resource is 23.6 Mt @ 8.08% and Au resource 2.61 Mt @ 6.78 g /t (Chang et al. 2006).

Cook & Ciobanu (Aug 2006) find unnamed Bi_2Te in the **Good Hope skarn in the Hedley district B.C.** [2.18 M. oz].

17.4 Composition of Unnamed Bi_2Te in Eloise Vein South

In the Eloise Vein South samples 0441a & 0441b (Map 1) unnamed Bi_2Te has a near-stoichiometric composition: $(Bi_{1.97}Pb_{0.02}Sb_{0.01})sum_{2.00}(Te_{0.93}S_{0.06}Se_{0.01})sum_{1.00}$. Pb Sb S & Se are near absent.

17.5 Native gold forms 'gold coronas' at ingodite - unnamed Bi_2Te grain boundaries in Eloise Vein South

In Eloise Vein South unnamed Bi_2Te partly replaces cores of auriferous ingodite with formation of native gold grains, displaying prominent 'gold coronas':

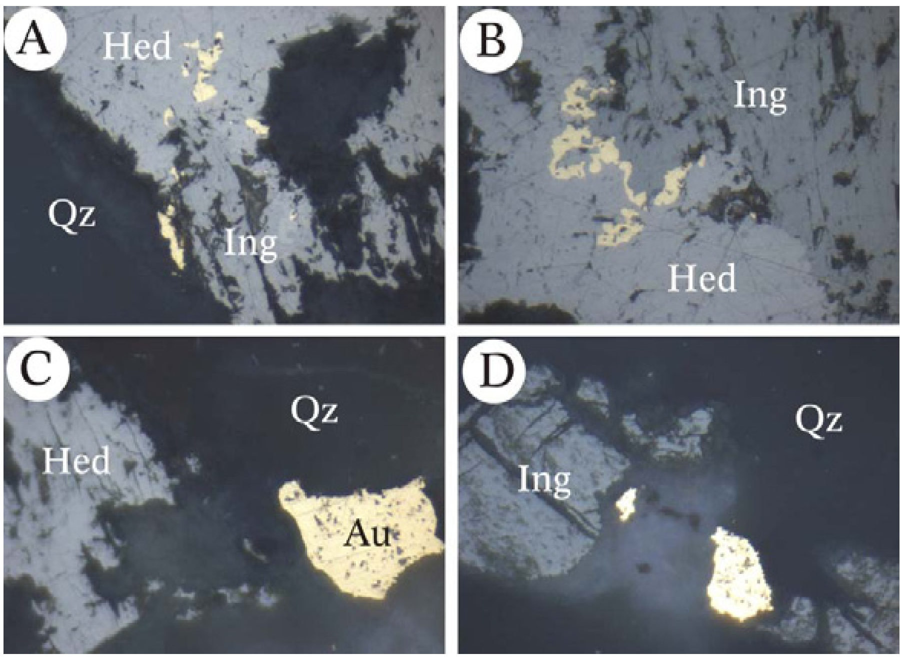

Fig. 8 Reflected light microscope images showing assemblages of gold and Bi-minerals in Eloise Vein South sample 0441. Initially hedleyite Hed was identified; further work confirms this as unnamed Bi_2Te. Ing: ingodite, Au: gold, Qz: quartz. Fig. 8A & 8B have a well developed corona texture at grain interfaces of ingodite–unnamed Bi_2Te with native gold deposited. Horizontal field of view is 50 µm. Fig. 3 from Cook & Ciobanu 2006.

"The mantling of ingodite by Bi_2Te and the rim of native gold formed at the boundary between the two (Fig. 2c, d) can be interpreted as replacement of ingodite that also may have released Au. This would explain the low values of Au in ingodite from this patch (0.05 ppm) relative to another in which no native gold is observed (9 ppm). …The jump over an order of magnitude in the Au signal obtained during ablation of Bi_2Te (their fig. 5) is indicative of formation of sub-micron scale inclusions of gold (Cook et al. 2007c.)."

This may be the first report of the reaction

ingodite $Bi_2TeS_{\text{with sub-microscopic Au + Ag}}$ ► unnamed Bi_2Te + native gold

in the literature. Sulfur is released. The maximum gold content of the 23 spots ablated by LA-ICP-MS analysis is 57 ± 8 ppm Au in unnamed Bi_2Te from Eloise Vein South. Two other analyses give 3.6 ± 0.7 and 6.8 ± 1 Au ppm (op. cit., fig. 3).

18 Does Jonassonite $Au(Bi,Pb)_5S_4$, a new gold + bismuth mineral, occur on CLY?

Jonassonite is a newly named and characterized gold + bismuth sulphosalt mineral $Au(Bi,Pb)_5S_4$ (Paar et al. 2006). It is found in old mining dumps of the abandoned Nagybörzsöny deposit in the Börzsöny Mountains, northern Hungary. “Mineralization is hosted by Miocene calc-alkaline volcanic rocks and occurs as a stockwork in a propylitized dacite breccia pipe (op. cit.).

“In [five] occurrences, jonassonite is part of a pronounced Bi association: either Bi-sulfosalts (e.g. Nagybörzsöny northern Hungary), Bi-tellurides (Yakutia Russia), or both sulfosalts and tellurides (Highiş Romania occurrence). Although the phase is generally only present as a trace constituent, **it can also form mineable concentrations**, for example in the New Occidental deposit, Cobar District, NSW, Australia (called ‘newoccidentallite’ by Stegman 2001). We note that in these occurrences, both native bismuth and native gold are present (Ciobanu et al. 2006a).”

In the Cobar deposits stage 2 gold-bismuth mineralization is overprinted by stage 3 fine-grained gold (850-900 fineness), bismuthinite (Bi_2S_3) and “newoccidentallite” (Bi_5AuS_4), properly the new mineral jonassonite. The latter two bismuth-bearing minerals may replace and rim earlier formed stage 2 gold, maldonite and native bismuth (Stegman 2001).

As CLY has abundant bismuth, approx. 70 times the abundance of gold (Howard 2006b), and a reduced telluride mineralogy, could jonassonite occur?

19 Triangular plot of analyses of bismuth telluride and sulphotelluride minerals in the BiTel Knoll auriferous quartz veins and their ideal formulae

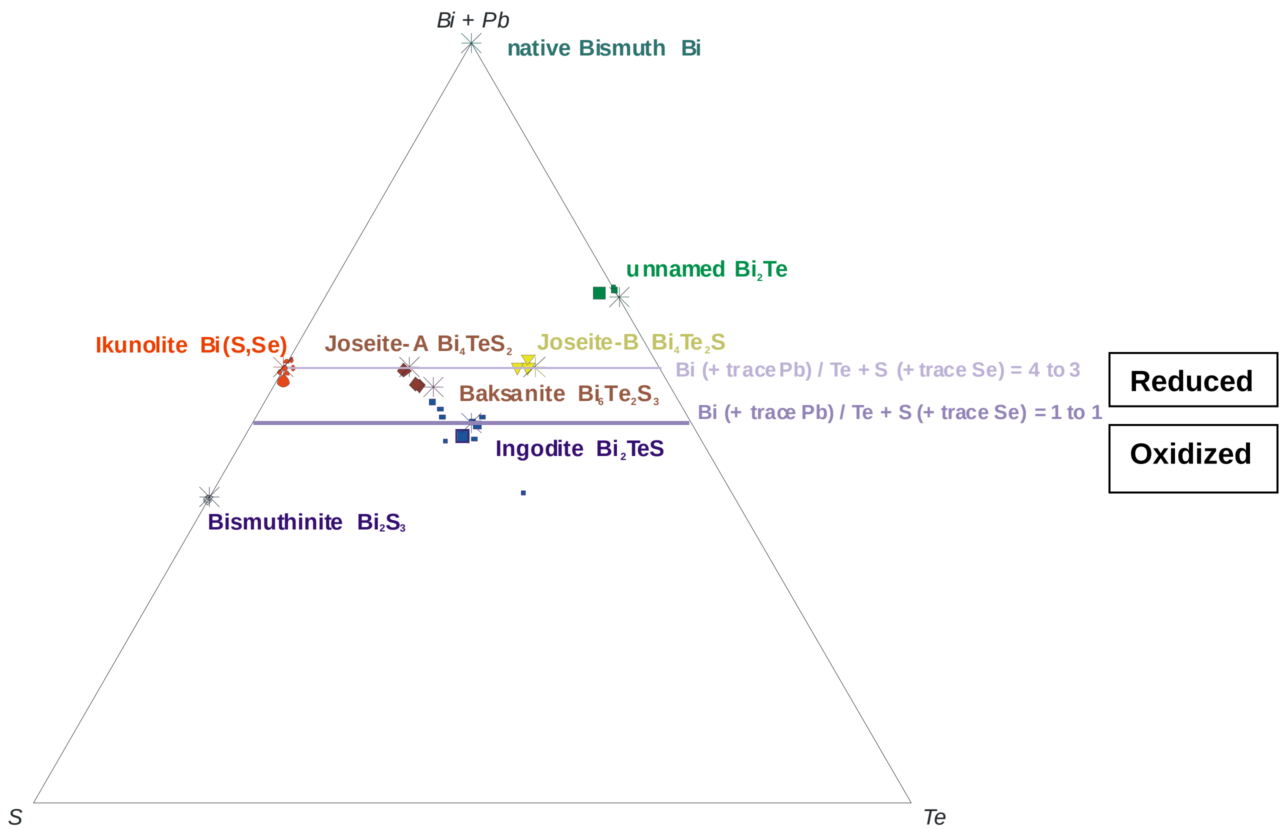

Fig. 9 Triangular plot of bismuth telluride and sulphotelluride minerals in the BiTel Knoll auriferous quartz veins in the chemical system Bi–Te–Se–S, in terms of the elements (Bi + Pb)–Te–(S + Se) at the apices.

Analyzed mineral grains are large symbols. Star symbols are ideal mineral formulae. Small symbols display range of ikunolites and ingodites from literature sources.

Blue grey line marks atomic ratio Bi (+ trace Pb) / Te + S (+ trace Se) = 1 to 1. Ratio is 4 to 3 for thin pastel blue line. Clearly Bi-Te-S mineral assemblages in the BiTel Knoll veins have ratios > 1.0 excepting bismuthinite dominant assemblages which do not occur. This is “characteristic for Au mineralization in which pyrrhotite is the stable sulphide at the time of deposition (Cook et al. 2002).

Concluding the BiTel Knoll Bi-Te mineral assemblages are chemically ‘reduced’, that is they formed in conditions of low fS_2 and low fO_2. Pyrrhotite, arsenopyrite and löllingite are expected to occur in association with native gold, native bismuth and molybdenite in the veins.

Fig. 9 was made by CSpace V1.0 freeware © Djinn Works 2000 (Torres-Roldan et al. 2000).

20 Conclusions

Electron microprobe analyses of the Au-Bi-Te-S-(Se) -bearing minerals in the BiTel Knoll quartz veins show Bi + trace Pb is more abundant than Te + Se + S in their compositional formulae (fig. 9). The minerals are 'reduced' phases (Cook et al. 2002) stable with pyrrhotite, arsenopyrite and löllingite. At BiTel Knoll varied Bi-Te mineral assemblages occur generally with native gold, native bismuth and molybdenite. These mineral assemblages formed in the pyrrhotite / magnetite stability fields. This is compatible with their setting in quartz veins in reduced graphitic metasediments near intrusive contacts with reduced ilmenite-bearing felsic granitoids.

Mineralogical research suggests that the gold-bearing blebs or patches of native bismuth + Bi-Te-S minerals in the BiTel Knoll quartz veins exsolved (crystallized) from gold-bearing Bi + Te (+S) melts. These formed in cooling Bunker Hill Sill felsic granitic magma and solidified at temperatures ~ 277°C (after Ciobanu et al. 2003). Similar conditions formed the Alaskan Fort Knox [5.4 M. oz] & Pogo [3.51] deposits and the Petráčkova hora [1.01] & Mokrsko [3.08] deposits in Czech Republic. Low Sb content of all analyzed bismuthinite grains is additional evidence that Bi-Te mineralization formed early at high temperatures at 'reduced' very low chemical activities of sulphur $fS_{2.}$ Late stage sulphidation in cooling hydrothermal solutions may be another mechanism of gold deposition.

Microprobe analyses show bismuth telluride and sulphotelluride [Bi-Te] minerals from the BiTel Knoll quartz veins in the central CLY Group claim area are near stoichiometric, meaning the mineral formulae have atomic proportions close to integer numbers. Lead is near absent except for ikunolite in the Blue Quartz Vein. Because bismuth contents are high in the central CLY area other rare Bi-Te minerals may be expected, e.g. jonassonite $Au(Bi,Pb)_5S_4$ (Paar et al. 2006) as identified in Petráčkova hora (Zachariáš et al. 2001).

LA-ICP-MS microanalysis shows "Au contents [of four Bi-Te minerals from Eloise Vein North] are higher [than five minerals from Eloise Vein South] by at least one order of magnitude[17]. Gold content in bismuthinite is comparable to that in coexisting tellurides. The highest Au concentrations do not appear to be restricted to one bismuth telluride species in particular. Gold content in bismuthinite is comparable to that in coexisting tellurides. Fig. 7 is a photo of a typical hand specimen of Eloise Vein North.

Ingodite in Eloise Vein South carries submicroscopic 'dissolved' gold to 57 ± 8 ppm. Some grains are partially altered forming native gold at unnamed Bi_2Te / ingodite boundaries. The 'gold corona' texture displaying this is quite pronounced (figs. 7A, 7B). Thus some ingodite must be early formed. Ingodite can be the most and least Au-enriched within individual Bi-Te mineral patches (Cook et al. 2007c). Eloise ingodite is not plumbian ingodite like that found in the Tyrnyauz W + Mo deposit or the Mazowe gold mine with Pb about 0.30 formula units.

Gold grains have high fineness; atomic ratios are $Au_{74}Ag_{26}$ in sample 0412 of Eloise Vein North and $Au_{75}Ag_{25}$ in sample 0412a of Eloise Vein South (Cook & Ciobanu Nov. 2006).

In the Blue Quartz Vein early formed native bismuth is replaced by any of the assemblages: ikunolite / ikunolite + joséite-A / bismuthinite / unnamed Bi_2Te + joséite-B.

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[17] **this also roughly concurs with Acme Analytical metallic screen fire assay analyses on ~500 g samples, 8.6 vs. 26 g/t Au see table 1**

A Tertiary Eocene overprint of the mid Cretaceous RIRG mineralization on CLY may have re-crystallized and redistributed native gold. This is advantageous to the possible formation of an economic gold deposit (Ciobanu et al. 2006b). As they are overprinted by fracturing the quartz veins are expected to have discrete Au-rich parts.

The 1.03 M. oz **Petráčkova hora deposit in Czech Republic** (Zachariáš et al. 2001, 2006, p.c. 2006) **has Bi-Te mineralogy similar to CLY** with minor ingodite and trace unnamed Bi_2Te. There quartz veins are "characterized by low sulfide content, native gold with auriferous Bi-Te minerals and no visible alteration (Zachariáš et al. 2006)." Petráčkova hora has all criteria of an *Intrusion-hosted* RIRG gold deposit. The Bi:Au ratio of 74.8 to 1, a very high Bi-Au correlation of +0.892 with max 5,625 ppm Bi[18] is much like CLY at ~ 76 to 1, +0.969 and > 2,000 ppm Bi. This is >0.2%, ore grade for bismuth.

Ingodite in Eloise Vein is only the third occurrence in North America. Very comparably, of 13 Bi-Te minerals in the Liese Zone of the 3.51 M. oz **Pogo deposit in Alaska** (Rombach et al. 2002, 2004) 7 Bi-Te occur in five microscopic mounts of the only eight prepared. Mineralogical research infers conditions of formation are markedly similar.

Trace ingodite, ikunolite and unnamed Bi_2Te also occur very sparsely in some researched intrusion-linked 'contact metasomatic' polymetallic deposits of any of Sn Mo W Bi Pb Zn Ag worldwide. Intriguingly three of these occurrences are in very large ore bodies (ikunolite in Vysokogorsk tin deposit and Vostok-2 skarn scheelite–sulphide tungsten deposit, ingodite in Tyrnyauz tungsten + molybdenum deposit, all in Russia). Why do these peculiar minerals denote high prospectivity for very large polymetallic mineral deposits, as well as well-endowed gold deposits?

It is surprising that these especially rare minerals occur in 5 of the polished sections (Table 1) of the only 8 prepared from surface samples of two partly outcropping quartz veins. The area is generally well covered.

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[18] 11 selected grab samples from J. Zachariáš p.c. 2005 & 2006

21 Appendices

Appendix 1 Rossland Camp
Appendix 2 Claim list
Appendix 3 Itemized Cost Statement
Appendix 4 Statement of Qualifications for Prof. Nigel John Cook
Appendix 5 Statement of Qualifications for Dr. Cristiana Ciobanu
Appendix 6 Statement of Qualifications for William R. Howard
Appendix 7 Mineralogy of Nakdong As + Bi deposit in South Korea

21.1 Appendix 1 Rossland Camp

"The Rossland Camp is the second largest gold producing camp in British Columbia, with 2.8 million ounces of gold produced between 1897 and the early 1940's. The majority of this production came from massive pyrrhotite veins in the interconnected, deep shaft, underground Le Roi, Centre Star, Josie and War Eagle mines in the central part of the camp.

In 1865, the Dewdney Trail was completed from Hope to the placer creeks in the East Kootenays, and the gossan on Red Mountain at Rossland attracted the attention of early travellers. The first lode claims were not staked in the area until 1887 however, and there was little activity until 1890. In the summer of 1890 the prospectors Bourjois and Morris located in one day the Le Roi, Centre Star, War Eagle, Idaho and Virginia claims. The Le Roi claim was given to E.S. Topping for paying the recording fee on the claims. Topping obtained specimens from the property and proceeded to Spokane. News of the strike was out and most of the claims at Rossland were staked within the next month.

For the first few years development was slow, due partly to lack of transportation. A small shipment of ore was made from the camp in 1891 to an American smelter, then in 1893 a second small shipment was made to Trail. Construction of the smelter at Trail and a tramway to connect the smelter to the mines at Rossland was started in 1895, and the smelter was blown in early in 1896….

Production … reached a peak of 360,000 tons per year in 1903. In 1906 the War Eagle and Centre Star Mines of Rossland joined with the St. Eugene Mine on Moyie Lake and the smelter at Trail to form the Consolidated Mining and Smelting Company. In 1910, the Le Roi Mining Co. sold its interests to the Consolidated Mining and Smelting Company, and closed its smelter at Northport. Production continued from the Rossland veins until 1928, although the rate of mining declined sharply after 1917. In the 1930's and early 1940's, lease miners continued small scale mining from the main deposits (Brock, 1906; Gilbert, 1948; Fyles, 1984)." These extracts from L. Caron (2003) with permission.

21.2 Appendix 2 Claim list

Table 1A: Details on the CLY Group new tenure mineral claims in Nelson Mining District, southernmost British Columbia, Canada.

New Tenure Numbers	(Legacy) Claim Name	Owner number	Work recorded, Good Standing to	Area, hectares
*516587	(CLY 1)	112341	2009.11.11	740.880
*516584	(CLY 2)	112341	2009.11.11	740.853

* These two claims totally surround the 2 Crown Grants (Table 1B following)

Table 1B: Details on the tenure of CLY Group Crown Grant Mineral Claims in the Pend d'Oreille River area, Kootenay Land district, British Columbia, Canada

Lot name	Lot number	area (hectares)	NTS map sheet	BCGS map sheet	Land district
Bunker Hill	2939	12.08	082F03W	082F.004	Kootenay
Mormon Girl	1949	17.65	082F03W	082F.004	Kootenay

Crown Granted. **Both administered from Kamloops, B.C.,** subject to annual taxes (current).
Crown Grants state one quarter of each claim surface area can be used for road building for mining purposes.

21.3 Appendix 3 Itemized Cost Statement

In period Oct. 20 2006 – Dec. 31 2006

Nov. 12 2006 Costs for mineralogical/microanalytical study of polished blocks of the CLY sample suite, samples 'Eloise' of Eloise Vein South and 0412a, 0412b both from Eloise Vein North and Blue Qtz Vein sample 0414b by C. Ciobanu & N. J. Cook (Prof.) at Adelaide Microscopy, Adelaide, South Australia as detailed in the report 'Short report on electron probe microanalysis on samples' 2 p. [included]

	484.64
reduced by ¼ [Blue Qtz Vein sample 0414b on Mormon Girl C.G.]	-121.16
Subtotal	363.48

In period Jan. 1 2007 – Oct 31 2007

Aug. 10 2007 Costs for preparation of the scientific publication 'Bi-tellurides in gold veins, BiTel Knoll…' 7 p. (Part II of this AR), a full summary of the mineralogical work

N.J. Cook	2,400.00
C.L. Ciobanu	1,050.00
	3,450.00
reduced by ¼ [Blue Qtz Vein sample 0414b on Mormon Girl C.G.]	-862.50
Subtotal	2,587.50

Aug. 2007 Costs for preparation of the scientific publication 'Telluride assemblages in a Reduced Intrusion-Related Gold (RIRG) Deposit, CLY Group… ' 1 p. (Part III of this AR), an abstract of the mineralogical work, Paper #130211 at GSA Denver Annual Meeting Oct. 28-31 2007

W.R. Howard	
N.J. Cook	
C.L. Ciobanu	not included

Oct. 2007 Costs to prepare this Assessment Report	
W. Howard 2 days @ $500/day	1000.00
Subtotal	1000.00

Total in period Sept. 12 2006 – Oct. 2007	$ 3950.98
(items discussed with A. Wilcox Oct. 11 2007)	

Misc. office expenses incurred but not charged

21.4 Appendix 4 Statement of Qualifications for Prof. Nigel John Cook

Nigel John Cook, a British citizen, was born in 1960 and is based at the Natural History Museum (Geology) in Oslo, Norway. After receiving his B.Sc. and Ph.D. degrees from the University of London, he worked as postdoctoral researcher in Canada (1987-1990) and later (1991-1998) in Germany, where he also obtained his Habilitation. He joined the Geological Survey of Norway in 1998, serving as leader of the Mineral Resources Section until 2001. He joined the University of Oslo in 2004 as Assistant Professor and was awarded a full professorship in 2005.

His research interests span both mineralogy and ore deposit studies and he is particularly interested in using detailed mineralogical investigation at the micro- and nanoscopic scales to understand ore-forming processes. Field work has taken him to many parts of the world, but he has been most active in Scandinavia and Southeastern Europe, investigating massive sulphide, skarn and epithermal deposits. More recently, he has developed a number of research projects addressing mineral systematics, structures and, in particular, non-stoichiometric minerals.

Nigel has been Secretary General of IAGOD since 2000 and Editor-in-Chief of the IAGOD journal, ‘Ore Geology Reviews’ since 2003. He is currently also Chairman of the IMA Commission on Ore Mineralogy and leader of International Geological Correlation Programme (IGCP) project 486 (2004-2008) and non-permanent Associate Professor at the University of Turku, Finland.

IGCP project 486 “focuses on studies of all types of Au-Ag-telluride-selenide mineralizations and their ore deposits and attempts to bridge the gap between scientists working in the laboratory and those working in the field from the microscopic- to orogen-scales. The project aimed to understand geological processes causing accumulations of Au (± Ag) with Te and Se over space and time, the mineralogy of these deposits and the internal and external controls on metal and mineral distributions.”

Nigel is the author of ca. 70 publications and more than 125 conference contributions on subjects ranging from nanoscale mineralogy to regional metallogenesis, and from platinum group elements to industrial minerals.

Aside from being a co-author of two of the abstracts listed in Appendix 5 for Dr. C.L. Ciobanu, Nigel Cook is the lead author of the recent important review papers ‘Compositional data for Bi-Pb tellurosulfides’ and ‘Minerals of the system Bi-Te-Se-S related to the tetradymite archetype: review of classification and compositional variation’ published in 2007 in volume 45 of the Canadian Mineralogist.

21.5 Appendix 5 Statement of Qualifications for Dr. Cristiana L. Ciobanu

Dr. Cristiana L. Ciobanu has co-written with Prof. N. J. Cook many published scientific papers on telluride mineralogy. She was a co-convener of the IGCP-486 scientific session 'Metallogeny of Au-Ag-Se-Te Mineralised Systems' during the 7th Biennial Meeting of the Society for Geology Applied to Ore Deposits titled ‘Mineral Deposit Research: Meeting the Global Challenge’ held in Beijing, China, August 20-23 2005.

Dr. Ciobanu is a co-author of the paper ‘Bismuth tellurides as gold scavengers’ with Nigel. J. Cook & Allan Pring, p. 1383-1386, and ‘Tellurides in Au deposits: Implications for modeling’ with Nigel J. Cook, p. 1387-1390. These are both in the conference text ‘Mineral Deposit Research: Meeting the Global Challenge’ ed. Mao, J.W. et al., 2005, published by Springer, Berlin-Heidelberg-New York, 1613 pp.

Recently she is the co-author of the paper “Tellurides from Sunrise Dam gold deposit, Yilgarn Craton, Western Australia: a new occurrence of nagyágite” in the journal ‘Mineralogy and Petrology’, volume 91, numbers 3-4, pub. Nov. 2007 by Springer Wien. Dr. Ciobanu is also the co-author of the first two and the lead author of the third presented abstracts WHAT MAKES A GOLD-TELLURIDE DEPOSIT? Paper No. 72-1, MODELLING MELTS IN HYDROTHERMAL SYSTEMS - THE LIQUID BISMUTH COLLECTOR MODEL Paper No. 72-4, and CAN TELLURIDES RECORD CHANGES IN FLUID CHARACTERISTICS? THE EXAMPLE OF NAGYÁGITE Paper No. 72-9 all presented at the GSA Denver Annual Meeting 28–31 October 2007 Session No. 72 Au-Ag-Te-Se Deposits and Other Precious Metal Deposits. She was also co-convener of this session.

Dr. Ciobanu is a co-author of the recent important rrview papers ‘Compositional data for Bi-Pb tellurosulfides’ and ‘Minerals of the system Bi-Te-Se-S related to the tetradymite archetype: review of classification and compositional variation’ published in 2007 in volume 45 of the Canadian Mineralogist.

Since 2005 Dr. Cristiana Ciobanu has been a Research Fellow at the South Australian Museum and the School of Earth and Environmental Sciences, University of Adelaide, North Terrace, Adelaide, South Australia, 5000, Australia.

21.6 Appendix 6 Statement of Qualifications for William R. Howard

I graduated in 1978 from the University of Alberta with a B.Sc. Honours with distinction in Geology. Thereafter I prospected at Dublin Gulch, Yukon for Canada Tungsten Mining Corp. in 1980 in the area of the Ray Gulch tungsten skarn during its exploratory drilling. This was before the discovery of the M. oz Eagle Zone gold deposit (StrataGold Corp.). A few years later I worked briefly for Noranda at the intrusion-related Marn gold skarn NE of Dawson City Yukon.

In 1997 I purchased the Bunker Hill and Mormon Girl Crown Grants. In 1999 the Bunker Hill project on the present CLY Group claims was awarded a BC Prospectors Assistance Program grant for $10,000 (Howard 2000). I have attended numerous conferences, field trips and courses on mineral exploration including

> 1997 Numerical techniques and strategies for evaluation of geochemical data by E.C Grunsky, 145 pp. Part of Exploration '97 Workshop: Current topics in GIS and Integration of Exploration Datasets Sept. 9 - 13 1997, Ottawa, Ont.
>
> 1999 Short Course on Intrusion-related Gold by Kamloops Exploration Group [KEG] April in Kamloops BC
>
> 2004 Short Course 'Gold Vein Deposits: Turning Geology into Discovery' by D. Rhys & P. Lewis. Cordilleran Exploration Round-up Jan. 24 – 25 2004 Vancouver BC
>
> 2005 Short Course 'Orogenic vs. Intrusion-Related gold' with emphasis on Yukon and Alaska deposits by C. Hart of Yukon Geological Survey & R. Goldfarb of USGS. at Minerals South 2005 Conference Oct. 25 - 27 2005, Cranbrook BC
>
> 2006 Private field trip to RIRG gold deposits in the Czech Republic near Prague: Mokrsko [3.08 M. oz] and Petráčkova hora [1.03 M. oz] with Dr. J. Zachariáš
>
> 2007 August 26-31 attended the International IGCP-486 Field Workshop on Au-Ag telluride-selenide deposits at GTK, Espoo Finland. Presented paper 'Structural setting and geochemical correlations in bismuth (sulfo)telluride - native gold–bearing veins, CLY group, British Columbia, Canada: A reduced intrusion-related gold system' at Symposium & Field trip
>
> 2007 Oct. 28-31 attended the Geological Society of America Denver Annual Meeting October 2007. Symposium & Field trip to the Cripple Creek gold mine, leaders E. Jensen & P. Spry in conjunction with IGCP-486
>
> 2008 Jan. 28-31 Mineral Exploration Round-up 2008 Vancouver BC and February 1-2 Short Course 'Understanding Mineralization Controls: Applied Structural Geology to 3D Modelling and Mining'
>
> 2008 April 15-18 Poster Presentation at 17th Annual Calgary Mining Forum, Calgary Mineral Exploration Group

I have been involved in prospecting in the Canadian Cordillera since 1976 and the Nelson Mining Division since 1988.

21.7 Appendix 7 Mineralogy of Nakdong As + Bi deposit in South Korea

As there are few descriptions of economic bismuth mineralization in the literature, the following excerpts are included for the reader from Shin et al. 2004 'Hydrothermal arsenic and bismuth mineralization in the Nakdong deposits, South Korea: Fluid inclusion and stable isotope studies', p. 1465-1481 in The Canadian Mineralogist Vol. 42.

Both unnamed Bi_2Te and ingodite occur in the Nakdong deposit (Shin et al. 2005), though note it has considerably more {poisonous} arsenic than CLY and is base metal-bearing.

"The Nakdong deposit contains > 20,000 tonnes of sulfide ore (mined + estimated reserves) grading 26.6% As and 0.58% Bi (KMPC 1974). The major bismuth-bearing orebody is [only] 5 m wide and 40–50 m in length (Shin et al. 2004)." Mineralization is genetically associated with numerous dykes of Cretaceous Jeongseon granitic rocks <100 m wide and <8 km in length. These intrude Ordovician age dark grey platey limestones with dolomite interbeds. Mid Cretaceous tectonism re-activated pre-existing extensional fractures and strike-slip faults (op. cit.).

This is very similar to CLY's geologic-structural setting. In contrast central CLY has very little copper, lead and zinc minerals and abundant non-poisonous bismuth in contrast to abundant arsenic at Nakdong.

At Nakdong early arsenopyrite, pyrite, sphalerite and minor chalcopyrite bearing quartz veins are replaced by Stage II quartz veins with

> "…open vugs with quartz crystals and calcite. Gangue minerals mainly consist of quartz (>80%), calcite, and small amounts of prismatic or acicular tremolite and tabular phlogopite. Ore minerals generally comprise less than 5 volume %. [Stage II] pyrrhotite, chalcopyrite, galena, bismuth minerals, Au–Ag alloy, and argentite were formed, as well as pyrite. They commonly replaced the Stage-I arsenopyrite and pyrite. The pyrrhotite is strongly anisotropic and *magnetic*, and is partly altered to marcasite and has a bird's-eye texture.
>
> Chalcopyrite is closely associated with pyrrhotite, galena, and native bismuth. Lead-gray to tin-white bismuthinite has a metallic lustre and weak lamellar twinning, and usually occurs as anhedral grains. Minerals containing Pb–Ag–Bi–S, such as cosalite and galena–matildite solid solutions, are also observed.
>
> Au–Ag alloy associated with native bismuth infills cracks in pyrite; the grain size ranges from 30-80 microns in general and in some cases 200 microns. [Native gold ranges from] 21.7 to 68.1 atom % Au. Argentite, coexisting with pyrrhotite, is present in trace amounts and also infills cracks in pyrite.
>
> Native bismuth occurs in small veinlets replacing arsenopyrite and pyrite. It coexists together with chalcopyrite, galena and pyrrhotite and ranges generally from 30-50 microns, up to 600 microns. Smoky calcite and quartz were precipitated during Stage III, which is barren of sulfides."

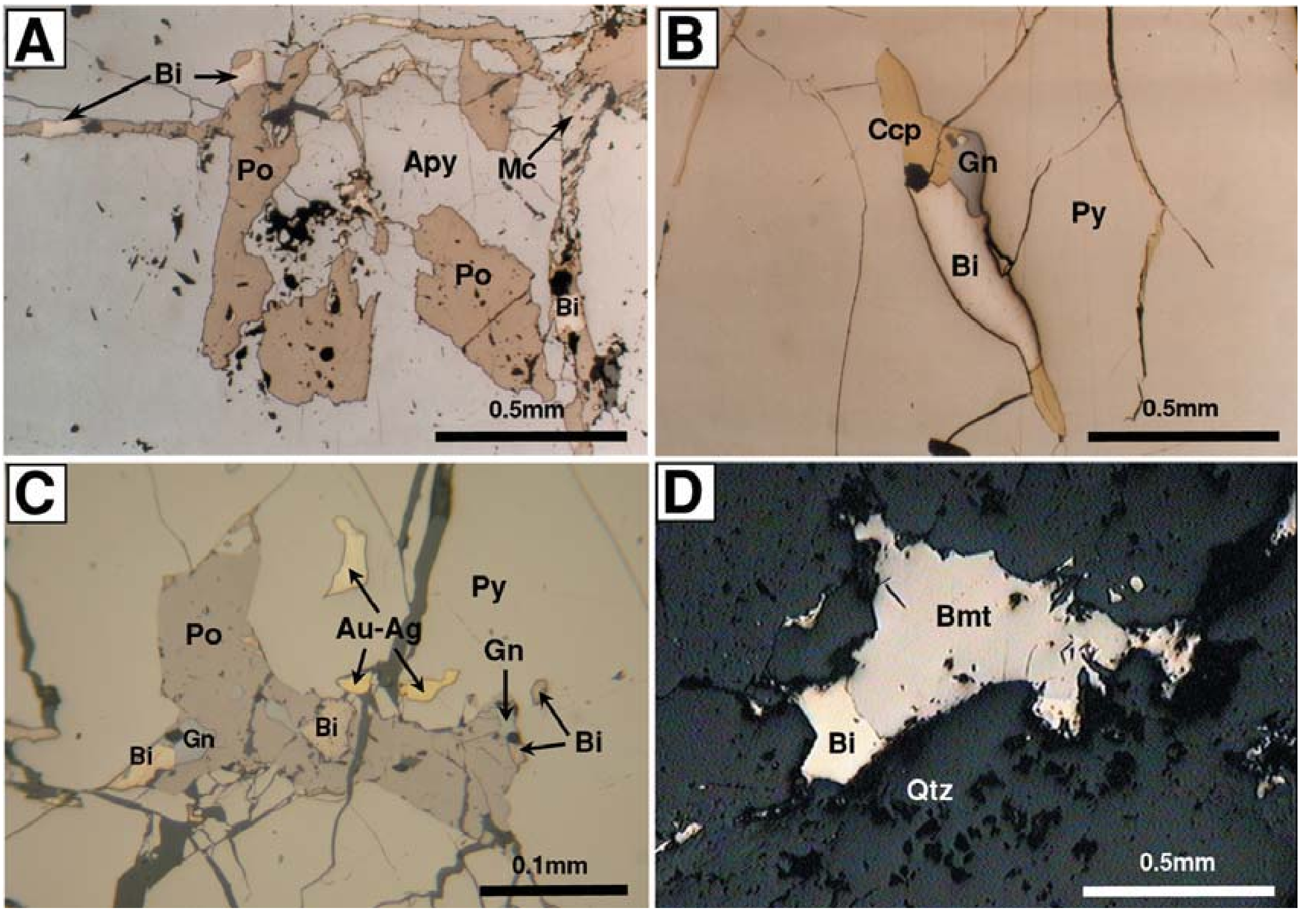

Fig. 3 of Shin et al. 2004, Microphotographs showing ore mineral assemblages from the Nakdong deposits. **A.** Arsenopyrite (Apy) replaced by pyrrhotite (Po) and native bismuth (Bi), marcasite (Mc) formed from pyrrhotite. **B.** Pyrite (Py) replaced by the assemblage of chalcopyrite (Ccp), galena (Gn) and native bismuth. **C.** Au–Ag alloy (Au–Ag) associated with pyrrhotite, native bismuth and galena in pyrite. **D.** Coexistence of bismuthinite (Bmt) with native bismuth (Bi).

A further study (Shin et al. 2005) finds Stage II Bi–Te–Se minerals include joséite-A, selenian joséite-B, unnamed Bi_2Te and ingodite. Like in Eloise Vein neither joséite-A nor joséite-B contacts ingodite. Rather bismuthinite grains are adjacent to ingodite (op. cit.).

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The occurrence of apparently stable pyrite–pyrrhotite and bismuth–bismuthinite assemblages suggests that deposition took place in a system closed with respect to sulphur [?]. Arsenopyrite, gudmundite(?), cassiterite, wolframite, gold and pyrargyrite occur."

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Electron microprobe analyses of 5 samples from the 2 localities gave Bi 68.8-73.3, Pb 0-1.2, Sb 0-0.15, Te 19.3-25.3, S 5.1-6.3, Se 0-0.4, sum 99.1-100.3%, giving the formula above. … Ingodite is silver-white, luster metallic, cleavage perfect, nonmagnetic, brittle, soft. …The name is for the locality. (precise formulas are not given in this review)

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"This paper looks at Bi/Au as a function of formation depth and distance from known or suspected causative intrusions. It relates this variable to the gold-associative mineralogy present in the different deposits. The data indicate that the strongest Bi–Au correlation and highest Bi/Au in the Fairbanks district are at Fort Knox, which in relation to other deposits **is hosted in the largest, deepest-emplaced intrusion; contains the most early higher temperature sheeted and/or stockwork veins**; and has the least shear-hosted gold ore contained in the surrounding schist.
Early high-temperature stockwork veins at the Fort Knox and Dolphin deposits contain the mineral maldonite Au_2Bi as well as wormy Bi-Au intergrowths suggestive of maldonite exsolution. **Because bismuth is nonrefractory as pertains to cyanide, the associated gold is thus highly amenable to cyanide leach.** *This suggests that a high Bi–Au correlation, together with a low arsenic content, may be predictive of ore that is more easily beneficiated".

abstract
"Plutonic-related" gold deposits in Interior and SW Alaska (Tintina Gold Belt) vary significantly in size, grade, vein/deposit morphology, depth of emplacement, distance from causative pluton and metal association. Metal associations such as Au–Bi and Au–As–(Sb–Hg) are a good empirical indicator of the depth of emplacement and distance from causative pluton. These associations have been used successfully in exploration. Results from several analytical techniques also suggest a phenomenological cause for these metal associations. Gold and bismuth have paired mineralogy at high temperatures and, thus, are best correlated (i.e. highly associated) at deposits that are deep and/or close to causative intrusions.

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"A late association of a number of Bi-minerals is notable in the ores, namely native bismuth, bismuthinite, tetradymite (Bi_2Te_2S), cosalite ($Pb_2Bi_2S_5$) with distinct Ag contents (0.49-1.95 wt % Ag, n=10), joséite-A (Bi_4TeS_2) and ingodite (Bi_2TeS)" with analytical formula $(Bi_{1.476}Pb_{0.319}Fe_{0.215})\Sigma_{2.009}Te_{0.885}S_{1.100}\Sigma_{1.985}$ (from their Table 2).

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http://www.geofuel.lviv.net/MISCEL/MPSab/sab048.htm
"Recent experiments on the partitioning of Au between hydrothermal solutions and liquid bismuth show that, above its melting point (271 °C), liquid Bi is a powerful scavenger for gold from gold-undersaturated hydrothermal solutions, especially when fS_2 is below the pyrrhotite / pyrite buffer (Douglas et al. 2000)… We believe that liquid Bi may scavenge other chalcogenides (e.g. Te) in a comparable way as for Au, precipitating them as blebs of {gold – bismuth tellurides}. The resulting assemblages, in which minerals of the Bi–Te–Se–S system typically have Metal / (Te + S + Se) >1 (e.g. hedleyite Bi_7Te_3, joséite-B Bi_4Te_2S and ikunolite $Bi_4(S,Se)_3$), are characteristic for Au in which pyrrhotite is the stable sulphide at the time of deposition, not uncommonly also with selenides and other, e.g. Ag-, tellurides (Ciobanu & Cook 2002). Similar gold-bismuth tellurides associations occur … in Au skarns worldwide (Meinert 2000). The presence of gold [with] bismuth tellurides can therefore be considered highly indicative for Au enrichment in deposits in which bismuth can be precipitated at higher temperatures than its melting point, even in the absence of boiling processes (Cook et al. 2002)".
"The absence of maldonite Au_2Bi … constrains the temperature range for the episode of Au–Bi precipitation from the fluids at between ~ 370-240 °C … Te-bearing Bi-rich melts crystallize at the point of metallic bismuth stability (271 °C), or closely thereafter …"

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Unnamed Bi_2Te
"One of three listed electron microprobe analyses has Bi 75.60, Sb 0.16, Ag 0.03, Fe 0.01, Te 24.01, sum 99.81 wt %, giving Bi / (Te+S) = 1.93; for the other two analyses, the ratio is 2.09 and 2.11, ideally Bi_2Te. Grains are 2-10 µm in size, occurring as veinlets along the grain boundaries of pilsenite and joséite-B in material from the Huangshaping Pb-Zn polymetallic deposit, about 45 km west of the city of Chengzhou, Hunan Province, China. Bright white color with a yellowish tint in reflected light, distinct bireflectance and anisotropism, optically similar to pilsenite."

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excerpt
"This paper looks at Bi/Au as a function of formation depth and distance from known or suspected causative intrusions.
It relates this variable to the gold-associative mineralogy present in the different deposits. The data indicate that the strongest Bi–Au correlation and highest Bi/Au ratio in the Fairbanks district are at Fort Knox, which in relation to other deposits , is hosted in the largest, deepest-emplaced intrusion; contains the most early higher temperature sheeted and/or stockwork veins; and has the least shear-hosted gold ore contained in the surrounding schist.
Early high-temperature stockwork veins at the Fort Knox and Dolphin deposits contain the mineral maldonite (Au_2Bi) as well as wormy Bi-Au intergrowths suggestive of maldonite exsolution. Because bismuth is nonrefractory as pertains to cyanide, the associated gold is thus highly amenable to cyanide leach.
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abstract
'Plutonic-related' gold deposits in Interior and SW Alaska (Tintina Gold Belt) vary significantly in size, grade, vein/deposit morphology, depth of emplacement, distance from causative pluton and metal association. Metal associations such as Au-Bi and Au-As-(Sb-Hg) are a good empirical indicator of the depth of emplacement and distance from causative pluton.
These associations have been used successfully in exploration. Results from several analytical techniques also suggest a phenomenological cause for these metal associations. Gold and bismuth have paired mineralogy at high temperatures and, thus, are best correlated (i.e. highly associated) at deposits that are deep and/or close to causative intrusions.

Rombach, C.S., Newberry, R.J., Goldfarb, R. & Smith, M. 2002 Geochronology and Mineralization of the Liese Zones, Pogo Deposit, Alaska.
The Geological Society of America (GSA) 2002 Denver Annual Meeting (October 27-30 2002) Session No. 52
http://gsa.confex.com/gsa/2002AM/finalprogram/abstract_45183.htm
abstract
Checked √ occur on central CLY Gp in surface samples:

The Pogo deposit, located 145 km east of Fairbanks in east-central Alaska, consists of Au-As-Bi-Te mineralization in four or more stacked, sub-parallel, low-angle, shear zone-hosted, quartz veins (termed Liese zones) that cut Paleozoic and older gneiss and schist of the Yukon-Tanana terrane. The current resource estimate is 10.7 Mt at an average grade of 0.52 oz/t, for a resource of 5.6 M. oz Au. Liese quartz veins contain ~3% sulfide minerals (arsenopyrite-pyrite-pyrrhotite) [all in Lefevre skarn √], with the majority as linear bands that are sub-parallel to the vein-wallrock contact and define multiple fluid pulses. The bismuth-gold mineralogy includes (in order of abundance): joséite-B (Bi_4Te_2S) √, gold (fineness 850-1000) √, tetradymite (Bi_2Te_2S), pilsenite (Bi_4Te_3), native bismuth Bi √, bismuthinite (Bi_2S_3) √, ingodite (BiTeS) √, hedleyite (Bi_7Te_3) √, sulphotsumoite (Bi_3Te_2S), joséite-A (Bi_4TeS_2) √, maldonite (Au_2Bi), tsumoite (BiTe), and baksanite ($Bi_6Te_2S_3$).

Measured arsenic compositions of arsenopyrite vary from 30.4-37.2 atomic %; most are 35-37. The high-arsenic arsenopyrites occur with loellingite and pyrrhotite (T = 450-600 °C). The low-arsenic arsenopyrites occur with pyrite (T = <450 °C).
Along with evidence for some arsenopyrites in disequilibrium with pyrite, and alteration of pyrrhotite to pyrite and marcasite [yes], these data indicate a change from very low fS_2 and/or high T (loellingite-pyrrhotite stable) to higher fS_2 and/or lower T (pyrite stable) over time.

Fluid inclusions in quartz from the main Liese veins are low salinity, liquid- and vapor-rich aqueous (T_h= 174-247 °C; 2-5 wt% NaCl eq.), saline aqueous (T_h= 188-348 °C; 14-18 wt% NaCl eq.), and aqueous-carbonic (T_h= 140-340 °C; 3-46 mol% CO_2>>CH_4). Several extension veins that splay off of the Liese veins contain more saline inclusions (T_h= 175-328 °C; 30-34 wt% NaCl eq.), with one or two daughter minerals and coexisting inclusions that exhibit properties of pure CH_4. (Note T_h is uncorrected for pressure). MoS_2 √ from the Liese vein has a Re/Os age of 104 Ma, which is 5-12 Ma younger than the age of last metamorphism (U-Pb, zircon) and constrained by Ar/Ar (hornblende) and U-Pb (zircon) ages of nearby intrusions (~107 Ma and 95-92 Ma). Biotites from intrusions, gneiss, and wall rock in quartz yield Ar/Ar ages of ~92 Ma, presumably due to thermal reset from the former intrusions.

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Baker, T. 2003b Intrusion related gold deposits; Classification, characterization and exploration: Society of Economic Geologists Regional VIP Lecturer Presentation
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http://pubs.nrc-cnrc.gc.ca/mineral/tcm-147541-6.html
Baksanite is ideally $Bi_6Te_2S_3$. “A sample of Pb-rich baksanite was recovered in a magnetite-andradite skarn from the Tyrnyauz W-Mo deposit, in the northern Caucasus … Russian Federation. Associated minerals are bismuthinite, tetradymite, joséite-A and ingodite; gangue minerals are calcite and andradite”.

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Ciobanu, C.L. & Cook, N.J. 2003 Tellurides and/or selenides in Au-ores: Examples from Shield and orogenic areas.
Extended abstract in Uzbekistan Gold 2003: 'Problems of Ore Deposits and Maximizing Prospecting Efficiency'. Tashkent, Uzbekistan, 21st - 24th October 2003
http://www.ngu.no/igcp486/Gold_enrichment_and_Bi-mineral_assemblages_in_ores.htm

…telluride speciation can be readily predicted from the local redox environment at the time of crystallisation, as reflected by the observed host minerals. Modelling of trace mineralogy can therefore assist in identifying formation conditions and deposition during processes characterised by abrupt changes in physical-chemical fluid parameters.
Investigations have allowed construction of a qualitative diagram for stability of Bi tellurides in fS_2 - fO_2 space, on the basis of Bi / (Te + Se + S) ratios. This diagram has implications for discriminating overprinting events in metamorphosed terranes within shield areas, with emphasis on the behaviour of Au during remobilisation and associated Au enrichment. Bi-tellurides / tellurosulphides, in particular, are commonly found closely associated with gold, due to their incorporation within bismuth melt at temperatures >295 °C. They may thus occur in association with native bismuth, Au and/or maldonite, reinforcing experimental work showing that Bi melt acts as a powerful 'scavenger' for Au in ore-forming systems, especially when buffered by evolving fS_2 / fO_2 conditions. The overall composition of the melt / fluids and the resultant Bi-tellurides and selenides, and their Bi / (Te + Se + S) ratios, reflect the reducing / oxidizing character of the melts / fluids that introduced or modified them.

Ciobanu, C.L., Cook, N. & Pring, A. 2003 Gold Enrichment and Bi-mineral Assemblages in ores: examples from Shield and Orogenic areas.
Geophysical Research Abstracts, Vol. 5, 13549, 2003 European Geophysical Society
http://www.cosis.net/abstracts/EAE03/13549/EAE03-J-13549.pdf
Part of abstract:
"A systematic study of the distribution of bismuth tellurides / selenides in gold-enriched ores from 25 deposits in the Fennoscandian / Ukrainian Shields and in European Phanerozoic orogenic belts allows comparison of telluride [mineral] speciation and association and **construction of a qualitative diagram for bismuth telluride stability in fugacity S_2 - fugacity O_2 space on the basis of Bi[19] / (Te + Se + S) {abbreviated $R_{Bi/Te}$}.** Tsumoite (the mineral BiTe) stability separates reducing environments where bismuth tellurides with $R_{Bi/Te}$ >1 are associated with native Bi and maldonite Au_2Bi, and oxidizing environments where bismuth tellurides with $R_{Bi/Te}$ <1 are associated with Au–Ag-bearing tellurides and native tellurium. Bismuth tellurides / selenides are closely associated with gold, due to incorporation within bismuth melt above 271° C. Such melts are powerful "scavengers" for gold, especially at the main fS_2 / fO_2 buffers. Overall compositions of Bi–Te–Se–Au melts, as seen in resultant bismuth telluride/selenide [mineral] associations, reflect the reducing or oxidizing character of source fluids. Telluride speciation has implications for discriminating overprinting events, with focus on local gold-enrichment at metamorphic peaks, during retrograde stages in skarn and secondary boiling in porphyry, irrespective of age or deposit type. … "

Cook, N.J. & Ciobanu, C.L. 2003 Telluride and selenide mineralogy as a tool in understanding gold deposits.
Extended abstract in Uzbekistan Gold 2003: 'Problems of Ore Deposits and Maximizing Prospecting Efficiency'. Tashkent, Uzbekistan, 21st - 24th October 2003
http://www.ngu.no/igcp486/Telluride_and_selenide_mineralogy_as_a_tool_in_understanding_gold_deposits.html
extract:
"Non-stoichiometry and disordering of Bi and Te atoms in the structure appears a common and characteristic feature of tsumoite (also nevskite, ingodite). The implications for interpretation of analyses in the extended Bi–S–Te and Bi–S–Te–Se systems are therefore considerable. …

[19] includes Pb content

Tellurides, selenides and related compounds are good tracers of fO_2 / fS_2 buffered reactions during ore formation (e.g. magnetite-hematite, pyrrhotite-pyrite)."

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p. 256-281 Ch. 4-5 in Intrusive Gold Final Report. pub. MDRU Vancouver BC

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Yukon Geological Survey Yukon Energy, Mines and Resources
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doi:10.1016/S0016-7037(00)01279-6
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In Mining Infrastructure – A Key to Alaska's Mineral Future, abstracts of Alaska Miners Association 2003 Annual Convention
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http://www.em.gov.bc.ca/DL/GSBPubs/GeoFldWk/2003/18-Jackaman-195-198-w.pdf
INAA gold-in-stream-sediment data is colour-gridded at a regional scale.

Klapotke, T.M. & Crawford, M.J. 2004 "Tellurium" in Chemistry: Foundations and Applications.

Mudrovska, I., Cook, N.J., Ciobanu, C.L., et al., 2004 Bi-Tellurides and Orogenic Gold: Examples from the Ukrainian Shield.
Poster Presentation in session: "G14.07 - Telluride and selenide minerals related to gold- and platinum-group element deposits" 32nd Int. Geol. Congr., Florence Italy, 2004 electronic version posted on-line on July 20, 2004, Abstract. Vol., part 54, abstract 54-29
http://www.32igc.info/igc32/search/
From abstract
In the low-sulphide Mayske [sp. Maiskoe] gold deposit "Scavenging of Au by Bi melt above 271°C (the Bi melting point) is evident. Temperatures ~ 266°C are indicated by paired Bi–telluride associations with Bi / (Te + S) > 1 [e.g. hedleyite–joséite-B; native bismuth–ikunolite], representing binary eutectics in the Bi–Te–(S) system. This can be correlated with pyrrhotite inversion and late pyrite formation. An increase in fS_2 triggered Bi-Au-Te droplet precipitation."

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BC MEMPR AR #27,513 Includes Map 1 Geology of part of the Bunker Hill Claims 1:5,000 scale & Map 2 Geology of part of the Bunker Hill Claims 1:2,000 scale
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abstract
The Fort Knox (~5 M. oz) and Pogo (~6 M. oz) gold deposits are located in the Tintina Gold Province in interior Alaska. Mineralization at Fort Knox occurs in pegmatite, stockwork, and sheeted veins in a granite stock, while Pogo is comprised of several, sub-parallel, shear-hosted, quartz veins in schist and gneiss. Both of these deposits contain telluride minerals in close association with gold mineralization. Despite the different deposit styles, the telluride mineralization at both deposits consists of Bi-tellurides and -sulfotellurides. Au-Ag tellurides are notably absent. The deposits share a reduced geochemistry (CO_2-CH_4) and are arsenopyrite-bearing (rare at Fort Knox), thus allowing an estimate of Temperature-fO_2-fS_2 conditions through the mineral paragenesis.

Fort Knox contains early joséite-A, joséite-B, and tetradymite (S-enriched) with an arsenopyrite-pyrite assemblage (300-490 °C), >900 gold finesses, and feldspathic alteration (other phases include native bismuth, maldonite, and bismuthinite). Only joséite-A is found among the later arsenopyrite-pyrite assemblage (<380 °C), <900 fineness electrum, and sericitic alteration. Native bismuth is commonly coated with bismuthinite.

Pogo is host to numerous telluride minerals, typically as composite grains. Early joséite-B, sulphotsumoite, native bismuth, hedleyite, ingodite, and pilsenite occur with an arsenopyrite -

loellingite ± pyrrhotite assemblage (450-600 °C), and 850-1000 fineness gold (other phases include maldonite, K-feldspar, and Mn-siderite). This is followed by joséite-B, tetradymite, tsumoite, and ingodite with an arsenopyrite-pyrite assemblage (350-500 °C), and 850-950 fineness gold.

Later tetradymite (S-enriched), bismuthinite (Sb-bearing), joséite-B, joséite-A, ingodite and various (Ag-Bi-Sb-Pb) sulfosalts are found with pyrite (no arsenopyrite) and < 850 fine electrum. Variably Sb-rich bismuthinite commonly corrodes or rims other Bi-mineral grains. This and the texture of composite grains imply disequillibrium among the telluride minerals.

At both deposits, these observations suggest that the telluride mineralogy changes in kind with the gold composition, and the sulfide-alteration assemblages. ★In general, paragenetically early, high temperature, and very low fS_2 (loellingite-pyrrhotite stable), native bismuth, Bi-telluride and S-poor sulfotelluride assemblages yield to late, lower temperature, higher relative fS_2 (pyrite stable) S-rich sulfotelluride, Sb-bearing bismuthinite and sulfosalt assemblages

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from abstract
Bi / (Te + S + Se) ratios of BTS indicate reduced (>1) or oxidised (<1) fluids. Our compilation suggests that orogenic-Au fluids in greenstone belts and gneissic terrains are predominantly oxidised, with the exception of Au in the Svecofennian Domain … with VHMS deposits. …**Telluride speciation respects regional and temporal trends.**

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"The ore composition was studied in the underground workings (levels 720–560 m) at the Vostok-2 skarn scheelite–sulfide deposit. These ores are similar to those that have been mined from the open pit. Bismuth, lead, silver, gold, tellurium, and selenium are extracted from the ores. The ores with an increased content of these metals consist of galena, native Bi and Au, kobellite, Bi-containing jamesonite, tetradymite, and some other minerals.
Some new minerals for the deposit were found with electron microprobe analysis: jaskolskiite, cosalite with a high Sb content, ikunolite, hessite, bismuth sulfotellurides (joséite group), sulfotellurides with complex composition (with Pb and Ag), and some others. The relation between minerals, the chemical composition of minerals, and some problems of the zonation and genesis of the Pb–Sb–Bi mineralization are discussed."

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A complex assemblage of minerals including arsenopyrite, cobaltite, chalcopyrite, scheelite, bismuth, erythrite, quartz, fluorite, stannite, bismuth, bismuthinite, aikinite, cosalite, gersdorffite, ikunolite and various bismuth-bearing supergene minerals is present on the dumps of the North Devon United Mine at Peter Tavy, Devon. The rare nickel bismuth sulphide parkerite (ideally $Ni_3Bi_2S_2$) has been identified as grains up to 50 µm across in quartz-fluorite veinstone associated with sphalerite, ullmannite, bismuth, bismite, gersdorffite, an unknown lead copper sulphide selenide and cassiterite. Quantitative analyses of the parkerite record significant substitution of antimony for bismuth and include the most highly antimonian composition yet described, with 5.3 wt% Sb. This is the first report of parkerite in the British Isles.

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"Bismuth sulfide – telluride – selenide solid solutions, such as ingodite Bi(S,Te), joséite-A Bi_4TeS_2, selenian joséite-B $Bi_4(Te,Se,S)_3$, and an unnamed phase $Bi_2(Te,Se)$ were formed during the As–Bi mineralization in the Nakdong deposits, South Korea.
Ingodite, a rarely reported mineral, has the general composition $(Bi_{1.94}Sb_{0.01}Ag_{0.04})\Sigma_{1.99}Te_{1.03}Se_{0.03}S_{1.08}\Sigma_{2.14}$, which is regarded as Te-rich ingodite. Compiled data of previous work indicates that joséite-A from the Nakdong deposits extends its compositional range toward joséite-B and there still remains an obvious compositional gap in the range of 19.7 to 24.6 atomic % S + Se and 16.4 to 21.9 atomic % Te between the two phases.
Selenian joséite-B has an intermediate compositional range between Bi_4Te_2S and Bi_4Te_2Se through the exchange between S and Se. The unnamed phase, $Bi_{1.97}Sb_{0.02}Te_{0.83}Se_{0.12}S_{0.01}$, with constant Bi / (Te + Se + S) ratio close to 2 but a variable Te / (Se + S) ratio from 5.7 to 8.2, is placed in the compositionally intermediate range between the two unnamed phases of Bi_2Te and $Bi_2(Te,Se)$ of Gu et al. (2001). Coexistence of native bismuth with joséite-B and the unnamed phase constrains their formation temperature below 266°C."

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excerpt
"… the porphyry Cu-Mo (Au), gold-skarn, gold-sulfide-quartz, gold-silver, Mo-W (Cu, Bi) greisen and tin-tungsten types of mineralization are related to the Triassic metallogenic stage… example the Khâm Đức ore cluster… . The ore bodies and zones at the Đắk Ripen and Đắk Roong deposits, at the Sa Thầy porphyry Cu-Mo (Au) and Ngọc Tụ Cu-Mo-W-Bi occurrences …is characterized by the geochemical specialization which is expressed in the increased Bi and Te content in all types of ores, Mo and W in ores from gold-ore deposits, Au in Mo-W (Cu, Bi) greisen and porphyry Cu-Mo (Au). For gold mineralization tellurides, bismuthinite, native bismuth, ikunolite, rossvietite (AuBiS - new mineral established by the authors from the Đắk Ripen deposit), scheelite and molybdenite are mineral forms for Bi, Te, Mo and W."

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Summary
Gold ores in skarns from the Río Narcea Gold Belt are associated with Bi-Te-(Se) -bearing minerals. These mineral assemblages have been used to compare two different skarns from this belt, a Cu–Au skarn (calcic and magnesian) from the El Valle deposit, and a Au-reduced calcic skarn from the Ortosa deposit … In Ortosa deposit gold essentially occurs as native gold and maldonite and is commonly related to pyrrhotite and to the replacement of löllingite by arsenopyrite, indicating lower fO_2 conditions for gold mineralization than those for El Valle deposit. This fact is confirmed by the speciation of Bi-tellurides and selenides (hedleyite, joséite-B, joséite-A, ikunolite–laitakarite) with Bi / Te + (Se + S) ≥ 1.
"At the Ortosa deposit, the typical assemblage (native bismuth–gold–hedleyite–joséite-B) limits the conditions … within the pyrrhotite stability field. The PbTe–PbS reaction constrains the fTe_2 and fS_2 values due to the presence of galena and the absence of altaite [PbTe]. The occurrence of hessite,

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Summary
Gold mineralization occurs in the Şoimuş Ilii vein, the main Cu prospect in the Highiş Massif, Western Apuseni Mts., Romania. The Highiş Massif is part of the Highiş Biharia Shear Zone, a 320–300 Ma Variscan greenschist belt, with a 114–100 Ma Alpine overprint. In Highiş, phyllonites enclose an igneous core consisting of an Early Permian basic complex intruded by Middle Permian granitoids. The vein is hosted within basalt hornfels at its contact with the 264 Ma Jernova granite. Gold is not only present as native gold, but also as jonassonite (ideally $AuBi_5S_4$). The latter occurs as inclusions 1-30 µm in size in chalcopyrite; microanalysis gives the empirical formulae $Au_{1.02}(Pb_{0.47}Bi_{4.51})_{4.98}S_{4.}$ The two Au minerals are spatially associated with Bi–(Pb) sulfosalts (over substituted bismuthinite, cosalite) and sulfotellurides / selenides (ingodite, ikunolite and laitakarite) in blebs/patches, mainly hosted in chalcopyrite. This Au–Bi–Te association overprints an earlier, chalcopyrite-quartz assemblage, occurring as trails along discrete zones of brecciation that crosscut former mineral boundaries. Curvilinear and cuspate boundary textures within the blebs/patches suggest deposition in a molten form. Mineral associations in combination with phase relations indicate that the Au–Bi–Te association formed as a result of melting of pre-existing native bismuth Bi (and possibly sulfosalts) at 400 °C under sulfidation conditions. These melts incorporated Au, Pb, Te and S as they moved in the vein during shearing and were locked within dilational sites. Native Bi occurs as coarse aggregates along vein margins, but in the Au–Bi–Te association, it is present only as small droplets in shear gashes, never together with other Bi- and Au-minerals. The Bi-derived melts are part of an internal remobilizate which also includes chlorite and adularia. Minerals in the system Au–Bi–Te were deposited from a neutral low reducing fluid during Alpine shearing in the Early Cretaceous. The fluid also assisted solid-state mobilisation of chalcopyrite and cobaltite. This study illustrates the significant potential of Bi, a low melting-point chalcophile element (LMCE), to act as Au scavenger at temperatures as low as 400 °C.

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Dedication

This report is dedicated to my twin daughters Claire Jennifer Whitby Howard and Elise Linda Moore Howard

Part II

12th November 2006

Short report on electron probe microanalysis on samples

Analysis was carried out on a CAMECA SX-51 instrument at Adelaide Microscopy, Adelaide, South Australia at an operating voltage of 20 kV and beam current of 20 microamperes. This report summarises the results, which largely confirm the results of earlier Scanning Electron Microscope study. The datasets will be worked on further – the data given here are provisional only.

Eloise Vein South sample

Microprobe analysis confirmed the presence of **joseite-A, joseite-B, ingodite, unnamed Bi_2Te** and **bismuthinite** in a sample of Eloise Vein South (0441 site). Mean analyses are given in Table 1, giving the empirical formulae, $(Bi_{3.68}Pb_{0.15}Sb_{0.01})_{3.84}Te_{1.15}S_{2.00}Se_{0.01}$, $(Bi_{4.03}Pb_{0.04}Sb_{0.02})_{4.08}Te_{1.89}S_{1.01}Se_{0.02}$, $(Bi_{0.94}Pb_{0.02})_{0.97}Te_{0.53}S_{0.50}Se_{0.01}$, $(Bi_{1.97}Pb_{0.02}Sb_{0.01})_{2.00}(Te_{0.93}S_{0.06}Se_{0.01})_{1.00}$ and $Pb^{*}_{0.03}Cu_{0.02}Bi_{1.96}S_{2.98}Se_{0.01}$, respectively.

Table 1. Mean analyses of Bi-minerals in the Eloise Vein South sample 0441

	Jo-A	**Jo-B**	**Ing**	**Bi_2Te**	**Bism**
	N=8	n=6	n=10	n=12	representative
Cu	0.00	0.00	0.00	0.00	0.23
Pb	3.03	0.68	1.74	0.79	1.03
Cd	0.32	0.27	0.18	0.25	0.04
Bi	75.34	74.99	68.54	76.78	78.73
Sb	0.11	0.17	0.15	0.32	0.46
Te	14.39	21.49	23.54	22.09	0.02
Se	0.10	0.11	0.15	0.21	0.17
S	6.29	2.88	5.57	0.34	18.31
Total	100.59	99.58	99.87	100.77	98.99

Samples '0412a' and '0412b' of Eloise Vein North

Microprobe analysis confirmed the presence of **joseite-A, joseite-B, ingodite** and **bismuthinite** in two polished blocks. Mean analyses are given in Table 2, giving empirical formulae $(Bi_{3.70}Pb_{0.14}Sb_{0.01})_{3.85}Te_{1.12}S_{2.01}Se_{0.01}$, $(Bi_{3.97}Pb_{0.02}Sb_{0.01})_{4.01}Te_{1.85}S_{1.13}Se_{0.01}$, $(Bi_{0.93}Pb_{0.05})_{0.98}Te_{0.49}S_{0.53}$ and $(Pb_{0.02}Cu_{0.03}Bi_{1.95}Sb_{0.02})_{2.02}S_{2.98}$, respectively.

*****typo corrected – Pb, not Cu as in original letter.

Table 2. Mean analyses of Bi-minerals in Eloise Vein North samples '0412a' and '0412b'

	Jo-A	**Jo-B**	**Ing**	**Bism**
	N=9	n=7	n=16	representative
Cu	0.00	0.00	0.00	0.34
Pb	2.89	0.42	3.29	0.73
Cd	0.20	0.27	0.30	0.00
Bi	75.57	74.13	66.96	79.04
Sb	0.11	0.14	0.16	0.41
Te	13.99	21.09	21.65	0.11
Se	0.10	0.07	0.06	0.03
S	6.31	3.24	5.81	18.83
Total	99.17	99.37	98.24	99.53

Sample '0414b' of the Blue Quartz Vein

Microprobe analysis confirmed the presence of **joseite-A, joseite-B, ikunolite** and **bismuthinite**. Mean analyses are given in Table 3, giving the empirical formulae, $(Bi_{3.95}Pb_{0.02}Sb_{0.01})_{3.98}Te_{0.95}S_{2.05}Se_{0.02}$, $(Bi_{4.00}Pb_{0.01}Sb_{0.01})_{4.02}Te_{1.91}S_{1.05}Se_{0.01}$, $(Bi_{3.72}Pb_{0.20})_{3.93}$ $S_{2.99}Te_{0.07}Se_{0.02})_{3.08}$ and $(Pb_{0.01}Cu_{0.01}Bi_{1.97})_{1.99}S_{3.01}$, respectively.

Table 3. Mean analyses of Bi-minerals in sample '0414b' of the Blue Quartz Vein.

	Jo-A	**Jo-B**	**Iku**	**Bism**
	n=14	representative	representative	representative
Cu	0.00	0.00	0.09	0.08
Pb	0.32	0.13	4.43	0.22
Cd	0.21	0.15	0.25	0.30
Bi	80.08	75.06	83.60	80.60
Sb	0.10	0.15	0.00	0.05
Te	11.80	21.87	0.95	0.01
Se	0.12	0.09	0.17	0.00
S	6.38	3.03	10.31	18.90
Total	99.03	100.47	99.80	100.15

Sample '163b' of the Good Hope skarn in the Hedley district

Microprobe analysis of this sample (for purposes of comparison) confirmed the presence of **joseite-B, unnamed Bi_2Te** and **hedleyite** (ranging in composition from Bi_7Te_3-Bi_8Te_3).

Gold analyses

The composition of native gold (or electrum) was determined in the above samples. Results (molecular %) gave $Au_{74}Ag_{26}$ for the Eloise Vein North sample, $Au_{75}Ag_{25}$ for sample '0412a' of 'Eloise Vein South' and between $Au_{76}Ag_{24}$ and $Au_{80}Ag_{20}$ for sample '0414b' of the Blue Quartz Vein.

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Bi-tellurides in gold veins, BiTel Knoll (CLY prospect), southeastern British Columbia, Canada

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Abstract. Gold ores from BiTel Knoll (CLY Group), Nelson District, B.C., Canada, contain a number of Bi minerals, notably tellurides and tellurosulphides of Bi. The Bi-mineral assemblage is varied from sample to sample. Typical minerals are joséite-B (Bi_4Te_2S), joséite-A (Bi_4S_2Te), unnamed Bi_2Te, hedleyite (Bi_7Te_3), ingodite (Bi(Te,S)), native bismuth (Bi), bismuthinite (Bi_2S_3) and ikunolite (Bi_4S_3). The Bi-assemblages in the two veins are of reduced type (species with $Bi/(Te+S)\geq1$). They differ in the presence of native bismuth only in the Blue Quartz vein and ingodite only in the Eloise vein. Native gold is present as inclusions in Bi-mineral patches in both veins. Gold concentrations measured in Bi-minerals from the Eloise vein are in the range between 0.02 and 57 ppm. Concentrations vary by orders of magnitude between samples in different locations. Phase relationships and the distribution of Au in Bi-minerals support a hypothesis in which the mineralization, although formed from Au-Bi-Te-S melts exsolved from fluids, has been overprinted by a subsequent (orogenic?) event.

Key Words: Bismuth minerals, sulphosalts, tellurides, gold deposits, British Columbia.

INTRODUCTION

The CLY Group of claims comprises a set of veins and skarns located near the contact to the mid-Cretaceous Bunker Hill sill, an outlier of the Wallack Creek granite, which in turn belongs to the Bayonne magmatic belt. This marks the boundary between Lower Jurassic rocks of the Quesnel Terrane to the NW and Paleozoic sedimentary rocks of the Kootenay Terrane. The geological setting of the region, structural geology of the claim area, and sulphide mineralogy have been described by Howard (this volume).

Some of the veins are sulphide-poor (at BiTel Knoll in the NE part of the claims area), others are sulphide (pyrite-pyrrhotite) rich (Bunker Hill) or are veins overprinting earlier skarn (Lefevre). All the veins contain variable amounts of gold. Geochemistry shows a strong correlation between Au and Bi in all veins in the claims area (Howard, this volume). This is most pronounced in the veins from the BiTel Knoll area, where higher gold assays are expressed as visible gold and, in some cases, are accompanied by bismuth minerals, including tellurides and tellurosulphides (collectively called ‘tellurides’ here). Other veins, in Bunker Hill, are characterised by micron-sized inclusions of gold within pyrite (pseudomorphosed after pyrrhotite). Rare Bi-minerals were, however, identified, but appear restricted to sulphosalts such as cosalite.

This study focuses on two veins from BiTel Knoll (Eloise vein and Blue Quartz vein) in which both native gold and bismuth minerals are present. Hand specimens from the veins show a pronounced fracturing. The blue colour is considered to be due to incorporation of bismuth minerals within the quartz. Polished blocks prepared from other veins (e.g., Ella and Clarissa veins) contained µm-sized inclusions of native gold within quartz but did not contain Bi-minerals.

The aim is to present the mineral associations in these veins. We also carried out LA-ICP-MS analysis on the Bi-minerals in the Eloise vein sample to determine their gold contents. Such measurements are useful, together with paragenetic observations, to discuss the distribution and partitioning of gold in different species and comment on their genesis.

SAMPLE DESCRIPTION

Blue quartz vein

The only sulphide in the samples is scarce molybdenite, both in host rock and vein. Iron- and Ti-oxides are abundant in the host rock (biotite schist/amphibolite?), whereas rare-earth minerals are present only in the vein. Both bismuth minerals and gold (~$Au_{75}Ag_{25}$) occur as μm-sized blebs along the fractures in quartz (Fig. 1). The Bi-mineral assemblage is dominated by joséite-A (Bi_4S_2Te), bismuthinite and native bismuth. Other species are joséite-B (Bi_4Te_2S), hedleyite (Bi_7Te_3) and ikunolite (Bi_4S_3). The blebs can be mono-component, but are typically multi-component, in which native gold is also part of the assemblage (e.g., Fig. 1a). Joséite-B is found especially in blebs that contain native bismuth (Fig. 1b) and also Bi_2Te and/or hedleyite (Fig. 1a, c). Sulphur-rich blebs dominated by joséite-A may occasionally also contain ikunolite (Fig. 1d). These Bi-rich associations are similar to those typically reported from gold skarns. Although the samples are affected by weathering, native bismuth is part of the primary association, based on mutual relationships with the Bi-tellurides (e.g., Fig. 1b, c). Most abundant are blebs containing an association of native Bi + bismuthinite.

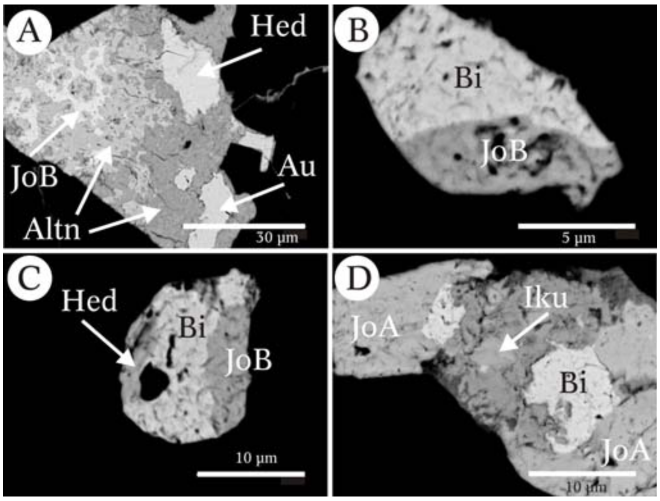

Figure 1. Back-scattered electron images showing assemblage of gold and Bi-minerals (Blue Quartz vein). Altn: alteration, Au: gold, Bi: native bismuth, Hed: hedleyite, Iku: ikunolite, JoA: joséite-A, JoB: joséite-B.

Eloise vein

Polished blocks from samples at two locations along the vein were studied. In both locations, native gold and Bi-minerals are present, although they differ in association.

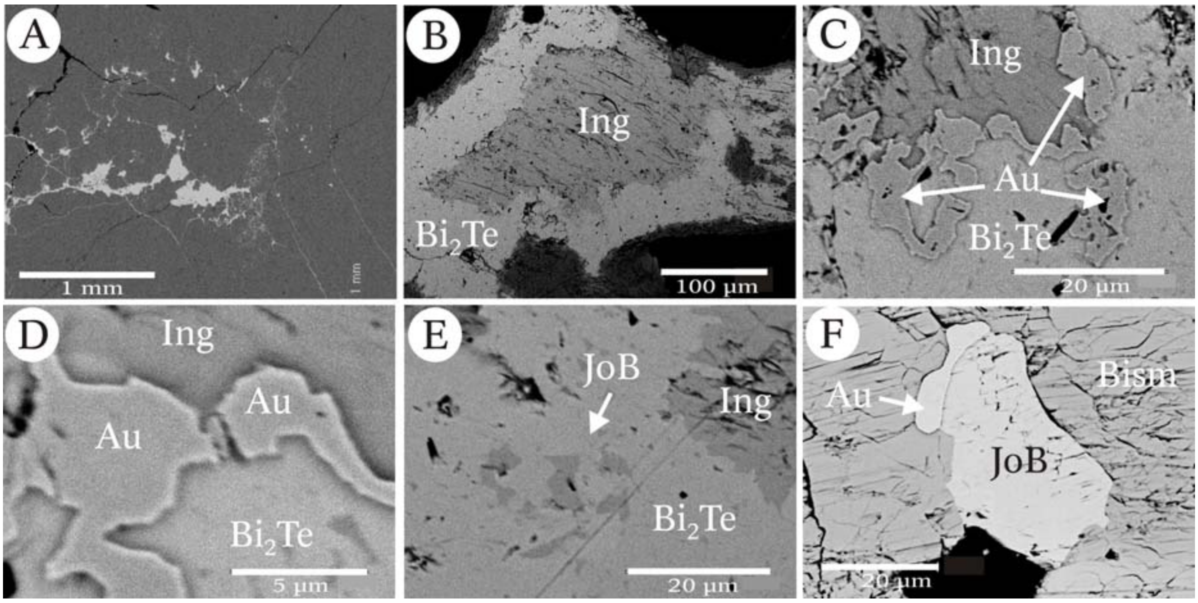

Figure 2. Back-scattered electron images showing Bi-minerals in sample 'Eloise' (a-e) and 0412a (second location, f). Bi_2Te: unnamed Bi_2Te, Bism: bismuthinite, Ing: ingodite, JoB: joséite-B, Au: gold.

LA-ICP-MS ANALYSIS

Analysis was carried out on the material from Eloise only. The small size of the phases in the Blue Quartz vein precluded satisfactory analysis.

Experimental

LA-ICP-MS analysis was carried out using the Agilent HP4500 Quadripole ICP-MS instrument at CODES, University of Tasmania, equipped with a high-performance New Wave UP-213 Nd:YAG Q-switched laser ablation system and MEOLaser 213 software operating at 5 Hz. We performed spot analyses (12-80 µm in diameter, depending on size of the target mineral), monitoring the following isotopic abundances: ^{197}Au, ^{130}Te, ^{209}Bi, ^{208}Pb, ^{107}Ag, ^{77}Se, ^{121}Sb, ^{57}Fe, ^{65}Cu, 66Zn and ^{75}As. Total analysis time was 90s (30s pre-ablation and 60s ablation time). Calibration was performed on a doped pyrite standard; Bi served as the internal standard for the tellurides and bismuthinite. Detection limits for gold were 0.01 to 0.05 ppm.

Results

In the 'Eloise' sample, we analysed (1) Symplectites of joséite-A and –B, (2) ingodite and (3) unnamed Bi_2Te (Figs. 3 and 4, with Au concentrations given in ppm). Au concentrations in the Bi-tellurides ranged from <1 ppm to 57 ppm. Representative LA-ICP-MS depth profiles are shown in Figs. 5 and 6. In the first patch (Fig. 3), three LA-ICP-MS spot analyses of Bi_2Te give Au contents stretching across an order of magnitude (3.6 to 57 ppm). We note the excellent correlation between the Au signal and the Ag and As signals on Fig. 5. Antimony, Pb and Se show trends parallel to Bi and Te, at values in agreement with microprobe data. Although steady for the first third of the ablation, the Au signal jumps over one order of magnitude and is then steady again for the remainder of the spot.

In the second patch (Fig. 4), the maximum gold value was obtained from a symplectite of joséite-A and –B (26 ppm). Two LA-ICP-MS spot analyses of coexisting ingodite give 3 and 10 ppm. These values are two orders of magnitude higher than in the first patch (0.05 ppm). The profile (Fig. 6) was integrated for Au over the second half of the ablation where Sb increases and Pb decreases. Gold is below detection limits in the first half of the profile. As in the previous case, the Au signal is paralleled by the As and Fe signals.

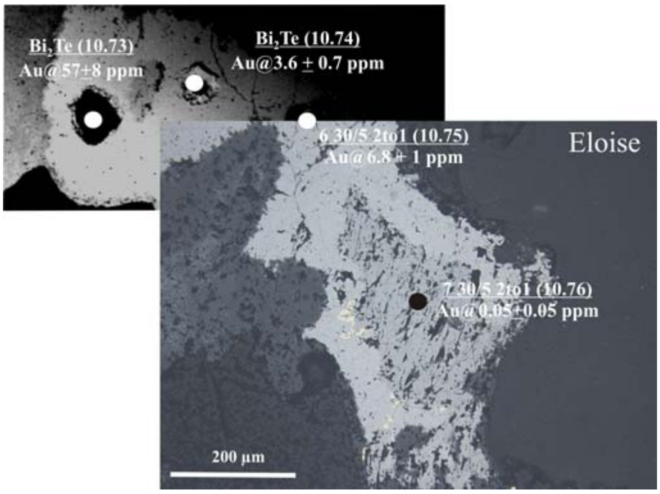

Figure 3. Back-scattered electron images showing ablated grains of Bi-tellurides in sample 'Eloise'. Gold concentrations are given in ppm.

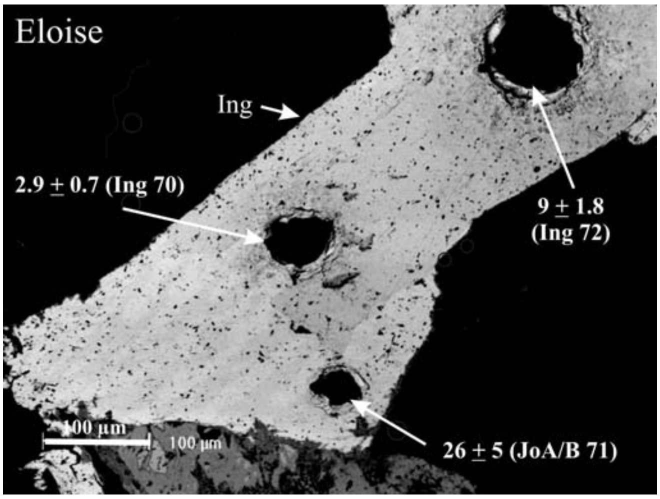

Figure 4. Back-scattered electron images showing ablated grains in sample 'Eloise'. Gold concentrations are given in ppm.

In samples from the second location, two analyses were made of the joséite-A and -B symplectites in the same area (Figs. 7 and 8), with values of 0.13 and 0.65 ppm. Ingodite was analysed by four spots of which two gave Au values below the detection limit (ca. 0.005 ppm); the other two gave 0.11 and 1.13 ppm. Six spot analyses were made of bismuthinite from the same

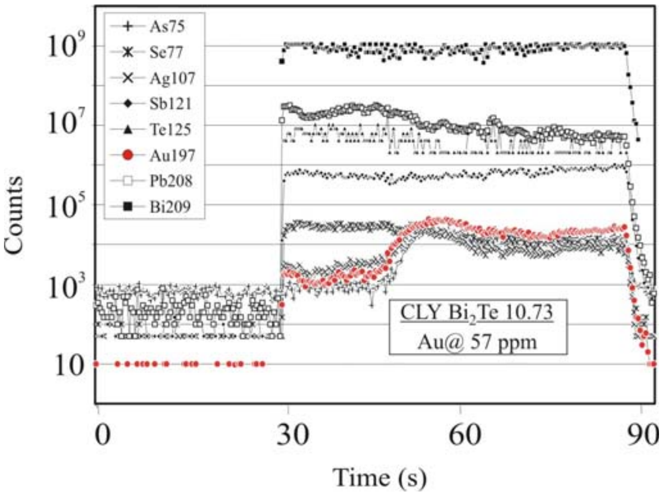

Figure 5. Laser ablation profile of a representative grain of Bi_2Te (point 73, see figure 3). Note that Au concentrations are strongly correlated with Ag and As.

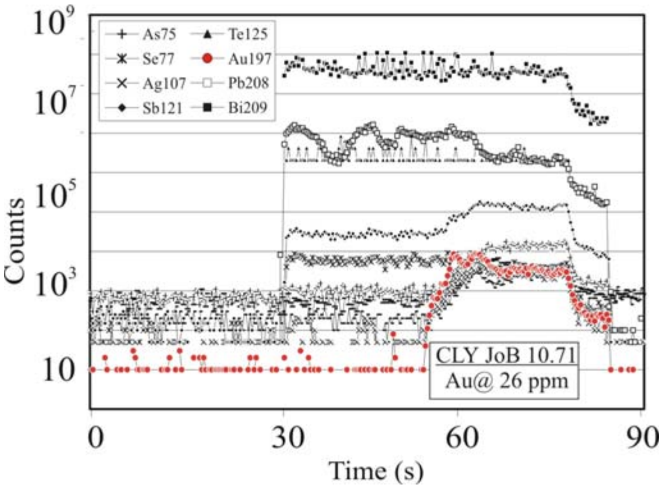

Figure 6. Laser ablation profile of a symplectite between joséite-A and - B (point 71, see figure 4). Note that the first half of the spectra after activation of the laser (30-55s) shows no Au (or Ag) present. Following transition into an included mineral at ca. 55s, Au, Ag and Sb increase markedly.

patch as the tellurides (Fig. 7) and an additional five spots were taken from another patch in which tellurides form small inclusions (attempts to determine Au in one of these inclusions failed because the laser intersected a gold inclusion below the surface). Gold values stretch over two orders of magnitude: 0.02 to 2 ppm in the first case, and from 0.07 to 0.42 ppm in the second.

Figure 9 shows the 11 individual spot analyses of bismuthinite, arranged in order of increasing Au content. Gold contents correlate well with those of Ag, as well as both As and Fe. The other minor components in bismuthinite (Pb, Cu, Sb and Se) show generally flat, parallel trends across the dataset. The same correlation between Au and some trace elements (Ag, As, Fe) was noted in individual spot analyses of tellurides above.

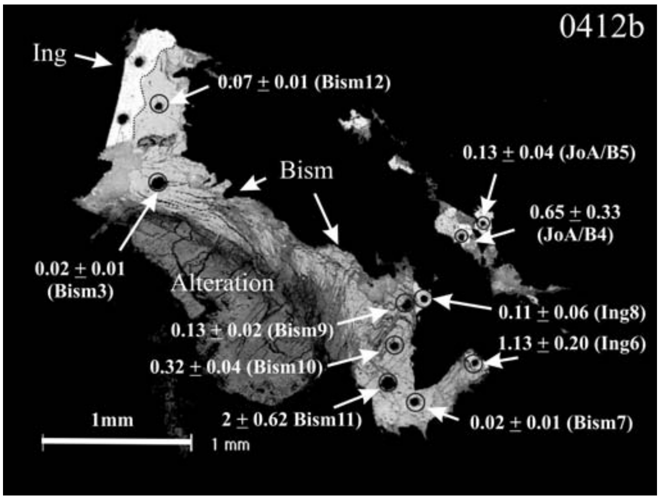

Figure 7. Back-scattered electron images showing ablated grains in sample '0412b'. Au concentrations are in ppm.

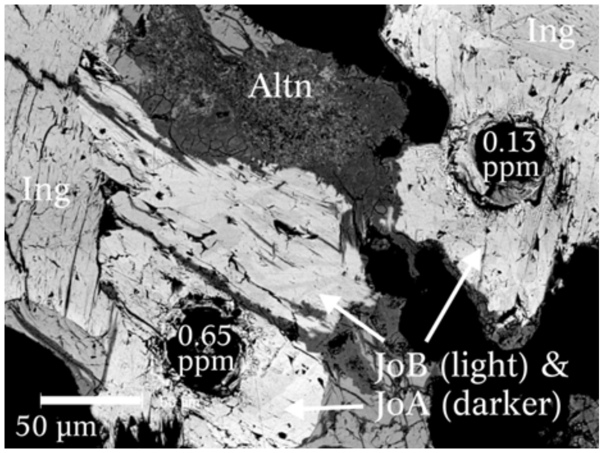

Figure 8. Coarse intergrowths of joséite-A and -B (brighter areas) in bismuthinite matrix (middle grey). LA-ICP-MS laser spots are clearly visible. Scale bar: 50 µm.

The full dataset for tellurides and sulphosalts is summarised in Fig. 10, arranged in order of increasing Au concentration. The figure also shows error bars for each individual analysis. From this, we see that Au contents from the first location are higher by at least one order of magnitude. The gold content in bismuthinite is comparable to that in the coexisting tellurides. The highest Au concentrations do not appear to be restricted to one telluride species in particular. For example, ingodite can be the most and least Au-enriched within individual patches.

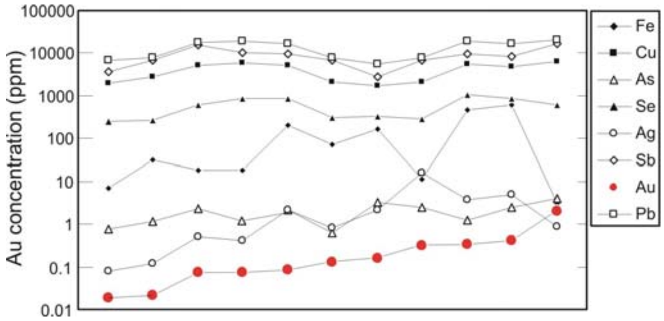

Figure 9. Laser ablation data for individual bismuthinite analyses arranged in order of increasing Au content from left to right. Note that both Ag and Fe correlate with Au. Lead, Cu, Se and Sb (common minor or trace components of bismuthinite) show relatively flat profiles.

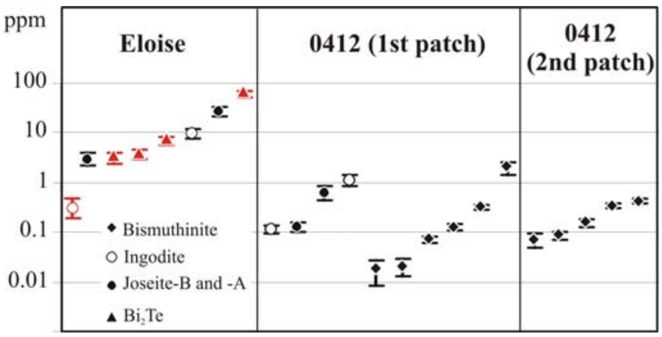

Figure 10. Laser ablation data for individual Bi-telluride analyses arranged in order of increasing Au content, sub-divided by sample. For Eloise, values from patch in Fig. 3 are in red and from Fig. 4 in black.

DISCUSSION AND CONCLUSIONS

In both veins, native gold is included within Bi-mineral associations that are characteristic for the Bi-rich side of the system Bi-Te-(S). They represent reduced associations (pyrrhotite, magnetite stability) since all species can be at equilibrium with native bismuth given their Bi/(Te+S)≥1 ratio. Native bismuth is however present only in the Blue Quartz vein, forming associations resembling those known from the gold skarn at Hedley. Native bismuth + Bi_2Te/ Bi_7Te_3 and Bi+Bi_2S_3 correspond to eutectics at 266ºC and 270ºC in the Bi-Te and Bi-S systems, respectively. This, together with the droplet-like shape, may be taken to presume their precipitation from fluids in a molten state, as considered for gold skarns (Meinert, 2000) and intrusion-related veins at Pogo, Fort Knox and elsewhere in the Tintina belt, Alaska (McCoy, 2000). However, the Blue Quartz associations differ from these examples in the fact that they lack maldonite or its breakdown products (symplectites of native gold = bismuth). Maldonite is the Au-bearing phase included in the two eutectic associations from the Bi-rich side of the Au-Bi-Te system (Bi + Au_2Bi, 241ºC and Bi_7Te_3+ Bi + Au_2Bi, 235ºC. Crystallization from melts will always conclude in forming eutectic associations following partial crystallization along the solvus curve (Ciobanu et al., 2005, 2006a, b). This implies that even though the droplets may have initially been precipitated in a molten state, they have suffered internal redistribution of Au (if this was indeed at all included in the melts). Relationships between phases with Bi_4X_3 (X=Te,S), i.e., joséite-B replaced by joséite-A and/or ikunolite, also suggest that the Bi-mineral assemblages are overprinted during a subsequent event. This is characterised by fluids with an increased content of S relative to Te (higher S/Te ratios in the replacing phases). Potentially, the same event could have redistributed and/or introduced gold.

The Bi-mineral associations in the Eloise vein differ from the above in that they do not contain primary native bismuth, and also include ingodite, a tellurosulphide with Bi/(Te+S) = 1, which is not observed in the Blue Quartz vein. Here, the relationships between (i) phases with the same Bi/X=4:3 ratio (symplectites of joséite-B and –A) and (ii) skeletal inclusions of joséite-B in Bi_2Te indicate immiscibility via exsolution rather than an overprint. The mantling of ingodite by Bi_2Te, however, and the rim of native gold formed at the boundary between the two (Fig. 2c, d) can be interpreted as replacement of ingodite that also may have released Au. This would explain the low values of Au in ingodite from this patch (0.05 ppm) relative to another in which no native gold is observed (9 ppm). The replacement can be paralleled with the transitory reaction liquid + BiTe = Bi_5Te_3 + Au at 374ºC in the system Au-Bi-Te. The jump over an order of magnitude in the Au signal obtained during ablation of Bi_2Te (Fig. 5) is indicative of formation of sub-µm-scale inclusions of gold. This can be easily remobilised between the layers in a telluride structure (see

Cook et al., this volume) during any overprinting event that would assist solid-state diffusion and/or fluid infiltration. The good correlation with other elements, such as Fe and As, which do not commonly replace the main components in the structure, also supports such an hypothesis. Although the Au signal across the joséite-B/-A symplectites (Fig. 6) shows a similar jump during the ablation interval, this can be interpreted as preferential concentration of Au in the component with lower Pb and higher Sb (joséite-B), rather than nucleation of Au inclusions. This is concurrent with the lack of evidence for overprinting in this particular patch.

Measured gold concentrations in the same bismuth tellurides within patches from samples in the second location from the Eloise vein are two orders of magnitude lower than those from the first location. There is no preferential concentration of Au in any specific telluride species or in bismuthinite (Fig. 10). Moreover, the ranges of Au values are the same in bismuthinite whether it contains inclusions of native gold or not. The good correlation across the dataset between Au and the same elements observed for the tellurides, i.e., Fe, As, Ag, indicates partitioning of Au at comparable values between the tellurides and the sulphosalt.

The residual Au content in Bi-minerals, the exsolution relationships, and also the fact that all Bi-minerals contain residual amounts of Au support the hypothesis that at Eloise, as in the Blue Quartz vein, they may have formed by crystallization of molten Bi-Te-S-(Au) precipitates. In the Eloise vein, however, no eutectic associations are preserved, given the fact that the overprint has modified the Bi/X ratios in the species. The highly variable gold contents in the Bi-tellurides from one location to another along the vein, as well as between patches in the same sample, indicates the impact of the overprinting event that assisted Au redistribution and is beneficial for nucleation of native Au.

The data presented here, however, needs to be supplemented in order to obtain a better, quantitative assessment of the role played by the overprinting in the BiTel Knoll veins. This study shows nonetheless the ability of Bi-minerals to incorporate Au and also to track overlapping events by subtle changes in their chemistry. An overprint is shown also by the replacement relationships between Fe-Ti-oxides in the same Bi-mineral samples. The presence of molybdenite (also abundant in other deposits from the same region, e.g., Hedley), as well as REE-phosphates, shows the affiliation of the mineralising fluid to a magmatic source, e.g., Bunker Hill Sill. The subsequent event, with an important role in remobilising and concentrating Au from the pre-existing Bi-Te-(S) assemblages in the veins, may be attributed to one or the other tectonic events (Late Cretaceous?) postdating intrusion emplacement in the area.

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Part III

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Paper #130211

Meeting: **2007 GSA Denver Annual Meeting (28–31 October 2007)**
Session Type: **Topical/Theme**
Selection: T70 **Au-Ag-Te Se Deposits and Other Precious Metal Deposits**

TELLURIDE ASSEMBLAGES IN A REDUCED INTRUSION-RELATED GOLD (RIRG) DEPOSIT, CLY GROUP PROSPECT, SOUTHEASTERN BRITISH COLUMBIA, CANADA

The BiTe Knoll (CLY Group) exploration target, Nelson District, B.C., comprises a set of veins and skarns located near the contact to the mid-Cretaceous Bunker Hill sill, an outlier of the Wallack Creek granite. The latter belongs to the Bayonne magmatic belt marking the boundary between Lower Jurassic rocks of the Quesnel Terrane to the NW and Paleozoic sedimentary rocks of the Kootenay Terrane. **Ore minerals occur in fracture-controlled clots in m-plus wide outcropping quartz veins. The mineralization has all criteria of a Reduced Intrusion-Related Gold deposit, e.g., as in the Tintina Belt, Alaska-Yukon, including a marked Au-Bi-Te correlation. Veins in three different sets occur over a 1.5 km N-S extent on the CLY property; the economic potential as an open pittable deposit is high.**

The Bi-mineral assemblage occurs as droplets consisting of native Bi, Bi-(sulfo)tellurides and bismuthinite. The (sulfo)tellurides include joséite-B (Bi_4Te_2S), joséite-A (Bi_4S_2Te), hedleyite (Bi_7Te_3), unnamed Bi_2Te, ingodite [Bi(Te,S)] and ikunolite (Bi_4S_3). We note the presence of coarse symplectites of joséite-A and -B, and exsolutions of joséite-B in Bi_2Te. Such morphologies, phase associations and the presence of mineral pairs representing eutectics at 266ºC in the systems Bi-Te or Bi-S (e.g., Bi+Bi_7Te_3 and Bi+Bi_2S_3, respectively) **suggest crystallisation from Bi-Te-S melts.**

Native gold occurs as inclusions within such patches, or forms rims at ingodite-Bi_2Te boundaries. **Gold is also present at concentrations of 0.02-55 ppm within Bi-minerals**. However, the eutectics on the Bi-rich side of the system Au-Bi-Te include maldonite instead of native gold as observed at CLY. Neither maldonite nor its breakdown products (Au+Bi symplectites) are observed within the blebs. Moreover, the native gold rim between ingodite and Bi_2Te is considered to result from subsequent Au release from tellurides.

A parallel can be drawn to the transition reaction: liquid+BiTe=Bi_5Te_3+Au at 374ºC in the system Au-Bi-Te. Remobilization of Au is also suggested by the irregular Au signals in the LA-ICPMS Bi-telluride analyses, indicating the presence of <µm inclusions. **Even if deposited as Bi-rich melts exsolved from a magmatically-derived fluid at >266°C, the associations were overprinted and recrystallized during a subsequent (orogenic?) event.**

(Editorial note by Howard: This is ascribed to the Tertiary Eocene Coryell event that formed gold deposits elsewhere in south B.C.)

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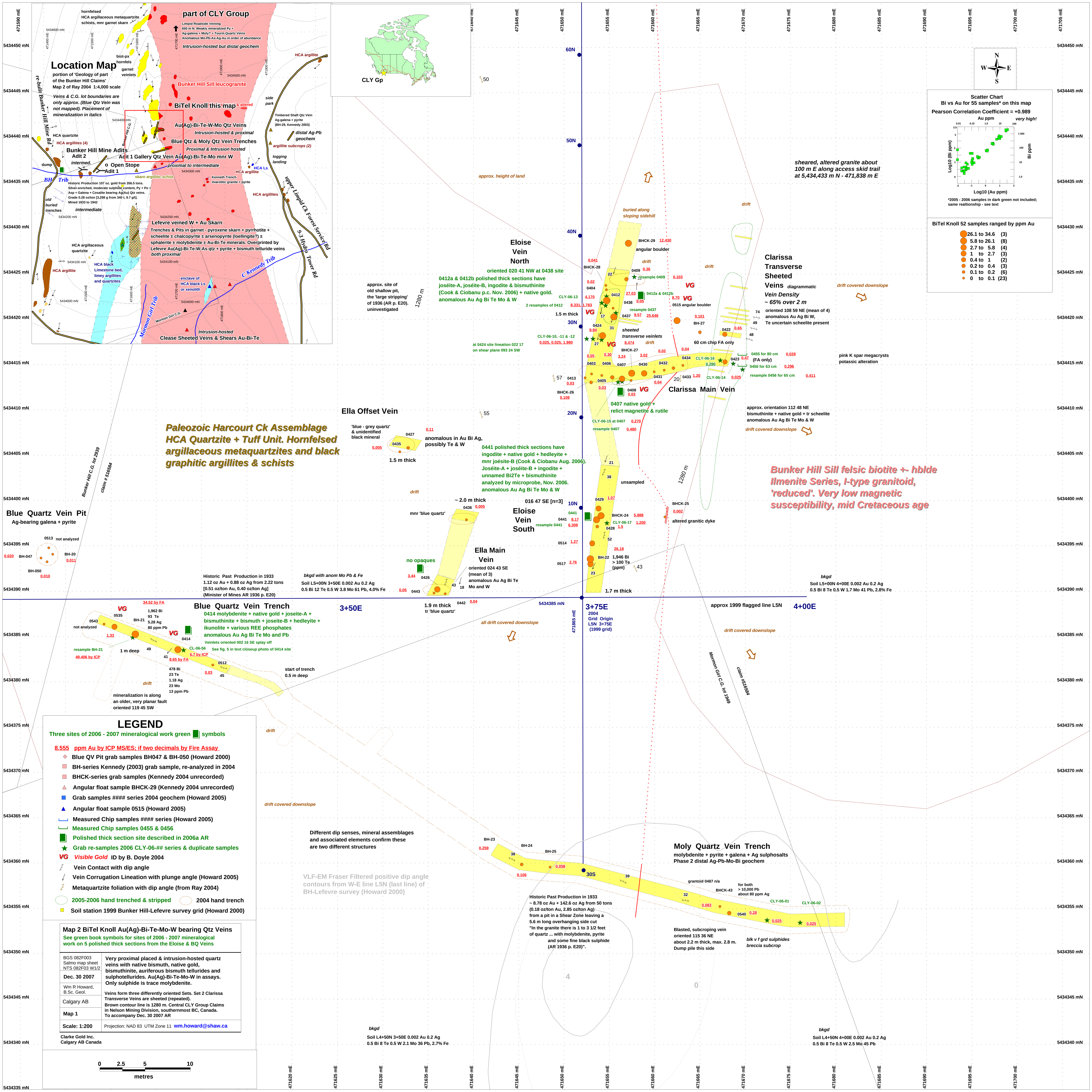

Location Map
portion of 'Geology of part of the Bunker Hill Claims' Map 2 of Ray 2004 1:4,000 scale
Veins & C.G. lot boundaries are only approx. (Blue Qtz Vein was not mapped). Placement of mineralization in italics
part of CLY Group
Bunker Hill Sill leucogranite
BiTel Knoll this map
Au(Ag)-Bi-Te-W-Mo Qtz Veins
Intrusion-hosted & proximal
Blue Qtz & Moly Qtz Vein Trenches
Proximal & Intrusion hosted
Adit 1 Gallery Qtz Vein Au(Ag)-Bi-Te-Mo mnr W
proximal to intermediate
Bunker Hill Mine Adits
Adit 2
Open Stope
Adit 1
Lefevre veined W + Au Skarn
Intrusion-hosted
Clease Sheeted Veins & Shears Au-Bi-Te
CLY Gp
Scatter Chart
Bi vs Au for 55 samples* on this map
Pearson Correlation Coefficient = +0.989
very high!
Log10 (Au ppm)
Log10 (Bi ppm)
*2005 - 2006 samples in dark green not included; same realtionship - see text
BiTel Knoll 52 samples ranged by ppm Au
26.1 to 34.6 (3)
5.8 to 26.1 (8)
2.7 to 5.8 (4)
1 to 2.7 (3)
0.4 to 1 (2)
0.2 to 0.4 (3)
0.1 to 0.2 (6)
0 to 0.1 (23)
sheared, altered granite about 100 m E along access skid trail at 5,434,433 m N - 471,838 m E
Eloise Vein North
oriented 020 41 NW at 0438 site
0412a & 0412b polished thick sections have joséite-A, joséite-B, ingodite & bismuthinite (Cook & Ciobanu p.c. Nov. 2006) + native gold.
anomalous Au Ag Bi Te Mo & W
Clarissa Transverse Sheeted Veins diagrammatic
Vein Density ~ 65% over 2 m
oriented 108 59 NE (mean of 4)
anomalous Au Ag Bi W, Te uncertain scheelite present
Clarissa Main Vein
pink K spar megacrysts potassic alteration
approx. orientation 112 48 NE
bismuthinite + native gold + tr scheelite
anomalous Au Ag Bi Te Mo & W
Ella Offset Vein
Paleozoic Harcourt Ck Assemblage
HCA Quartzite + Tuff Unit. Hornfelsed argillaceous metaquartzites and black graphitic argillites & schists
0441 polished thick sections have ingodite + native gold + hedleyite + mnr joséite-B (Cook & Ciobanu Aug. 2006). Joséite-A + joséite-B + ingodite + unnamed Bi2Te + bismuthinite analyzed by microprobe, Nov. 2006.
anomalous Au Ag Bi Te Mo & W
Bunker Hill Sill felsic biotite +- hblde Ilmenite Series, I-type granitoid, 'reduced'. Very low magnetic susceptibility, mid Cretaceous age
Eloise Vein South
Ella Main Vein
oriented 024 43 SE (mean of 3)
anomalous Au Ag Bi Te Mo and W
Blue Quartz Vein Pit
Ag-bearing galena + pyrite
Historic Past Production in 1933
1.12 oz Au + 0.88 oz Ag from 2.22 tons
[0.51 oz/ton Au, 0.40 oz/ton Ag]
(Minister of Mines AR 1936 p. E20)
Blue Quartz Vein Trench
0414 molybdenite + native gold + joseite-A + bismuthinite + bismuth + joséite-B + hedleyite + ikunolite + various REE phosphates
anomalous Au Ag Bi Te Mo and Pb
3+50E
3+75E
4+00E
2004 Grid Origin L5N 3+75E (1999 grid)
approx 1999 flagged line L5N
mineralization is along an older, very planar fault oriented 119 45 SW
LEGEND
Three sites of 2006 - 2007 mineralogical work green symbols
8.555 ppm Au by ICP MS/ES; if two decimals by Fire Assay
Blue QV Pit grab samples BH047 & BH-050 (Howard 2000)
BH-series Kennedy (2003) grab sample, re-analyzed in 2004
BHCK-series grab samples (Kennedy 2004 unrecorded)
Angular float sample BHCK-29 (Kennedy 2004 unrecorded)
Grab samples #### series 2004 geochem (Howard 2005)
Angular float sample 0515 (Howard 2005)
Measured Chip samples #### series (Howard 2005)
Measured Chip samples 0455 & 0456
Polished thick section site described in 2006a AR
Grab re-samples 2006 CLY-06-## series & duplicate samples
VG Visible Gold ID by B. Doyle 2004
Vein Contact with dip angle
Vein Corrugation Lineation with plunge angle (Howard 2005)
Metaquartzite foliation with dip angle (from Ray 2004)
2005-2006 hand trenched & stripped
2004 hand trench
Soil station 1999 Bunker Hill-Lefevre survey grid (Howard 2000)
Map 2 BiTel Knoll Au(Ag)-Bi-Te-Mo-W bearing Qtz Veins
See green book symbols for sites of 2006 - 2007 mineralogical work on 5 polished thick sections from the Eloise & BQ Veins
BGS 082F003 Salmo map sheet NTS 082F03 W1/2
Dec. 30 2007
Wm R Howard, B.Sc. Geol.
Calgary AB
Map 1
Scale: 1:200
Very proximal placed & intrusion-hosted quartz veins with native bismuth, native gold, bismuthinite, auriferous bismuth tellurides and sulphotellurides. Au(Ag)-Bi-Te-Mo-W in assays. Only sulphide is trace molybdenite.
Veins form three differently oriented Sets. Set 2 Clarissa Transverse Veins are sheeted (repeated).
Brown contour line is 1280 m. Central CLY Group Claims in Nelson Mining Division, southernmost BC, Canada.
To accompany Dec. 30 2007 AR
Projection: NAD 83 UTM Zone 11 wm.howard@shaw.ca
Clarke Gold Inc.
Calgary AB Canada
metres
Different dip senses, mineral assemblages and associated elements confirm these are two different structures
VLF-EM Fraser Filtered positive dip angle contours from W-E line L5N (last line) of BH-Lefevre survey (Howard 2000)
Moly Quartz Vein Trench
molybdenite + pyrite + galena + Ag sulphosalts
Phase 2 distal Ag-Pb-Mo-Bi geochem
Historic Past Production in 1933
~ 8.78 oz Au + 142.6 oz Ag from 50 tons (0.18 oz/ton Au, 2.85 oz/ton Ag) from a pit in a Shear Zone leaving a 5.6 m long overhanging side cut
"In the granite there is 1 to 3 1/2 feet of quartz ... with molybdenite, pyrite and some fine black sulphide (AR 1936 p. E20)".
Blasted, subcroping vein oriented 115 36 NE about 2.2 m thick, max. 2.8 m. Dump pile this side
blk v f grd sulphides breccia subcrop
Mormon Girl C.G. lot 1949
claim #516584
Bunker Hill C.G. lot 2939
drift covered downslope
approx. height of land