BRITISH COLUMBIA

Ministry of Employment and Investment
Hon. Dan Miller, Minister

ENERGY AND MINERALS DIVISION
Geological Survey Branch

SELECTED BRITISH COLUMBIA MINERAL DEPOSIT PROFILES

Volume 2 - Metallic Deposits

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INTRODUCTION

The British Columbia Geological Survey (BCGS) started a mineral potential assessment in 1992 utilizing deposit models for defining and characterizing mineral and coal deposits which exist, or could exist, in the province. The methodology for this resource assessment process is described by Grunsky *et al.* (1994), Kilby (1995) and Grunsky (1995). A fundamental part of this process is compilation of information about mineral deposits including descriptions, classification and resource data (Lefebure *et al.*, 1995a). The resulting deposit models are being used to classify known deposits and occurrences, to guide experts in their estimation of the number of possible undiscovered mineral deposits, and to group deposits to allow compilation of representative grade and tonnage data.

The BCGS relied initially on mineral deposit models published by the United States Geological Survey (USGS) and Geological Survey of Canada (GSC). The USGS published the first comprehensive set of mineral deposit models and related grade and tonnage probability curves (Cox and Singer, 1986). They present 85 mineral deposit models and 60 associated grade and tonnage curves. Almost all the deposits described contain metallic commodities. Since then the USGS has produced a number of other publications containing summary deposit models, including two significant Open File reports with a large number of industrial minerals models (Orris and Bliss, 1991, 1992). More recently the USGS has published more seminal work on deposit models, focusing on descriptive geoenvironmental mineral deposit models (du Bray, 1995).

As the BCGS carried out the mineral potential assessments it became apparent that some USGS models needed revision, and that there are British Columbia deposit types lacking published models. This work is proceeding using the BCGS's considerable in-house expertise (McMillan *et al.*, 1991) with assistance from economic geologists of the GSC, USGS, industry and academia.

These deposit models are called 'deposit profiles' to distinguish them from other published descriptions, such as the USGS 'deposit models'. One value of the profiles is that they will provide geologists and prospectors with a reference guide to deposits with which they have little familiarity.

This open file is the second report containing deposit profiles and includes descriptions of a variety of metallic deposits, including epithermal, vein and manto deposits, that were not covered in the first report (Lefebure and Ray, 1995).

CITATION

This report reflects the contributions of many individuals, particularly the authors of the individual deposit models and the staff who tabulated the grade and tonnage data. Please cite the individual authors whenever appropriate, rather than the entire Open File.

BRITISH COLUMBIA MINERAL DEPOSIT PROFILES

Mineral deposit profiles are concise descriptions of a group of deposits with common characteristics tied to a series of headings which will commonly fit on less than five pages. This format is similar to those of deposit models published by the GSC, USGS and Ontario Geological Survey (Eckstrand, 1984; Cox and Singer, 1986; Rodgers *et al.*, 1995). They are designed to be primarily descriptive because the ore-forming processes are sometimes poorly understood. As with the USGS models, the profiles are intended to be global models with sufficient information to describe the deposit type anywhere in the world. However, they incorporate more information specific to British Columbia with respect to tectonic setting, age of mineralization, examples, references, resource data and economic factors. The guidelines given to the authors for the profiles are presented in Appendix I of Open File 1995-20 (Lefebure and Ray, 1995).

A number of deposit types that are not thought to be relevant to British Columbia have not been addressed by completing profiles. For example, there seems very little likelihood of komatiitic nickel deposits occurring in the province. In some cases very specific deposit models have been combined to provide a more general model that better meets the needs of the mineral potential assessment process.

Profiles are based on a combination of published information and the personal knowledge of the authors and, in many cases, information provided informally by industry geologists. More than 140 general deposit models are thought to be relevant to British Columbia, including 75 metal, 70 industrial mineral and four coal profiles. The BCGS is currently working towards completing descriptions for approximately 100 of the deposit models.

One of the objectives of this Open File is to elicit comments and criticisms from readers. These inputs will assist the authors and editors to improve the deposit profiles before their incorporation in a final volume. BCGS staff can be contacted at the following addresses:

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CLASSIFICATION

The different methods of grouping of the deposit types has generated considerable discussion. This reflects the difficulties in any subdivision of complex natural phenomena, particularly when some deposit types are end members of a continuum. The many classification systems developed since Agricola are testimony to the elusive nature of a satisfactory classification scheme for mineral deposits. This is not surprising given ongoing advances in our understanding of ore-forming processes. The reader is directed to summaries by Jensen and Bateman (1979) and Peters (1978) for a review of different classification systems.

With the profiles, the approach has been to regard the deposit models as the key element and any classification system as merely an index for placing the models into a useful context for the user. Profiles will be published with multiple indexes, such as by deposit examples, commodity and host lithology. In Bulletin 1693, the USGS use a lithologic-tectonic environment classification system to organize the table of contents which is complimented by commodity/geochemical, mineralogical and deposit name indexes (Cox and Singer, 1986). Another example of providing multiple indexes to mineral deposit types is Laznicka's text on "Empirical Metallogeny" (1985).

Two classification schemes for British Columbia deposit profiles are presented in this open file. The first is organized by deposit groups (Appendix I, Table 22) which uses a combination of characteristics to separate deposits into groupings. This is a single entry listing with headings, such as porphyry, industrial rocks, skarn and placer deposit groups. Many of these groups relate well to areas of expertise of economic geologists. The second classification system lists deposit profiles by commodities that have been recovered from them (Appendix II, Table 23). It is a multiple entry with byproducts followed by an asterisk.

In Open File 1995-20 there is an index that classifies profiles according to the most commonly associated host lithologies. This is another multiple entry index. It is particularly useful for mineral potential assessments where the bedrock geology can be the most important criterion for estimating the number of undiscovered deposits.

The deposit group table in Appendix I provides related information, including roughly synonymous, alternate deposit model names. In many cases example deposits from British Columbia, Canada and the world are listed for each profile. The BCGS alphanumeric reference code for the deposit profiles is recorded in both tables. This is a single letter followed by a two digit number which is used in the British Columbia mineral occurrence database, MINFILE, and provides a short exact code for the profiles. If the BCGS does not yet have an existing draft profile for a deposit type, this is indicated by an asterisk after the code (e.g. B01*).

Within the list of deposit types for British Columbia (Table 22), the reader will notice several new deposit types that reflect the influence of new discoveries or new data. For example, there is a deposit model for "Shallow Subaqueous Hot Spring Au-Ag" (Alldrick, 1995). This is based on the Eskay Creek deposit and recent research results from the southeast Pacific (Hannington, 1993) documenting shallow, precious metal-rich, exhalative sulphide deposits.

GRADE AND TONNAGE DATA

As part of the mineral potential assessments of the province grade and tonnage data was compiled for mines and significant deposits in the province (Grunsky, 1995). This data was used to compliment data from the USGS (Singer et al., 1993). British Columbia grade and tonnage data for 21 deposit types is tabulated in this open file (pages 131 to 160).

ACKNOWLEDGMENTS

The authors would like to thank all the economic geologists who have contributed their input to the deposit profiles. BCGS staff have contributed the majority of the deposit models and participated in number of meetings to determine which deposit types should be included.

A number of geologists from government, universities and industry have also written or co-authored profiles allowing us to tackle more deposit models. Staff of the Geological Survey of Canada have been particularly helpful.

Comments volunteered by James MacDougall of J.J. MacDougall and Associates Ltd., Paul Barton of the USGS and Felix Mutschler of Eastern Washington University were much appreciated. John Newell provided editorial comments which improved the manuscript content and consistency.

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VOLCANIC REDBED CU D03

by David V. Lefebure and B. Neil Church

IDENTIFICATION

SYNONYMS: Basaltic Cu, volcanic-hosted copper, copper mantos.

COMMODITIES (BYPRODUCTS): Cu (Ag)

EXAMPLES (British Columbia - *Canada/International*): Sustut Copper (094D063), Shamrock (092HNE092), NH (093L082), North Star (094D032); *White River (Yukon, Canada), 47 Zone and June, Coppermine River area (Northwest Territories, Canada) Mountain Grill and Radovan (Alaska, USA), Calumet-Hecla and Kearsarga, Keweenaw Peninsula (Michigan, USA), Mantos Blancos, Ivan and Altamira (Chile).*

GEOLOGICAL CHARACTERISTICS

CAPSULE DESCRIPTION: Chalcocite, bornite and/or native copper occur in mafic to felsic volcanic flows, tuff and breccia and related sedimentary rocks as disseminations, veins and infilling amygdules, fractures and flowtop breccias. Some deposits are tabular, stratabound zones, while others are controlled by structures and crosscut stratigraphy.

TECTONIC SETTINGS: These deposits occur in intracontinental rifts with subaerial flood basalt sequences and near plate margins with island-arc and continental-arc volcanics.

DEPOSITIONAL ENVIRONMENT / GEOLOGICAL SETTING: Continental to shallow-marine volcanic settings which formed in "low to intermediate latitudes" with arid to semi-arid environments. The metamorphic grade is sub-greenschist.

AGE OF MINERALIZATION: Proterozoic to Tertiary.

HOST/ASSOCIATED ROCK TYPES: Amygdaloidal basaltic lavas, breccias and coarse volcaniclastic beds with associated volcanic tuffs, siltstone, sandstone and conglomerate are the most common rock types. The volcanics may cover the spectrum from basalt to rhyolite composition. Redbed sedimentary rocks are common and often exhibit shallow water sedimentary structures (small-scale crossbedding, mud cracks, algal mats). Any of these units may host the deposits, although typically it is the mafic volcanics that have widespread elevated background values of copper due to the presence of native copper or chalcocite in amygdules, flow breccias or minor fractures.

DEPOSIT FORM: Many deposits are tabular lenses from a few to several tens of metres thick which are roughly concordant with the host strata over several hundred metres. Other deposits are strongly influenced by structural controls and crosscut the stratigraphy as veins, veinlets, fault breccias and disseminated zones.

TEXTURE/STRUCTURE: Disseminations, open-space fillings, veins and some replacement textures. Open spaces may be amygdules, cavities in flowtop breccias or fractures. Mineralization is commonly fine-grained, although spectacular examples of copper "nuggets" are known.

ORE MINERALOGY [Principal and *subordinate*]: Chalcocite, bornite, native copper, digenite, djurleite, *chalcopyrite, covellite, native silver* and *greenockite. Iron sulphides, including pyrite, typically peripheral to the ore.* Some deposits are zoned from chalcocite through bornite and chalcopyite to fringing pyrite. Copper-arsenic minerals, such as domeykite, algodonite and whitneyite, occur in fissure veins in the Keewenaw Peninsula.

VOLCANIC REDBED CU D03

GANGUE MINERALOGY [Principal and *subordinate*]: Typically little or no gangue; *hematite, magnetite, calcite, quartz, epidote, chlorite and zeolite minerals.*

ALTERATION MINERALOGY: Generally no associated alteration, although many deposits occur in prehnite-pumpellyite grade regionally metamorphosed volcanic rocks with minerals such as calcite, zeolites, epidote, albite, prehnite, pumpellyite, laumontite and chlorite.

WEATHERING: These deposits commonly have no associated gossans or alteration; locally minor malachite or azurite staining.

ORE CONTROLS: Deposits appear to be confined to subaerial to shallow-marine volcanic sequences commonly with intercalated redbeds. One of the major ore controls is zones of high permeability due to volcaniclastics, breccias, amygdules and fractures.

ASSOCIATED DEPOSIT TYPES: Sediment-hosted copper deposits (E04) often occur in the same stratigraphic sequences. The carbonate-hosted copper deposits at Kennicott, Alaska are associated with basaltic Cu deposits in the Nikolai greenstone.

GENETIC MODELS: Most authors have favoured metamorphism of copper-rich, mafic volcanic rocks at greater depth for the source of the metal-bearing fluids, and subsequent deposition higher in the stratigraphic sequence, in oxidized subaerial hostrocks at lower metamorphic grade. More recently analogies have been drawn to diagenetic models for sediment-hosted Cu deposits which predate the metamorphism. Low-temperature fluids migrating updip along permeable strata to the margins of basins, or along structures, deposit copper upon encountering oxidized rocks. These rocks are typically shallow-marine to subaerial volcanic rocks which formed in arid and semi-arid environments. Both models require oxidized rocks as traps, which requires the presence of an oxygen-rich atmosphere; therefore, all deposits must be younger than ~2.4 Ga.

EXPLORATION GUIDES

GEOCHEMICAL SIGNATURE: Simple ore mineralogy produces a very specific geochemical signature for Cu and usually Ag. Lithogeochemical and stream sediment samples may return high values of Cu±Ag, typically high Cu/Zn ratios and low gold values.

GEOPHYSICAL SIGNATURE: Induced polarization surveys can be used to delineate mineralized lenses and areas of more intense veining.

OTHER EXPLORATION GUIDES: Malachite-staining. A red liverwort-like organism (Tentopholia iolithus) is often found in abundance on the surface of outcrops with copper mineralization in northern British Columbia.

ECONOMIC FACTORS

TYPICAL GRADE AND TONNAGE: The deposits range in size from hundreds of thousands to hundreds of millions of tonnes grading from less than 1% Cu to more than 4% Cu. Silver values are only reported for some deposits and vary between 6 and 80 g/t Ag. Sustut contains 43.5 Mt grading 0.82% Cu. The Calumet conglomerate produced 72.4 Mt grading 2.64% Cu.

ECONOMIC LIMITATIONS: Only a few deposits have been high enough grade to support underground mines and the majority of occurrences are too small to be economic as open pit operations.

IMPORTANCE: The Keweenaw Peninsula deposits in Michigan produced 5 Mt of copper between 1845 and 1968. Otherwise production from basaltic copper deposits has been limited; the only currently operating mines producing significant copper are in Chile. However, there are numerous deposits of this type in British Columbia which underlines the potential to find significant copper producers.

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CARBONATE-HOSTED DISSEMINATED Au-Ag E03

by Tom Schroeter and Howard Poulsen

IDENTIFICATION

SYNONYMS: Carlin-type gold, sediment-hosted micron gold, siliceous limestone replacement gold, invisible ("no-seeum") gold.

COMMODITIES (BYPRODUCTS): Au (Ag). In rare cases Ag dominates over Au.

EXAMPLES (British Columbia (MINFILE #) - *Canada/International*): Golden Bear? (104K079)*; parts of Brewery Creek (Yukon, Canada), Carlin, Getchell, Cortez, Gold Acres, Jerrett Canyon, Post and Gold Quarry (Nevada, USA), Mercur (Utah, USA), Mesel? (Indonesia), Guizhou (China).*

GEOLOGICAL CHARACTERISTICS

CAPSULE DESCRIPTION: Very fine grained, micron-sized gold and sulphides disseminated in zones of decarbonated calcareous rocks and associated jasperoids. Gold occurs evenly distributed throughout hostrocks in stratabound concordant zones and in discordant breccias.

TECTONIC SETTINGS: Passive continental margins with subsequent deformation and intrusive activity, and possibly island arc terranes.

DEPOSITIONAL ENVIRONMENT / GEOLOGICAL SETTING: Host rocks to the Nevadan deposits were deposited in shelf-basin transitional (somewhat anoxic) environments, formed mainly as carbonate turbidites (up to 150 m thick), characterized by slow sedimentation. These rocks are presently allochthonous in thrust fault slices and have been overprinted by Miocene basin and range extension. There are Mesozic to Tertiary felsic plutons near many deposits.

AGE OF MINERALIZATION: Mainly Tertiary, but can be any age.

HOST/ASSOCIATED ROCK TYPES: Hostrocks are most commonly thin-bedded silty or argillaceous carbonaceous limestone or dolomite, commonly with carbonaceous shale. Although less productive, non-carbonate siliciclastic and rare metavolcanic rocks are local hosts. Felsic plutons and dikes are also mineralized at some deposits.

DEPOSIT FORM: Generally tabular, stratabound bodies localized at contacts between contrasting lithologies. Bodies are irregular in shape, but commonly straddle lithological contacts which, in some cases, are thrust faults. Some ore zones (often higher grade) are discordant and consist of breccias developed in steep fault zones. Sulphides (mainly pyrite) and gold are disseminated in both cases.

TEXTURE/STRUCTURE: Silica replacement of carbonate is accompanied by volume loss so that brecciation of hostrocks is common. Tectonic brecciation adjacent to steep normal faults is also common. Generally less than 1% fine-grained sulphides are disseminated throughout the hostrock.

ORE MINERALOGY [Principal and *subordinate*]: Native gold (micron-sized), *pyrite with arsenian rims, arsenopyrite, stibnite, realgar, orpiment, cinnabar, fluorite, barite, rare thallium minerals.*

CARBONATE-HOSTED DISSEMINATED Au-Ag E03

GANGUE MINERALOGY [Principal and *subordinate*]: Fine-grained quartz, barite, clay minerals, carbonaceous matter (late-stage calcite veins).

ALTERATION MINERALOGY: Strongly controlled by local stratigraphic and structural features. Central core of strong silicification close to mineralization with silica veins and jasperoid; peripheral argillic alteration and decarbonation ("sanding") of carbonate rocks common in ore. Carbonaceous material is present in some deposits.

WEATHERING: Nevada deposits have undergone deep supergene alteration due to Miocene weathering. Supergene alunite and kaolinite are widely developed and sulphides converted to hematite. Such weathering has made many deposits amenable to heap-leach processing.

GENETIC MODELS:

a) Epithermal model: Once widely accepted but now discounted for most deposits. Mineralization was thought to result from shallow Miocene magmatism related to basin and range extension. New discoveries of deep orebodies, overprinting basin and range deformation, and recognition of a supergene origin of alunite have cast doubt on this model.
b) Distal skarn model: Currently very popular because many deposits occur near intrusions, skarns and calcsilicate rocks. Carbonate-hosted disseminated gold is thought to be related to collapse of intrusion-centred porphyry-type hydrothermal systems. Although compelling for many deposits, this model fails to explain several districts (e.g., Jerritt Canyon; Guizhou, China) where no related magmatism has been observed.
c) Deep crustal fluid model: Recently proposed to account for inferred deep mixing of different fluids from different reservoirs as demanded by light stable isotopic and fluid inclusion data. Variants of this model imply only indirect links to magmatism, suggest a single Paleogene age for the Nevadan deposits and relate them to a unique period of pre-basin and range crustal extension and associated faults that are controlled by pre-existing Paleozoic and Mesozoic structures.

ORE CONTROLS: 1. Selective replacement of carbonaceous carbonate rocks adjacent to and along high-angle faults, regional thrust faults or bedding. 2. Presence of small felsic plutons (dikes) that may have caused geothermal activity and intruded a shallow hydrocarbon reservoir or area of hydrocarbon-enriched rocks, imposing a convecting geothermal system on the local groundwater. 3. Deep structural controls are believed responsible for regional trends and may be related to Precambrian crystalline basement structures and/or accreted terrane boundaries.

ASSOCIATED DEPOSIT TYPES: Porphyry (L04, L05), Au, W or Mo skarns (K04, K05, K07), polymetallic manto (J01).

COMMENTS: B.C.: 1. Limestone fault slices (part of accreted Stikine terrane) which have been intruded by felsic plutons, especially near high-angle fault zones, may host deposits (*e.g.*, Golden Bear mine area). 2. Interior Plateau region - if carbonate units present - potential basin and range setting.

CARBONATE-HOSTED DISSEMINATED Au-Ag E03

EXPLORATION GUIDES

GEOCHEMICAL SIGNATURE: Two geochemical asemblages - Au+As+Hg+W or ? Mo and As+Hg+Sb+Tl or Fe. NH_3 important in some deposits. Au:Ag 10:1 or greater. Anomalous values in rock: As (100-1000 ppm); Sb (10-50 ppm); Hg (1-30 ppm).

GEOPHYSICAL SIGNATURE: Resistivity lows for some deposits. Aeromagnetic surveys may highlight spatially associated intrusions, skarns if present and possibly regional trends.

OTHER EXPLORATION GUIDES: In Nevada the deposits exhibit regional alignments or trends. Satellite imagery is useful to identify regional structures.

ECONOMIC FACTORS

TYPICAL GRADE AND TONNAGE: Grades range from 1 to 35 g/t Au and deposit sizes from 1 to 150 Mt of ore. For 43 significant deposits the median tonnages and grades for low-grade oxide and higher grade hypogene deposits are 20 Mt grading 1.2 g/t Au and 6 Mt containing 4.5 g/t Au, respectively. Supergene deposits amenable to heap leaching typically grade 1-2 g/t Au; whereas, production grades for deposits with hypogene ore typically grade 5 to 10 g/t or greater.

ECONOMIC LIMITATIONS: Parts of deposits are amenable to open-pit mining and heap leaching (especially oxidized zones), but roasting and autoclave extraction is required for more refractory ores. New discoveries of high-grade hypogene ore have resulted in increased underground mining.

IMPORTANCE: Between 1965 and 1995, deposits along the Carlin Trend (70 x 10 km), have yielded approximately 750 t of Au. Deposits that are unquestionably of this type are not presently known in Canada but may be present.

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CARBONATE-HOSTED DISSEMINATED Au-Ag E03

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SEDIMENT-HOSTED Cu±Ag±Co E04

by David V. Lefebure and Dani J. Alldrick

IDENTIFICATION

SYNONYMS: Sediment-hosted stratiform copper, shale-hosted copper, Kupferschiefer-type, redbed Cu, Cu-shale, sandstone Cu.

COMMODITIES (BYPRODUCTS): Cu, Ag (Co, Pb, Zn, rarely PGE, Au, U, Va).

EXAMPLES (British Columbia (MINFILE #) - *Canada/International*): Roo (082GSW020), Commerce (082GSE065), Chal 4 (092K068); *Redstone (Northwest Territories, Canada), Kennicott (Alaska, USA), Spar Lake (Troy), Rock Creek and Montanore (Montana, USA), White Pine (Michigan, USA), Creta (Oklahoma, USA), Corocoro (Bolivia), Mansfield-Sangerhausen and Spremberg, Kupferschiefer district (Germany), Konrad and Lubin (Poland), Dzherkazgan (Kazakhstan), Copper Claim (Australia), Kamoto and Shaba, Zambia-Zaire copperbelt (Zaire).*

GEOLOGICAL CHARACTERISTICS

CAPSULE DESCRIPTION: Stratabound disseminations of native copper, chalcocite, bornite and chalcopyrite in a variety of continental sedimentary rocks including black shale, sandstone and limestone. These sequences are typically underlain by, or interbedded with, redbed sandstones with evaporite sequences. Sulphides are typically hosted by grey, green or white strata.

TECTONIC SETTINGS: Predominantly rift environments located in both intracontinental and continental-margin settings; they can also occur in continental-arc and back-arc settings.

DEPOSITIONAL ENVIRONMENT / GEOLOGICAL SETTING: The characteristic presence of redbed and evaporite sequences points to deposition of sediments in a hot, arid to semi-arid paleoclimate near the paleoequator. The host rocks are produced in a variety of local anoxic depositional environments, including deltaic sediments, Sabkha-type lagoonal carbonate basins or high intertidal mudflats, and shallow "coal basins".

AGE OF MINERALIZATION: Proterozoic or younger; Middle Proterozoic, Permian and early Mesozoic most favourable ages.

HOST/ASSOCIATED ROCK TYPES: Most deposits are hosted by pale gray to black shale, but some are found in sandstone, siltstone, limestone, silty dolomite, laminated carbonate units (sabkha origin) and quartzites. Favourable horizons contain reactive organic matter or sulphur. Algal mats, mudcracks and scour-and-fill structures indicative of shallow-water deposition are common. Local channel-conglomerate beds sometimes contain wood fragments. The associated sequence includes redbed sediments, evaporites and sometimes volcanics. In many cases the rift-related layered rocks rest unconformably on older basement rocks.

DEPOSIT FORM: Orebodies are generally conformable with the bedding, although in detail ore may transgress bedding at low angles and is typically more transgressive near the margins of the deposit. Mineralized horizons are from tens of centimetres to several metres thick (rarely more than 5 m); they are often contained within broader zones of anomalous copper values. Tabular ore zones extend laterally for kilometres to tens of kilometres. Less commonly the deposits are elongate lobes. Some deposits have a C-shaped, "roll front" configuration in cross-section. Common lateral and/or vertical zoning is from hematite (barren) > chalcocite > bornite > chalcopyrite > pyrite, or from a chalcocite±bornite core grading to chalcopyrite with peripheral galena and sphalerite.

SEDIMENT-HOSTED Cu±Ag±Co E04

TEXTURE/STRUCTURE: Sulphides are fine grained and occur as disseminations, concentrated along bedding, particularly the coarser grained fractions, or as intergranular cement. Sharp-walled cracks or veinlets (< 1 cm thick, < than a metre in length) of chalcopyrite, bornite, chalcocite, galena, sphalerite or barite with calcite occur in some deposits, but are not an important component of the ore. Pyrite can be framboidal or colloform. Cu minerals often replace pyrite grains, framboids and nodules; less commonly they form pseudomorphs of sulphate nodules or blade-shaped gypsum/anhydrite grains. They also cluster around carbonaceous clots or fragments.

ORE MINERALOGY [Principal and *subordinate]:* Chalcocite, bornite and chalcopyrite; native copper in some deposits. Pyrite is abundant in rocks outside the ore zones. *Enargite, digenite, djurleite, sphalerite, galena, tennantite, native silver with minor Co-pyrite and Ge minerals.* In many deposits carrollite ($CuCo_2S_4$) is a rare mineral, however, it is common in the Central African Copperbelt.

GANGUE MINERALOGY [Principal and *subordinate]:* Not well documented; in several deposits carbonate, quartz and feldspar formed synchronously with the ore minerals and exhibit zonal patterns that are sympathetic with the ore minerals. They infill, replace or overgrow detrital or earlier authigenic phases.

ALTERATION MINERALOGY: Lateral or underlying reduced zones of green, white or grey colour in redbed successions. In the Montana deposits these zones contain chlorite, magnetite and/or pyrite. Barren, hematite-rich, red zones grade into ore in the Kupferschiefer. Kupferschiefer ore hosts also show elevated vitrinite reflectances compared to equivalent stratigraphic units.

WEATHERING: Surface exposures may be totally leached or have malachite and azurite staining. Near surface secondary chalcocite enrichment is common.

ORE CONTROLS: Most sediment-hosted Cu deposits are associated with the sag phase of continental rifts characterized by deposition of shallow-water sediments represented by redbed sequences and evaporites. These formed in hot, arid to semi-arid paleoclimates which normally occur within 20-30° of the paleoequator. Hostrocks are typically black, grey or green reduced sediments with disseminated pyrite or organics. The main control on fluid flow from the source to redoxcline is primary permeability within specific rock units, commonly coarse-grained sandstones. In some districts deposits are located within coarser grained sediments on the flanks of basement highs. Growth faults provide local controls in some deposits (*e.g.*, Spar Lake).

ASSOCIATED DEPOSIT TYPES: Sandstone U (D05), volcanic redbed Cu (D03), Kipushi Cu-Pb-Zn (E02), evaporite halite, sylvite, gypsum and anhydrite (F02); natural gas (mainly CH_4) in Poland.

GENETIC MODELS: Traditionally these deposits have been regarded as syngenetic, analogous to sedex deposits or late hydrothermal epigenetic deposits. Currently most researchers emphasize a two-stage diagenetic model. Carbonaceous shales, sandstones and limestones deposited in reducing, shallow subaqeuous environments undergo diagenesis which converts the sulphur in these sediments to pyrite. At a later stage during diagenesis, saline low-temperature brines carrying copper from a distant source follow permeable units, such as oxidized redbed sandstones, until they encounter a reducing unit. At this point a redoxcline is established with a cuperiferous zone extending "downstream" until it gradually fades into the unmineralized, often pyritic, reducing unit. The source of the metals is unresolved, with possible choices including underlying volcanic rocks, labile sediments, basement rocks or intrusions.

COMMENTS: Sediment-hosted Cu includes Sabkha Cu deposits which are hosted by thin-bedded carbonate-evaporite-redbed 'sabkha' sequences.

SEDIMENT-HOSTED Cu±Ag±Co E04

EXPLORATION GUIDES

GEOCHEMICAL SIGNATURE: Elevated values of Cu, Ag, Pb, Zn and Cd are found in hostrocks, sometimes with weaker Hg, Mo, V, U, Co and Ge anomalies. Dark streaks and specks in suitable rocks should be analysed as they may be sulphides, such as chalcocite.

GEOPHYSICAL SIGNATURE: Weak radioactivity in some deposits.

OTHER EXPLORATION GUIDES: Deposits often occur near the transition from redbeds to other units which is marked by the distinctive change in colour from red or purple to grey, green or black. The basal reduced unit within the stratigraphy overlying the redbeds will most often carry the highest grade mineralization.

ECONOMIC FACTORS

TYPICAL GRADE AND TONNAGE: Average deposit contains 22 Mt grading 2.1 % Cu and 23 g/t Ag (Mosier *et al.*, 1986). Approximately 20% of these deposits average 0.24 % Co. The Lubin deposit contains 2600 Mt of >2.0% Cu and ~ 30-80 g/t Ag. Spar Lake pre-production reserves were 58 Mt grading 0.76% Cu and 54 g/t Ag. Montanore contains 134.5 Mt grading 0.74% Cu and 60 g/t Ag, while Rock Creek has reserves of 143.7 Mt containing 0.68 % Cu and 51 g/t Ag.

ECONOMIC LIMITATIONS: These relatively thin horizons require higher grades because they are typically mined by underground methods. The polymetallic nature and broad lateral extent of sediment-hosted Cu deposits make them attractive.

IMPORTANCE: These deposits are the second most important source of copper world wide after porphyry Cu deposits. They are an interesting potential exploration target in British Columbia, although there has been no production from sediment-hosted Cu deposits in the province. The stratigraphy that hosts the Spar Lake, Montanore and Rock Creek deposits in Montana extends into British Columbia where it contains numerous small sediment-hosted Cu-Ag deposits.

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SEDIMENT-HOSTED Cu±Ag±Co E04

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SANDSTONE-Pb E05

by D.F. Sangster[1]

IDENTIFICATION

COMMODITIES (BYPRODUCTS): Pb (Zn, Ag).

EXAMPLES (British Columbia - *Canada/International*): None in British Columbia; *only two are known in Canada; Yava (Nova Scotia) and George Lake (Saskatchewan), Laisvall (Sweden), Largentière (France), Zeida (Morocco), Maubach and Mechernich (Germany).*

GEOLOGICAL CHARACTERISTICS

CAPSULE DESCRIPTION: Disseminated galena with minor sphalerite, in transgressive basal quartzite or quartzofeldspathic sandstones resting on sialic basement.

TECTONIC SETTING: Platformal deposits commonly found in sandstones resting directly on basement (usually cratonic) of sialic composition.

DEPOSITIONAL ENVIRONMENT / GEOLOGICAL SETTING: Hostrocks were deposited in environments ranging from continental fluvial to shallow marine or tidal beach. The most common environment is one of mixed continental and marine character (*i.e.*, paralic). Host rocks in most districts are succeeded by marine sediments, suggestive of marine transgression onto the craton. Terrestrial organic debris, ranging from trace to abundant, is present in most of the post-Devonian deposits. Paleomagnetic data available in several districts indicate a low paleolatitude position (0-30°) for all deposits. Paleoclimatic conditions ranged from warm arid to cool humid but in a majority of cases, were semiarid and warm.

AGE OF MINERALIZATION: Mineralization age has not been established with certainty; however, deposits are found in rocks ranging from Middle Proterozoic to Cretaceous age. Rocks of Late Proterozoic - Early Cambrian and Triassic ages contain a majority of deposits of this type.

HOST/ASSOCIATED ROCK TYPES: Hostrocks are grey or white (never red) quartzitic or quartzo-feldspathic sandstones and conglomerates; they are rarely siltstone or finer grained clastics. Sialic basement rocks, typically granites or granitic gneisses, underly sandstone lead deposits. Shales and associated evaporites as beds, nodules or disseminations are intercalated with the host sandstones.

DEPOSIT FORM: Orebodies are commonly conformable with bedding in the sandstone, especially on a mine scale. In detail, however, the ore zones may actually transgress bedding at a low angle. Sedimentary channels in the sandstone are preferentially mineralized; consequently, most deposits have a generally lensoid form. In plan, ore zones tend to be sinuous and laterally discontinous. Ore zones tend to be delimited by assay, rather than geological, boundaries. Characteristically, a higher grade core is surrounded by material that progressively decreases in grade outward. Rarely, higher grade zones occur in, and adjacent to, steep faults; consequently, in these deposits, many ore zones are narrow, lenticular bodies oriented at high angles to bedding.

TEXTURE/STRUCTURE: The preferred site of ore minerals is as cement between sand grains resulting in disseminated sulphide blebs or spots in massive sandstones or concentrations of sulphides along the lower, more porous portions of graded beds. The disseminated sulphides are not normally homogeneously dispersed throughout the sandstone. Two very common textures are:

i) spots, representing local accumulations of galena, as much as 2 cm in diameter. Spots may be randomly distributed in the sandstone or may show a slight preferential alignment parallel to bedding;

ii) discontinous galena-rich streaks distributed parallel to bedding, including crossbedding.

[1] Geological Survey of Canada, Ottawa

SANDSTONE-Pb E05

Where carbonaceous material is present, sulphides fill wood cells or replace cell walls. Concretionary-like sulphide concentrations are abundant in some deposits. Epitaxial quartz overgrowths on detrital quartz grains are very common and in some deposits more abundant within or near ore zones than regionally. Paragenetic studies indicate the epitaxial quartz predates galena.

ORE MINERALOGY [Principal and *subordinate*]: Galena, sphalerite, and pyrite, *chalcopyrite and various Ni-Co-Fe sulphides.* Replacement of sulphides by secondary analogues has been reported in one or more deposits.

GANGUE MINERALOGY [Principal and *subordinate*]: Silica, usually chalcedonic, and various carbonate minerals constitute the most abundant non-sulphide cement.

ALTERATION MINERALOGY: If the hostrocks were originally arkosic, pre-mineralization alteration (sometimes referred to as "chemical erosion") of the host sandstones commonly results in complete, or near-complete, destruction of any feldspars and mafic minerals which may have been present. Otherwise, alteration of quartz sandstone hosts is nil. Neomorphic formation of quartz overgrowths and authigenic clay minerals, however, is a common feature of these deposits; calcite and sulphates are less common cements. Pre-sandstone weathering of granitic basement, as evidenced by the presence of paleoregolith and the destruction of feldspar and mafic minerals, has been observed beneath several deposits.

ORE CONTROLS: 1. Sialic basement; those with average lead content greater than ~30 ppm are particularly significant. 2. Basal portion of grey or white (not red) quartzitic sandstone of a transgressive sequence on sialic basement. The "cleaner" portions, with minimum intergranular material, are the preferred host lithologies because they are more porous. 3. Channels in sandstone, especially on the periphery of the sedimentary basin. These channels may also be evident in the basement.

GENETIC MODEL: Groundwater transport of metals leached from lead-rich basement, through porosity channels in sandstone; precipitation of metals by biogenically-produced sulphide. A genetic model involving compaction of brine-bearing basins by over-riding nappes has been proposed for deposits in Sweden.

ASSOCIATED DEPOSIT TYPES: Sandstone Cu and sandstone U (D05).

EXPLORATION GUIDES

GEOCHEMICAL SIGNATURE: Stream sediment and soil geochemical surveys; analyze for Pb and Zn.

GEOPHYSICAL SIGNATURE: Induced polarization anomalies (?)

OTHER EXPLORATION GUIDES: Epitaxial quartz overgrowths are abundant, especially within and near the ore zones. Host sandstones deposited at low paleolatitudes. Sialic basement with high lead content (>30 ppm). Basal quartz sandstone of a transgressive sequence, overlying basement. Channels in sandstone as evidenced by thickening, lateral conglomerate-to-sandstone facies changes, etc. Permeable zones in sandstone (i.e., "cleanest" sandstone, minimum of intergranular clayey material).

SANDSTONE-Pb E05

ECONOMIC FACTORS

TYPICAL GRADE AND TONNAGE: Deposits range in grade from 2 to 5% Pb, 0.2 to 0.8% Zn, 1 to 20 g/t Ag; most are less than 10 Mt in size. Because of the disseminated nature of the ore, tonnages and grades can be markedly affected by changes in cut-off grades. At Yava, for example, at cut-off grades of 1, 2, and 3%, tonnages and grades are as follows: 71.2 Mt at 2.09% Pb, 30.3 Mt at 3.01%, and 12.6 Mt at 3.95%, respectively.

ECONOMIC LIMITATIONS: Because of the typically low Pb grades and the general paucity of byproduct commodities, this deposit type has always been a minor player in the world's base metal markets.

IMPORTANCE: In some countries where other sources of Pb are limited, sandstone-Pb deposits have constituted major national resources of this metal (*e.g.* Sweden).

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IRISH-TYPE CARBONATE-HOSTED Zn-Pb E13

By Trygve Höy

IDENTIFICATION

SYNONYMS: Kootenay Arc Pb-Zn, Remac type.

COMMODITIES (*BYPRODUCTS*): Zn, Pb, Ag; (*Cu, barite, Cd*).

EXAMPLES (British Columbia (MINFILE #) - *Canada/International*): Reeves MacDonald (082FSW026), HB (082FSW004), Aspen (082FSW001), Jack Pot (082SW255), Jersey (082SW009), Duncan (082KSE020) , Wigwam (082KNW068); *Navan, Lisheen, Tynagh, Silvermines, Galmoy, Ballinalack, Allenwood West (Ireland); Troya (Spain).*

GEOLOGICAL CHARACTERISTICS

CAPSULE DESCRIPTION: Irish-type carbonate-hosted deposits are stratabound, massive sphalerite, galena, iron sulphide and barite lenses with associated calcite, dolomite and quartz gangue in dolomitized platformal limestones. Deposits are structurally controlled, commonly wedge shaped adjacent to normal faults. Deformed deposits are irregular in outline and commonly elongate parallel to the regional structural grain.

TECTONIC SETTING: Platformal sequences on continental margins which commonly overlie deformed and metamorphosed continental crustal rocks.

DEPOSITIONAL ENVIRONMENT/GEOLOGICAL SETTING: Adjacent to normal growth faults in transgressive, shallow marine platformal carbonates; also commonly localized near basin margins.

AGE OF MINERALIZATION: Known deposits are believed to be Paleozoic in age and younger than their host rocks; Irish deposits are hosted by Lower Carboniferous rocks; Kootenay Arc deposits are in the Lower Cambrian.

HOST/ASSOCIATED ROCK TYPES: Hosted by thick, non-argillaceous carbonate rocks; these are commonly the lowest pure carbonates in the stratigraphic succession. They comprise micritic and oolitic beds, and fine-grained calcarenites in a calcareous shale, sandstone, calcarenite succession. Underlying rocks include sandstones or argillaceous calcarenites and shales. Iron-formations, comprising interlayered hematite, chert and limestone, may occur as distal facies to some deposits. Deformed Kootenay Arc deposits are enveloped by fine-grained grey, siliceous dolomite that is generally massive or only poorly banded and locally brecciated.

DEPOSIT FORM: Deposits are typically wedge shaped, ranging from over 30 m thick adjacent to, or along growth faults, to 1-2 cm bands of massive sulphides at the periphery of lenses. Economic mineralization rarely extends more than 200 m from the faults. Large deposits comprise individual or stacked sulphide lenses that are roughly concordant with bedding. In detail, however, most lenses cut host stratigraphy at low angles. Contacts are sharp to gradational. Deformed deposits are typically elongate within and parallel to the hinges of tight folds. The Reeves MacDonald deposit forms a syncline with a plunge length of approximately 1500 m and widths up to 25 m. Others (HB) are elongate parallel to a strong mineral lineation. Individual sulphide lenses are irregular, but typically parallel to each other and host layering, and may interfinger or merge along plunge.

TEXTURE/STRUCTURE: Sulphide lenses are massive to occassionally well layered. Typically massive sulphides adjacent to faults grade outward into veinlet-controlled or disseminated sulphides. Colloform sphalerite and pyrite textures occur locally. Breccias are common with sulphides forming the matrix to carbonate (or as clasts?). Sphalerite-galena veins, locally brecciated, commonly cut massive sulphides.

IRISH-TYPE CARBONATE-HOSTED Zn-Pb E13

Rarely (Navan), thin laminated, graded and crossbedded sulphides, with framboidal pyrite, occur above more massive sulphide lenses. Strongly deformed sulphide lenses comprise interlaminated sulphides and carbonates which, in some cases (Fyles and Hewlett, 1959), has been termed shear banding.

ORE MINERALOGY (Prinicipal and *subordinate*): Sphalerite, galena; *barite, chalcopyrite, pyrrhotite, tennantite, sulfosalts, tetrahedrite, chalcopyrite.*

GANGUE MINERALOGY (Prinicipal and *subordinate*): Dolomite, calcite, quartz, pyrite, marcasite; *siderite, barite, hematite, magnetite; at higher metamorphic grades, olivine, diopside, tremolite, wollastonite, garnet.*

ALTERATION MINERALOGY: Extensive early dolomitization forms an envelope around most deposits which extends tens of metres beyond the sulphides. Dolomitization associated with mineralization is generally fine grained, commonly iron-rich, and locally brecciated and less well banded than limestone. Mn halos occur around some deposits; silicification is local and uncommon. Fe in iron-formations is distal.

WEATHERING: Gossan minerals include limonite, cerussite, anglesite, smithsonite, hemimorphite, pyromorphite.

ORE CONTROLS: Deposits are restricted to relatively pure, shallow-marine carbonates. Regional basement structures and, locally, growth faults are important. Orebodies may be more common at fault intersections. Proximity to carbonate bank margins may be a regional control in some districts.

GENETIC MODEL: Two models are commonly proposed:
(1) syngenetic seafloor deposition: evidence inludes stratiform geometry of some deposits, occurrence together of bedded and clastic sulphides, sedimentary textures in sulphides, and, where determined, similar ages for mineralization and host rocks.
(2) diagenetic to epigenetic replacement: replacement and open-space filling textures, lack of laminated sulphides in most deposits, alteration and mineralization above sulphide lenses, and lack of seafloor oxidation.

ASSOCIATED DEPOSIT TYPES: Mississippi Valley type Pb-Zn (E12), sediment-hosted barite (E17), sedimentary exhalative Zn-Pb-Ag (E14)), possibly carbonate-hosted disseminated Au-Ag (E03).

COMMENTS: Although deposits such as Tynagh and Silvermines have structures and textures similar to sedex deposits, and are associated with distal iron-formations, they are included in the Irish-type classification as recent work (e.g., Hizman, 1995) concludes they formed by replacement of lithified rocks. Deposits that can be demonstrated to have formed on the seafloor are not included in Irish-type deposits. It is possible that the same continental margin carbonates may host sedex (E14), Irish-type (E13) and Mississippi Valley-type (E12) deposits.

EXPLORATION GUIDES

GEOCHEMICAL SIGNATURE: Elevated base metal, Ag and Mn values in both silt and soil samples; however, high carbonate content, and hence high Ph may reduce effectiveness of stream silts.

GEOPHYSICAL SIGNATURE: Induced polarization surveys are effective and ground electromagnetic methods may work for deposits with iron sulphides. Deposits can show up as resistivity lows and gravity highs.

OTHER EXPLORATION GUIDES: The most important control is stratigraphic. All known deposits are in carbonate rocks, commonly the lowest relatively pure carbonate in a succession. Other guides are proximity to growth faults and intersection of faults, regional and local dolomitization and possibly laterally equivalent iron-formations.

ECONOMIC FACTORS

TYPICAL GRADE AND TONNAGE: Irish deposits are typically less than 10 Mt with 5-6% Zn, 1-2% Pb and 30g/t Ag. Individual deposits can contain up to 90 g/t Ag. The largest, Navan, produced 36 Mt and has remaining reserves of 41.8 Mt containing 8% Zn and 2% Pb. Mined deposits in the Kootenay Arc averaged between 6 and 7 Mt and contained 3-4 % Zn, 1-2 % Pb, and 3-4 g/t Ag. Duncan has reserves of 2.76 Mt with 3.3% Pb and 3.1% Zn; Wigwam contains 8.48 Mt with 2.14% Pb and 3.54% Zn.

ECONOMIC LIMITATIONS: These deposits are attractive because of their simple mineralogy and polymetallic nature, although significantly smaller than sedex deposits. In British Columbia the Kootenay Arc deposits are generally lower grade with up to only 6 % Pb+Zn. These deposits are also structurally complex making them more complicated to mine.

IMPORTANCE: Production from these deposits makes Ireland a major world zinc producer. Recent discovery of concealed deposits (Galmoy in 1986 and Lisheen in 1990) assures continued production. In British Columbia, a number of these deposits were mined intermittently until 1979 when H.B. finally closed. Some still have substantial lead and zinc reserves. However, their current potential for development is based largely on the precious metal content. The high carbonate content of the gangue minimizes acid-rock drainage problems.

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IRISH-TYPE CARBONATE-HOSTED Zn-Pb E13

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ALGOMA-TYPE IRON-FORMATION G01

by G.A. Gross[1]

IDENTIFICATION

SYNONYMS: Taconite, itabirite, banded iron-formation.

COMMODITIES (BYPRODUCTS): Fe (Mn).

EXAMPLES (British Columbia (MINFILE #) - *Canada/International*): Falcon (093O016), Lady A (092B029); *McLeod (Helen), Sherman, Adams, Griffith (Ontario, Canada), Woodstock, Austin Brook (New Brunswick, Canada), Kudremuk (India), Cerro Bolivar (Venezuela), Carajas (Brazil), part of Krivoy Rog (Russia).*

GEOLOGICAL CHARACTERISTICS

CAPSULE DESCRIPTION: Iron ore deposits in Algoma-type iron-formations consist mainly of oxide and carbonate lithofacies that contain 20 to 40 % Fe as alternating layers and beds of micro- to macro-banded chert or quartz, magnetite, hematite, pyrite, pyrrhotite, iron carbonates, iron silicates and manganese oxide and carbonate minerals. The deposits are interbedded with volcanic rocks, greywacke, turbidite and pelitic sediments; the sequences are commonly metamorphosed.

TECTONIC SETTINGS: Algoma-type iron-formations are deposited in volcanic arcs and at spreading ridges.

AGE OF MINERALIZATION: They range in age from 3.2 Ga to modern protolithic facies on the seafloor and are most widely distributed and achieve the greatest thickness in Archean terranes (2.9 to 2.5 Ga).

DEPOSITIONAL ENVIRONMENT / GEOLOGICAL SETTING: They formed both near and distal from extrusive centres along volcanic belts, deep fault systems and rift zones and may be present at any stage in a volcanic succession. The proportions of volcanic and clastic sedimentary rocks vary and are rarely mutually exclusive.

HOST/ASSOCIATED ROCKS: Rocks associated with Algoma-type iron-formations vary greatly in composition, even within local basins, and range from felsic to mafic and ultramafic volcanic rocks, and from greywacke, black shale, argillite, and chert interlayered with pyroclastic and other volcaniclastic beds or their metamorphic equivalents. Algoma-type iron-formations and associated stratafer sediments commonly show a prolific development of different facies types within a single stratigraphic sequence. Oxide lithofacies are usually the thickest and most widely distributed units of iron-formation in a region and serve as excellent metallogenetic markers.

DEPOSIT FORM: Iron ore deposits are sedimentary sequences commonly from 30 to 100 m thick, and several kilometres in strike length. In most economic deposits, isoclinal folding or thrust faulting have produced thickened sequences of iron-formation.

STRUCTURE/TEXTURE: Micro-banding, bedding and penecontemporaneous deformation features of the hydroplastic sediment, such as slump folds and faults, are common, and can be recognized in many cases in strongly metamorphosed oxide lithofacies. Ore mineral distribution closely reflects primary sedimentary facies. The quality of oxide facies crude ore is greatly enhanced by metamorphism which leads to the development of coarse granular textures and discrete grain enlargement.

[1] Geological Survey of Canada, Ottawa

ALGOMA-TYPE IRON-FORMATION G01

ORE MINERALOGY: Oxide lithofacies are composed of magnetite and hematite. Some deposits consist of siderite interbedded with pyrite and pyrrhotite.

GANGUE MINERALOGY [Principal and *subordinate*]: Quartz, siderite or ferruginous ankerite and dolomite, manganoan siderite and silicate minerals. *Silicate lithofacies are characterized by iron silicate minerals including grunerite, minnesotaite, hypersthene, reibeckite and stilpnomelane, associated with chlorite, sericite, amphibole, and garnet.*

WEATHERING: Minor oxidation of metal oxide minerals and leaching of silica, silicate and carbonate gangue. Algoma-type iron-formations are protore for high-grade, direct shipping types of residual-enriched iron ore deposits.

GENETIC MODEL: Algoma-type iron deposits were formed by the deposition of iron and silica in colloidal size particles by chemical and biogenic precipitation processes. Their main constituents evidently came from hydrothermal-effusive sources and were deposited in euxinic to oxidizing basin environments, in association with clastic and pelagic sediment, tuff, volcanic rocks and a variety of clay minerals. The variety of metal constituents consistently present as minor or trace elements evidently were derived from the hydrothermal plumes and basin water and adsorbed by amorphous iron and manganese oxides and smectite clay components in the protolithic sediment. Their development and distribution along volcanic belts and deep-seated faults and rift systems was controlled mainly by tectonic rather than by biogenic or atmospheric factors. Sulphide facies were deposited close to the higher temperature effusive centres; iron oxide and silicate facies were intermediate, and manganese-iron facies were deposited from cooler hydrothermal vents and in areas distal from active hydrothermal discharge. Overlapping and lateral transitions of one kind of lithofacies to another appear to be common and are to be expected.

ORE CONTROLS: The primary control is favourable iron-rich stratigraphic horizons with little clastic sedimentation, often near volcanic centres. Some Algoma-type iron-formations contain ore deposits due to metamorphic enhancement of grain size or structural thickening of the mineralized horizon.

ASSOCIATED DEPOSITS: Algoma-type iron-formations can be protore for residual-enriched iron ore deposits (B01?). Transitions from Lake Superior to Algoma-type iron-formations occur in areas where sediments extend from continental shelf to deep-water environments along craton margins as reported in the Krivoy Rog iron ranges. Oxide lithofacies of iron-formation grade laterally and vertically into manganese-rich lithofacies (G02), and iron sulphide, polymetallic volcanic-hosted and sedex massive sulphide (G04, G05, G06, E14).

COMMENTS: Lithofacies selected for iron and manganese ore are part of the complex assemblage of stratiform units formed by volcanogenic-sedimentary processes that are referred to collectively as stratafer sedimentary deposits, and includes iron-formation (more than 15% Fe) and various other metalliferous lithofacies.

EXPLORATION GUIDES

GEOCHEMICAL SIGNATURE: Elevated values for Fe and Mn; at times elevated values for Ni, Au, Ag, Cu, Zn Pb, Sn, W, REE and other minor elements.

GEOPHYSICAL SIGNATURE: Electromagnetic, magnetic, and electrical conductance and resistivity survey methods are used effectively in tracing and defining the distribution of Algoma-type beds, either in exploring for iron and manganese ore, or for using these beds as metallogenetic markers.

OTHER EXPLORATION GUIDES: Discrete, well defined magnetite and hematite lithofacies of iron-formation are preferred with a minimum of other lithofacies and clastic sediment interbedded in the crude ore. Iron- formations are usually large regional geological features that are relatively easy to define. Detailed stratigraphic information is an essential part of the database required for defining grade, physical and chemical quality, and beneficiation and concentration characteristics of the ore. Basin analysis and sedimentation modeling enable definition of factors that controlled the development, location and distribution of different iron-formation lithofacies.

ALGOMA-TYPE IRON-FORMATION G01

ECONOMIC FACTORS

GRADE AND TONNAGE: Orebodies range in size from about 1000 to less than 100 Mt with grades ganging from 15 to 45% Fe, averaging 25% Fe. Precambrian deposits usually contain less than 2% Mn, but many Paleozoic iron-formations, such as those near Woodstock, New Brunswick, contain 10 to 40 % Mn and have Fe/Mn ratios of 40:1 to 1:50. The largest B.C. deposit, the Falcon, contains inferred reserves of 5.28 Mt grading 37.8% Fe.

ECONOMIC LIMITATIONS: Usually large-tonnage open pit operations. Granular, medium to coarse-grained textures with well defined, sharp grain boundaries are desirable for the concentration and beneficiation of the crude ore. Strongly metamorphosed iron-formation and magnetite lithofacies are usually preferred. Oxide facies iron-formation normally has a low content of minor elements, especially Na, K, S and As, which have deleterious effects in the processing of the ore and quality of steel produced from it.

IMPORTANCE: In Canada, Algoma-type iron-formations are the second most important source of iron ore after the taconite and enriched deposits in Lake Superior-type iron-formations. Algoma-type iron-formations are widely distributed and may provide a convenient local source of iron ore.

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TRAVERTINE H01

by Z.D. Hora

IDENTIFICATION

SYNONYMS: Tufa, calcareous sinter; certain varieties also referred to as onyx marble or Mexican onyx.

COMMODITIES (*BYPRODUCTS*): Decorative stone, building stone products, soil conditioner, agriculture lime; *onyx marble*.

EXAMPLES (British Columbia (MINFILE #) - *Canada/International*): Clinton (O92P079), Slocan (82KSW074,075), Wishing Well (Deep River, 094N001); *Gardiner (Montana, USA), Salida (Colorado, USA), Bridgeport (California, USA); Lazio, Tuscany (Italy); Pamukkale (Turkey); Mexico, Spain, Iran.*

GEOLOGICAL CHARACTERISTICS

CAPSULE DESCRIPTION: Mounds, sheets, sometimes terraced, shallow lake in-fills, valley in-fill.

TECTONIC SETTING: Young orogenic belts with carbonate sediments in the subsurface; thrusts and faults with deep water circulation. Also intercontinental rift zones with strike-slip faulting, with or without associated volcanic activity.

DEPOSITIONAL ENVIRONMENT / GEOLOGICAL SETTING: Subaerial precipitation of calcium carbonate from mineral springs; also in shallow lacustrine basins with influx of mineralized CO_2-rich water. Hotspring waters which give rise to travertine deposits usually do not originate at temperatures in excess of 100°C. Circulating ground waters are channeled by thrusts, faults and fractured rocks and mineralized by dissolution of subsurface carbonate rocks.

AGE OF MINERALIZATION: Tertiary to recent.

HOST/ASSOCIATED ROCK TYPES: Carbonate rocks in the subsurface; hydrothermal breccia and siliceous sinters, lacustrine sediments, carbonate veins (usually aragonite) in form of “Mexican onyx”.

DEPOSIT FORM: Conical mounds, sheets, basin in-fills. As it is deposited by precipitation from warm spring waters, it shows successive layers with sometimes different colours and textures. May be elongated above underlying feeder zones following faults and breccia zones.

TEXTURE: Banded, porous, brecciated; may be pisolitic. Generally fine-grained carbonate matrix with numerous irregular cavities ranging in size from a pin head to 1 cm or more across. The cavities are usually oriented in lines giving the rock parallel texture. Lacustrine varieties are more massive. The mounds may be criss-crossed by veins of “Mexican onyx”, a varicoloured banded aragonite.

ORE MINERALOGY [Principal and *subordinate*]: Calcite, aragonite, *silica, fluorspar, barite, native sulphur.*

WEATHERING: Clay/iron stains filling the voids, joints and bedding planes.

ORE CONTROLS: Commonly developed along high-angle faults and shear zones in young orogenic belts.

TRAVERTINE H01

GENETIC MODEL: Travertine forms as surface deposits from geothermal systems of generally less than 100°C in temperature. The carbonate deposition results from the loss of some of the carbon dioxide by cooling, evaporation or presence of algae.

ASSOCIATED DEPOSIT TYPES: Hotsprings Au-Ag (H03), Hotspring Hg (H02), marl, solfatara sulphur, geyserite silica.

COMMENTS: To be economically of interest, the size must be suitable to open a quarry face, the carbonate must be recrystallized and cemented to be strong and hard for ornamental stone applications. Sediments of similar texture and composition may occur in karst regions, where the carbonate precipitated from cold water.

EXPLORATION GUIDES

GEOCHEMICAL SIGNATURE: Mineral springs with carbon dioxide.

OTHER EXPLORATION GUIDES: Precipitation of tufa from small streams on moss and other organic matter, presence of thermal spring and solfatara exhalations.

ECONOMIC FACTORS

TYPICAL GRADE AND TONNAGE: Large deposits may reach 1-2 Mt, but even the small deposits of several tens to a hundred thousand tonnes may be of importance for local and custom type work. The travertine has to meet the minimum physical test requirements for intended use.

END USES: Interior and exterior facing, tile, ashlar, custom-made shapes as steps and sills, lapidary work and precious stone applications.

ECONOMIC LIMITATIONS: Even small occurrences can be exploited for local and custom markets.

IMPORTANCE: Locally important facing stone, however the usage does not match marble or granite. Mexican onyx is an important decorative stone.

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HOT-SPRING Hg H02

by A. Panteleyev

IDENTIFICATION

SYNONYMS: (Epithermal) hotspring, subaerial siliceous sinter.

COMMODITIES (*BYPRODUCTS*): Hg (*Au*).

EXAMPLES (British Columbia - *Canada/International*): Ucluelet; *Knoxville district, Sulphur Bank (California, USA), McDermitt and Steamboat Springs (Nevada, USA), Abuta mine(Japan).*

GEOLOGICAL CHARACTERISTICS

CAPSULE DESCRIPTION: Uppermost portions of epithermal systems develop clay altered zones and siliceous caps a few metres to hundreds of metres below surface and silica sinter deposits above the groundwater table as hotspring deposits. Travertine ledges and other silica-carbonate accumulations may be present nearby as peripheral or deeper deposits.

TECTONIC SETTING: Continental margin rifting and strike-slip faulting associated with small volume mafic to intermediate volcanism.

DEPOSITIONAL ENVIRONMENT / GEOLOGICAL SETTING: Modern and fossil hotspring settings with silica and silica-carbonate deposition near the paleo groundwater table and as subaerial silica sinter precipitates.

AGE OF MINERALIZATION: Tertiary and younger; some currently active hotsprings.

HOST/ASSOCIATED ROCK TYPES: Intermediate to basic volcanic flows, tuffs and breccias, minor diabasic dykes; hydrothermal breccias, travertine and siliceous sinters, lacustrine sediments. Country rocks commonly include greywacke, shale and fault-related serpentinized ultramafic bodies.

DEPOSIT FORM: Lensoid hotspring deposits and tabular lithologic replacement zones; commonly with cone- or wedge-like underlying feeder zones centered on regional-scale fault and fracture zones. Commonly less than 300 metres in vertical extent from paleosurface. Locally phreatic explosion pits.

TEXTURE: Disseminated sulphides in country rocks and hydrothermal breccias, quartz stockworks of banded to vuggy, multiple-generation quartz-chalcedony veins. Hydrofracturing textures are common. Less frequently cinnabar occurs as grains, lenses and fracture coatings in opaline silica sinter deposits. In some deposits cinnabar is concentrated on surfaces of wood and other organic matter.

ORE MINERALOGY [Principal and *subordinate*]: Cinnabar, pyrite, *native sulphur and mercury, stibnite, gold, marcasite.*

GANGUE MINERALOGY [Principal and *subordinate]:* Quartz, chalcedony; *opal, carbonate, iron oxides, manganese oxides.*

ALTERATION MINERALOGY [Principal and *subordinate]*: Kaolinite, alunite, Fe-Mn oxides and sulphur above water table (minor amounts of cinnabar). Opaline quartz deposited at the water table, with cinnabar. Quartz, pyrite, zeolites, chlorite and minor *adularia* below the water table; silica-carbonate ± magnesite assemblages in mafic, commonly serpentinized, rocks.

HOT-SPRING Hg H02

GENETIC MODEL: Deposits form in geothermal systems from near surface hot waters at less than 150°C, and generally cooler. Organic materials in solution and high CO_2 vapour concentration may be important in the transporting of elevated amounts of Hg.

ORE CONTROLS: Located just below the paleo groundwater table within hotspring systems. Commonly developed along high-angle faults and generally in young volcanic terranes.

ASSOCIATED DEPOSIT TYPES: Hotspring Au-Ag (H03), epithermal Au-Ag (H04, H05), placer Au (C01, C02).

COMMENTS: There has been little work in recent years on this deposit type other than to examine their potential for related gold deposits, for example, McLaughlin mine in California (Gustafson, 1991). The significant Hg deposits typically contain no other recoverable constituents.

EXPLORATION GUIDES

GEOCHEMICAL SIGNATURE: Hg, Sb, As. Generally <5 ppb Au but rare deposits with elevated gold are known.

GEOPHYSICAL SIGNATURE: VLF to identify favourable structures; magnetic lows in mafic volcanic hosts due to alteration envelope. .

OTHER EXPLORATION GUIDES: Can be overlain by native sulphur occurrences or hot spring deposits with siliceous sinters and clay-altered rocks. Recent deposits are commonly associated with modern hot springs or geothermal fields. Silica-carbonate alteration with distinctive orange-coloured, amorphous limonite in weathered zones, typically in mafic and serpentizized hostrocks.

ECONOMIC FACTORS

TYPICAL GRADE AND TONNAGE: Commercially exploited deposits tend to be very small; the largest deposits rarely exceed 1 mt in size. The median production from 20 Cordilleran USA mines is <1000 tonnes with 0.35% Hg. Typical mineable reserves contain ores ranging from 0.2 to 0.6% Hg. Productive deposits are Sulphur Bank and 5 small mines in the Knoxville District in California which produced 4, 700 tonnes of Hg and ~5,520 tonnes Hg respectively.

ECONOMIC LIMITATIONS: There probably is no operating mine of this type in the world today.

IMPORTANCE: These are relatively small deposits from near surface geological environments that are easily eroded and therefore rarely preserved. They currently are not important sources of mercury but can be associated with auriferous epithermal deposits.

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HOT-SPRING Au-Ag H03

by Andre Panteleyev

IDENTIFICATION

SYNONYMS: (Epithermal) hotspring, subaerial siliceous sinter.

COMMODITIES (BYPRODUCTS): Au, (Ag, Hg).

EXAMPLES (British Columbia (MINFILE #) - *Canada/International*): Cinola (uppermost part, 103F034), Clisbako (093C016), Wolf? (093F045), Trout? (093F044); *McLaughlin (California, USA), Round Mountain (Nevada, USA).*

GEOLOGICAL CHARACTERISTICS

CAPSULE DESCRIPTION: Auriferous chalcedonic or opaline silica and fine-grained quartz form veins, stockworks and matrix filling in breccias hosted by volcanic and, less commonly, sedimentary rocks. These are the uppermost parts of epithermal systems which develop mineralized siliceous caps a few metres to hundreds of metres below surface with subaerial siliceous sinter deposits at the water table and explosion breccias above.

TECTONIC SETTINGS: Continental margin rifting and district-scale fracture systems with associated bimodal or low volume mafic to intermediate volcanism. Commonly in regions of strike-slip faulting with transform faults and transtensional basin margins. Also extensional tectonism with related caldera development and resurgence, flow-dome complexes and high-level subvolcanic intrusive activity.

DEPOSITIONAL ENVIRONMENT / GEOLOGICAL SETTING: Shallow parts of fossil geothermal systems. Hotsprings deposit silica near the paleo groundwater table and as subaerial, ponded precipitates. Deeper fluids are channeled by permeable stratigraphic units, hydrothermal breccia bodies and faulted/fractured rocks. Subaerial volcanic centres including flow-dome or caldera complexes and related radial and ring fracture systems.

AGE OF MINERALIZATION: Tertiary and Quaternary are most common; some currently active hotsprings. Hotspring sinters as old as Late Devonian have been described (Cunneen and Sillitoe, 1989).

HOST/ASSOCIATED ROCK TYPES: Intermediate or bimodal basaltic-rhyolitic volcanics including volcanic flows, flow domes, tuffs and breccias; hydrothermal breccias and siliceous sinters. Any type of permeable or structurally prepared country rock can be mineralized, most commonly ash flow units and caldera-fill sediments. In some cases, serpentinized ultramafic and mafic rocks in major fault zones in areas of post-faulting volcanic activity are mineralized. Sedimentary rocks occur at Cinola and many other deposits.

DEPOSIT FORM: Near-surface, lensoid hotspring deposits and planar lithologic replacement zones. Individual zones are up to hundreds of metres in two dimensions and tens of metres in the third. Underlying these are cone or wedge-like hydrothermal feeder systems with quartz stockworks and veins centred on regional-scale fault and fracture zones, or their splays. Locally phreatic and phreatomagmatic explosion pits formed at the paleosurface.

TEXTURE/STRUCTURE: Generally very fine grained disseminated sulphides in silicified (opalized and chalcedonic) country rocks and silica sinter; hydrothermal breccias, quartz stockworks and banded to vuggy, sheeted, multiple-generation quartz-chalcedony veins. Hydrofracturing textures are common.

ORE MINERALOGY [Principal and *subordinate*]: Pyrite, marcasite, gold, electrum; *stibnite, sulphosalt minerals, realgar, cinnabar (cinnibar only near tops of deposits).*

HOT-SPRING Au-Ag H03

GANGUE MINERALOGY [Principal and *subordinate*]: Quartz, chalcedony; *opal, calcite, dolomite, barite.* Strong silicification with quartz, chalcedony and opal in crustified, banded veins, sheeted veins and stockworks is characteristic in ores. Silica in some deposits contains abundant hydrocarbons that impart a characteristic brownish colour to the quartz.

ALTERATION MINERALOGY [Principal and *subordinate*]: Multiple episodes of silicification to form veins and stockworks, and pervasive silicified hostrocks adjacent to them, is typical. Country rocks containing the silicified zones have argillic and, less commonly, advanced argillic assemblages with quartz-kaolinite and rarely *alunite*. They are flanked, or underlain, by propylitic rocks with chlorite, Fe oxides, zeolites and minor *adularia.* Selenite, alunite and other sulphate minerals and native sulphur can be abundant locally near surface.

WEATHERING: Limonite (jarosite, hematite, goethite) is locally prominent near surface in strongly oxidized deposits.

ORE CONTROLS: A key element at the McLaughlin deposit was the superposition of multiple generations of auriferous veinlets each carrying a small amount of gold (Lehrman, 1986).

GENETIC MODEL: Hydrothermal breccias and multiple generations of veins with calcite replacement by silica attest to boiling of hydrothermal fluids as an important ore-depositing mechanism. The boiling levels are related to the paleosurface and commonly have a surficial expression as active or paleo-hotsprings. The deeper hydrothermal fluid systems, generaly within 500 m of surface (paleosurface for older deposits), can be developed along active, regional high-angle faults and other volcanic and subvolcanic intrusion-related structures. The structures commonly cut or flank domes in flow-dome complexes.

ASSOCIATED DEPOSIT TYPES: Hotspring Hg (H02), solfatara sulphur; epithermal Au-Ag (H04, H05), placer Au (C01, C02).

COMMENTS: Many deposits currently being exploited throughout the world have grades between 1 and 2 g/t Au and range from a few to tens of millions of tonnes in size. They are viable generally because the rocks are commonly strongly oxidized and the gold can be recovered by heap leaching methods. The siliceous sinters formed at or very near to the surface rarely contain economic mineralization These deposits have a greater depth extent then hotspring mercury deposits. In their deeper parts they may grade into precious metal bearing and base metal epithermal veins.

EXPLORATION GUIDES

GEOCHEMICAL SIGNATURE: Au, Sb, As, Hg, Tl near surface, increasing Ag, Ba at depth; locally Ni, B, Li and W. The Ag/Au ratio varies from 1:1 at surface to 30:1 at a depth of a few hundred metres. Mineralized rocks can be strongly leached at surface. Notably absent are: Se, Te, F, Mo, Sn and Mn. Base metal content is relatively low, for example, common amounts are Cu <60 ppm, Pb <5 ppm and Zn <450 ppm.

GEOPHYSICAL SIGNATURE: Resistivity, VLF to identify faults.

OTHER EXPLORATION GUIDES: Siliceous sinter can be used to identify the paleosurface; Hg mineralization may overlie deeper gold ores.

ECONOMIC FACTORS

TYPICAL GRADE AND TONNAGE: Mineralization tends to be low grade. Economically attractive bulk-mineable deposits contain >10 Mt of 1 to 2 g/t Au, or greater. High-grade veins and stockworks within the larger mineralized zones can be exploited by underground methods. The McLaughlin deposit, a superior discovery, contained initial reserves of 17.5 Mt with 5.2 g/t Au and about 16 g/t Ag, including a sheeted vein zone with 2.45 Mt with 9.15 g/t Au. Reserves for Cinola are about 31 Mt with 2.19 g/t Au; the deposit has a feeder zone at depth that contains material containing in excess of 100 g/t Au.

ECONOMIC LIMITATIONS: Refractory primary ore in deposits that lack significant oxidation renders many of the lower grade deposits uneconomic.

IMPORTANCE: Individual deposits are attractive economically, for example, the McLaughlin mine in California.

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EPITHERMAL Au-Ag-Cu: HIGH SULPHIDATION H04

by Andre Panteleyev

IDENTIFICATION

SYNONYMS: (Epithermal) acid-sulphate, quartz-alunite Au, alunite-kaolinite ± pyrophyllite, advanced argillic, Nansatsu-type, enargite gold. The deposits are commonly referred to as *acid-sulphate* type after the chemistry of the hydrothermal fluids, *quartz-alunite* or *kaolinite-alunite* type after their alteration mineralogy, or *high-sulphidation* type in reference to the oxidation state of the acid fluids responsible for alteration and mineralization.

COMMODITIES (*BYPRODUCTS*): Au, Ag, Cu (*As, Sb*).

EXAMPLES (British Columbia (MINFILE #) - *International*): Mt. McIntosh/Hushamu (EXPO, 92L240), Taseko River deposits - Westpine (Empress) (92O033), Taylor-Windfall (92O028) and Battlement Creek (92O005); *Goldfield and Paradise Peak (Nevada, USA), Summitville (Colorado, USA); Nansatsu (Japan), El Indio (Chile); Temora (New South Wales, Australia), Pueblo Viejo (Dominica), Chinkuashih (Taiwan), Rodalquilar (Spain), Lepanto and Nalesbitan (Philippines).*

GEOLOGICAL CHARACTERISTICS

CAPSULE DESCRIPTION: Veins, vuggy breccias and sulphide replacements ranging from pods to massive lenses occur in volcanic sequences associated with high level hydrothermal systems marked by acid-leached, advanced argillic, siliceous alteration.

TECTONIC SETTING: Extensional and transtensional settings, commonly in volcano-plutonic continent-margin and oceanic arcs and back-arcs. In zones with high-level magmatic emplacements where stratovolcanoes and other volcanic edifices are constructed above plutons.

DEPOSITIONAL ENVIRONMENT / GEOLOGICAL SETTING: Subvolcanic to volcanic in calderas, flow-dome complexes, rarely maars and other volcanic structures; often associated with subvolcanic stocks and dikes, breccias. Postulated to overlie, and be genetically related to, porphyry copper systems in deeper mineralized intrusions that undelie the stratovolcanoes.

AGE OF MINERALIZATION: Tertiary to Quaternary; less commonly Mesozoic and rarely Paleozoic volcanic belts. The rare preservation of older deposits reflects rapid rates of erosion before burial of subaerial volcanoes in tectonically active arcs.

HOST/ASSOCIATED ROCK TYPES: Volcanic pyroclastic and flow rocks, commonly subaerial andesite to dacite and rhyodacite, and their subvolcanic intrusive equivalents. Permeable sedimentary intervolcanic units can be sites of mineralization.

DEPOSIT FORM: Veins and massive sulphide replacement pods and lenses, stockworks and breccias. Commonly irregular deposit shapes are determined by hostrock permeability and the geometry of ore-controlling structures. Multiple, crosscutting composite veins are common.

TEXTURE/STRUCTURE: Vuggy 'slaggy' silica derived as a residual product of acid leaching is characteristic. Drusy cavities, banded veins, hydrothermal breccias, massive wallrock replacements with fine-grained quartz.

ORE MINERALOGY (Principal and *subordinate*): pyrite, enargite/luzonite, chalcocite, covellite, bornite, gold, electrum; *chalcopyrite, sphalerite, tetrahedrite/tennantite, galena, marcasite, arsenopyrite, silver sulphosalts, tellurides including goldfieldite.* Two types of ore are commonly present: massive enargite-pyrite and/or quartz-alunite-gold.

GANGUE MINERALOGY (Principal and *subordinate*): Pyrite and quartz predominate. Barite may also occur; carbonate minerals are absent.

EPITHERMAL Au-Ag-Cu: HIGH SULPHIDATION H04

ALTERATION MINERALOGY (Principal and *subordinate*): Quartz, kaolinite/dickite, alunite, barite, hematite; sericite/illite, amorphous clays and silica, pyrophyllite, andalusite, diaspore, corundum, tourmaline, *dumortierite, topaz, zunyite, jarosite, Al-P sulphates (hinsdalite, woodhouseite, crandalite, etc.*) and native sulphur. Advanced argillic alteration is characteristic and can be areally extensive and visually prominent. Quartz occurs as fine-grained replacements and, characteristically, as vuggy, residual silica in acid-leached rocks.

WEATHERING: Weathered rocks may contain abundant limonite (jarosite-goethite-hematite), generally in a groundmass of kaolinite and quartz. Fine-grained supergene alunite veins and nodules are common.

ORE CONTROLS: In volcanic edifices - caldera ring and radial fractures; fracture sets in resurgent domes and flow-dome complexes, hydrothermal breccia pipes and diatremes. Faults and breccias in and around intrusive centres. Permeable lithologies, in some cases with less permeable cappings of hydrothermally altered or other cap rocks. The deposits occur over considerable depths, ranging from high-temperature solfataras at paleosurface down into cupolas of intrusive bodies at depth.

GENETIC MODEL: Recent research, mainly in the southwest Pacific and Andes, has shown that these deposits form in subaerial volcanic complexes or composite island arc volcanoes above degassing magma chambers. The deposits can commonly be genetically related to high-level intrusions. Multiple stages of mineralization are common, presumably related to periodic tectonism with associated intrusive activity and magmatic hydrothermal fluid generation.

ASSOCIATED DEPOSIT TYPES: Porphyry Cu±Mo±Au deposits (L04), subvolcanic Cu-Ag-Au (As-Sb) (L01), epithermal Au-Ag deposits: low sulphidation type (H05), silica-clay-pyrophyllite deposits (Roseki deposits) (H09), hotspring Au-Ag (H03), placer Au deposits (C01,C02).

COMMENTS: High-sulphidation epithermal Au-Ag deposits are much less common in the Canadian Cordillera than low-sulphidation epithermal veins. However, they are the dominant type of epithermal deposit in the Andes.

EXPLORATION GUIDES

GEOCHEMICAL SIGNATURE: Au, Cu, As dominate; also Ag, Zn, Pb, Sb, Mo, Bi, Sn, Te, W, B and Hg.

GEOPHYSICAL SIGNATURE: Magnetic lows in hydrothermally altered (acid-leached) rocks; gravity contrasts may mark boundaries of structural blocks.

OTHER EXPLORATION GUIDES: These deposits are found in second order structures adjacent to crustal-scale fault zones, both normal and strike-slip, as well as local structures associated with subvolcanic intrusions. The deposits tend to overlie and flank porphyry copper-gold deposits and underlie acid-leached siliceous, clay and alunite-bearing 'lithocaps'.

ECONOMIC FACTORS

TYPICAL GRADE AND TONNAGE: There is wide variation in deposit types ranging from bulk-mineable, low-grade to selectively mined, high-grade deposits. Underground mines range in size from 2 to 25 Mt with grades from 178 g/t Au, 109 g/t Ag and 3.87% Cu in direct smelting ores (El Indio) to 2.8 g/t Au and 11.3 g/t Ag and 1.8% Cu (Lepanto). Open pit mines with reserves of <100 Mt to >200 Mt range from Au-Ag mines with 3.8 g/t Au and 20 g/t Ag (Pueblo Viejo, Dominica) to orebodies such as the Nansatsu deposits, Japan that contain a few million tonnes ore grading between 3 and 6 g/t Au. Porphyry Au (Cu) deposits can be overprinted with late-stage acid sulphate alteration zones which can contain in the order of ~1.5 g/t Au with 0.05 to 0.1% Cu in stockworks (Marte and Lobo) or high-grade Cu-Ag-Au veins (La Grande veins, Collahausi). More typically these late stage alteration zones carry <0.4 to 0.9 g/t Au and >0.4 to 2% Cu (Butte, Montana; Dizon, Philippines).

EPITHERMAL Au-Ag-Cu: HIGH SULPHIDATION H04

ECONOMIC LIMITATIONS: Oxidation of primary ores is commonly neccessary for desireable metallurgy; primary ores may be refractory and can render low-grade mineralization noneconomic.

IMPORTANCE: This class of deposits has recently become a focus for exploration throughout the circum-Pacific region because of the very attractive Au and Cu grades in some deposits. Silica-rich gold ores (3-4 g/t Au) from the Nansatsu deposits in Japan are used as flux in copper smelters.

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EPITHERMAL Au-Ag: LOW SULPHIDATION H05

by Andre Panteleyev

IDENTIFICATION

SYNONYMS: (Epithermal) adularia-sericite; quartz-adularia, Comstock, Sado-type; bonanza Au-Ag; alkali chloride (hydrothermal).

COMMODITIES (*BYPRODUCTS*): Au, Ag (*Pb, Zn, Cu*).

EXAMPLES (British Columbia (MINFILE #) - *International*): Toodoggone district deposits - Lawyers (94E066), Baker (94E026), Shas (94E050); Blackdome (92O050-053); Premier Gold (Silbak Premier), (104B054); Cinola (103F034); *Comstock, Aurora (Nevada, USA), Bodie (California, USA), Creede (Colorado, USA), Republic (Washington, USA), El Bronce (Chile), Guanajuato (Mexico), Sado, Hishikari (Japan), Colqui (Peru), Baguio (Philippines) Ladolam (Lihir, Papua-New Guinea).*

GEOLOGICAL CHARACTERISTICS

CAPSULE DESCRIPTION: Quartz veins, stockworks and breccias carrying gold, silver, electrum, argentite and pyrite with lesser and variable amounts of sphalerite, chalcopyrite, galena, rare tetrahedrite and sulphosalt minerals form in high-level (epizonal) to near-surface environments. The ore commonly exhibits open-space filling textures and is associated with volcanic-related hydrothermal to geothermal systems.

TECTONIC SETTING: Volcanic island and continent-margin magmatic arcs and continental volcanic fields with extensional structures.

DEPOSITIONAL ENVIRONMENT / GEOLOGICAL SETTING: High-level hydrothermal systems from depths of ~1 km to surficial hotspring settings. Regional-scale fracture systems related to grabens, (resurgent) calderas, flow-dome complexes and rarely, maar diatremes. Extensional structures in volcanic fields (normal faults, fault splays, ladder veins and cymoid loops, etc.) are common; locally graben or caldera-fill clastic rocks are present. High-level (subvolcanic) stocks and/or dikes and pebble breccia diatremes occur in some areas. Locally resurgent or domal structures are related to underlying intrusive bodies.

AGE OF MINERALIZATION: Any age. Tertiary deposits are most abundant; in B.C. Jurassic deposits are important. Deposits of Paleozoic age are described in Australia. Closely related to the host volcanic rocks but invariably slightly younger in age (0.5 to 1 Ma, more or less).

HOST/ASSOCIATED ROCK TYPES: Most types of volcanic rocks; calcalkaline andesitic compositions predominate. Some deposits occur in areas with bimodal volcanism and extensive subaerial ashflow deposits. A less common association is with alkalic intrusive rocks and shoshonitic volcanics. Clastic and epiclastic sediments in intra-volcanic basins and structural depressions.

DEPOSIT FORM: Ore zones are typically localized in structures, but may occur in permeable lithologies. Upward-flaring ore zones centred on structurally controlled hydrothermal conduits are typical. Large (> 1 m wide and hundreds of metres in strike length) to small veins and stockworks are common with lesser disseminations and replacements. Vein systems can be laterally extensive but ore shoots have relatively restricted vertical extent. High-grade ores are commonly found in dilational zones in faults at flexures, splays and in cymoid loops.

TEXTURE/STRUCTURE: Open-space filling, symmetrical and other layering, crustification, comb structure, colloform banding and multiple brecciation.

EPITHERMAL Au-Ag: LOW SULPHIDATION H05

ORE MINERALOGY (Principal and *subordinate*): Pyrite, electrum, gold, silver, argentite; *chalcopyrite, sphalerite, galena, tetrahedrite, silver sulphosalt and/or selenide minerals.* Deposits can be strongly zoned along strike and vertically. Deposits are commonly zoned vertically over 250 to 350 m from a base metal poor, Au-Ag-rich top to a relatively Ag-rich base metal zone and an underlying base metal rich zone grading at depth into a sparse base metal, pyritic zone. From surface to depth, metal zones contain: Au-Ag-As-Sb-Hg, Au-Ag-Pb-Zn-Cu, Ag-Pb-Zn. In alkalic hostrocks tellurides, V mica (roscoelite) and fluorite may be abundant, with lesser *molybdenite.*

GANGUE MINERALOGY (Principal and *subordinate*): Quartz, amethyst, chalcedony, quartz pseudomorphs after calcite, calcite; *adularia, sericite, barite, fluorite, Ca-Mg-Mn-Fe carbonate minerals such as rhodochrosite, hematite and chlorite.*

ALTERATION MINERALOGY: Silicification is extensive in ores as multiple generations of quartz and chalcedony are commonly accompanied by adularia and calcite. Pervasive silicification in vein envelopes is flanked by sericite-illite-kaolinite assemblages. Intermediate argillic alteration [kaolinite-illite-montmorillonite (smectite)] formed adjacent to some veins; advanced argillic alteration (kaolinite-alunite) may form along the tops of mineralized zones. Propylitic alteration dominates at depth and peripherally,.

WEATHERING: Weathered outcrops are often characterized by resistant quartz ± alunite 'ledges' and extensive flanking bleached, clay-altered zones with supergene alunite, jarosite and other limonite minerals.

ORE CONTROLS: In some districts the epithermal mineralization is tied to a specific metallogenetic event, either structural, magmatic, or both. The veins are emplaced within a restricted stratigraphic interval generally within 1 km of the paleosurface. Mineralization near surface takes place in hotspring systems, or the deeper underlying hydrothermal conduits. At greater depth it can be postulated to occur above, or peripheral to, porphyry and possibly skarn mineralization. Normal faults, margins of grabens, coarse clastic caldera moat-fill units, radial and ring dike fracture sets and both hydrothermal and tectonic breccias are all ore fluid channeling structures. Through-going, branching, bifurcating, anastamosing and intersecting fracture systems are commonly mineralized. Ore shoots form where dilational openings and cymoid loops develop, typically where the strike or dip of veins change. Hangingwall fractures in mineralized structures are particularly favourable for high-grade ore.

GENETIC MODEL: These deposits form in both subaerial, predominantly felsic, volcanic fields in extensional and strike-slip structural regimes and island arc or continental andesitic stratovolcanoes above active subduction zones. Near-surface hydrothermal systems, ranging from hotspring at surface to deeper, structurally and permeability focused fluid flow zones are the sites of mineralization. The ore fluids are relatively dilute and cool solutions that are mixtures of magmatic and meteoric fluids. Mineral deposition takes place as the solutions undergo cooling and degassing by fluid mixing, boiling and decompression.

ASSOCIATED DEPOSIT TYPES: Epithermal Au-Ag: high sulphidation (H04); hotspring Au-Ag (H03); porphyry Cu±Mo±Au (L04) and related polymetallic veins (I05); placer gold (C01, C02).

EXPLORATION GUIDES

GEOCHEMICAL SIGNATURE: Elevated values in rocks of Au, Ag, Zn, Pb, Cu and As, Sb, Ba, F, Mn; locally Te, Se and Hg.

GEOPHYSICAL SIGNATURE: VLF has been used to trace structures; radiometric surveys may outline strong potassic alteration of wallrocks. Detailed gravity surveys may delineate boundaries of structural blocks with large density contrasts.

OTHER EXPLORATION GUIDES: Silver deposits generally have higher base metal contents than Au and Au-Ag deposits. Drilling feeder zones to hotsprings and siliceous sinters may lead to identification of buried deposits. Prospecting for mineralized siliceous and silica-carbonate float or vein material with diagnostic open-space textures is effective.

ECONOMIC FACTORS

TYPICAL GRADE AND TONNAGE: The following data describe the median deposits based on worldwide mines and U.S.A. models:

- Au-Ag deposits (41 Comstock-type 'bonanza' deposits) - 0.77 Mt with 7.5 g/t Au, 110 g/t Ag and minor Cu, Zn and Pb. The highest base metal contents in the top decile of deposits all contain <0.1% Cu, Zn and 0.1% Pb
- Au-Cu deposits (20 Sado-type deposits) - 0.3 Mt with 1.3% g/t Au, 38 g/t Ag and >0.3% Cu; 10 % of the deposits contain, on average, about 0.75% Cu with one having >3.2% Cu.

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Sn-Ag VEINS **H07**

by Andre Panteleyev

IDENTIFICATION

SYNONYMS: Polymetallic Sn veins, Bolivian polymetallic veins, polymetallic tin-silver deposits, polymetallic xenothermal.

COMMODITIES (*BYPRODUCTS*): Ag, Sn (*Zn, Cu, Au, Pb, Cd, In, Bi, W*).

EXAMPLES (British Columbia (MINFILE #) - *Canada/International*): D zone (104P044, 080,081) and Lang Creek veins ('Pant', 104P082), Cassiar district; *Cerro Rico de Potosi, Oruro, Chocaya, (Bolivia), Pirquitas (Argentina), Ashio, Akenobe and Ikuno (Japan).*

GEOLOGICAL CHARACTERISTICS

CAPSULE DESCRIPTION: Sulphide and quartz-sulphide veins carrying cassiterite, a wide variety of other base metals and zones with silver minerals. They are associated with epizonal (subvolcanic) quartz-bearing intrusions, or their immediate hostrocks. In some places the ore is in volcanic rocks within dacitic to quartz latitic flow-dome complexes.

TECTONIC SETTING: Continental margin; synorogenic to late orogenic belts with high-level plutonism in intermediate to felsic volcanoplutonic arcs. In British Columbia the only significant Sn-bearing deposits occur with S or A-type granites in eastern tectonic assemblages underlain by continental rocks of North American origin.

DEPOSITIONAL ENVIRONMENT / GEOLOGICAL SETTING: In faults, shears and fractures that cut or are proximal to high-level felsic intrusions and in flow-dome complexes, namely domes and their surrounding tuff rings and explosive breccias.

AGE OF MINERALIZATION: Tertiary in the type area of Bolivia; Cretaceous and Tertiary in Japan; Tertiary and older in British Columbia.

HOST/ASSOCIATED ROCK TYPES: Hostrocks for veins can be of any type and do not appear to be an important control on the occurrence of the deposits; they include sedimentary, volcanic and intrusive rocks and sometimes, metasedimentary rocks at depth. Intrusive rocks with which the mineralization is associated are quartz bearing and peraluminous, but seem to be restricted to intermediate compositions between 60 and 70% SiO_2 (dacite to rhyodacite); more felsic rocks are present, but are less common.

DEPOSIT FORM: Veins, commonly with swarms of closely spaced, splaying smaller veins in sheeted zones. Veins vary in width from microveinlets to a few metres, and commonly are less than a metre wide. The ore shoots in veins are commonly 200-300 m along strike and dip but the veins may extend to more than 1000 m in depth and strike length. Vein systems and related stockworks cover areas up to a square kilometre along the tops of conical domes or intrusions 1 to 2 km wide.

TEXTURE/STRUCTURE: Multistage composite banded veins with abundant ore minerals pass at depth into crystalline quartz veins and upwards into vuggy quartz-bearing veins and stockworks.

ORE MINERALOGY [Principal and *subordinate*]: Pyrite, cassiterite; *pyrrhotite, marcasite*; *sphalerite, galena, chalcopyrite, stannite, arsenopyrite, tetrahedrite, scheelite, wolframite, andorite, jamesonite, boulangerite, ruby silver (pyrargyrite), stibnite, bismuthinite, native bismuth, molybdenite, argentite, gold and complex sulphosalt minerals.* These deposits are characterized by their mineralogical complexity. There is no consistency between deposits in vertical or lateral zoning, but individual deposits are markedly spatially and temporally zoned. In some deposits,

Sn-Ag VEINS H07

notably intrusion or dome-hosted examples, core zones are denoted by the high-temperature minerals cassiterite, wolframite, bismuthinite and arsenopyrite. Surrounding ores have varying amounts of stannite and chalcopyrite with, most significantly, sphalerite, galena and various Pb sulphosalt and Ag minerals. Silver in the upper parts of the vein systems occurs in argentite, ruby silver and native silver and at depth is mainly present in tetrahedrite.

GANGUE MINERALOGY [Principal and *subordinate*]: Quartz, sericite, pyrite; *tourmaline at depth, kaolinite and chalcedony near surface; rare barite, siderite, calcite, Mn carbonate and fluorite.*

ALTERATION MINERALOGY: Quartz-sericite-pyrite is characteristic; elsewhere quartz-sericite-chlorite occurs in envelopes on veins. Near-surface argillic and advanced argillic alteration overprinting is present in some deposits.

WEATHERING: Prominent limonite cappings are derived from the oxidation of pyrite.

ORE CONTROLS: Sets of closely spaced veins, commonly in sheeted zones, fractures and joints within and surrounding plutons are related to the emplacement and cooling of the host intrusions. The open space filling and shear-replacement veins are associated with stockworks, breccia veins and breccia pipes. A few deposits occur in faults, shears, fold axes and cleavage or fracture zones related to regional tectonism. Some early wallrock replacement along narrow fissures is generally followed and dominated by open-space filling in many deposits.

GENETIC MODEL: Dacitic magma and the metal-bearing hydrothermal solutions represent the uppermost products of large magmatic/hydrothermal systems. The Sn is probably a remobilized component of sialic rocks derived from recycled continental crust.

ASSOCIATED DEPOSIT TYPES: Polymetallic veins Ag-Pb-Zn (I05); epithermal Au-Ag: low sulphidation (H05), mantos (J01, J02), porphyry Sn (L06), placers (C01, C02). This deposit type grades with depth into Sn veins and greissens (I13) associated with mesozonal granitic intrusions into sediments. Cassiterite in colluvium can be recovered by placer mining. Mexican-type rhyolite Sn or "wood tin" deposits represent a separate class of deposit (Reed *et al.*, 1986).

COMMENTS: Many Sn-bearing base metal vein systems are known to occur in eastern British Columbia, but there is poor documentation of whether the Sn is present as cassiterite or stannite. The former can be efficiently recovered by simple metallurgy, the latter cannot.

EXPLORATION GUIDES

GEOCHEMICAL SIGNATURE: Ag, Cu, Zn, Pb, Sn, W, As, Bi.

OTHER EXPLORATION GUIDES: The vein systems may display impressive vertical and horizontal continuity with marked metal zoning. Bolivian polymetallic vein deposits have formed at depths of 0.5 to 2 km below the paleosurface. Deeper veins of mainly massive sulphide minerals contain Sn, W and Bi; the shallower veins with quartz-barite and chalcedony-barite carry Ag and rarely Au. Metal zoning from depth to surface and from centres outward shows: Sn + W, Cu + Zn, Pb + Zn, Pb + Ag and Ag ± Au; commonly there is considerable 'telescoping' of zones. Oxidized zones may have secondary Ag minerals, such as Ag chlorides.

ECONOMIC FACTORS

TYPICAL GRADE AND TONNAGE: Considerable variation in metal contents of ores is evident between deposits. Potentially bulk-mineable bedrock deposits contain in the order of 0.2% Sn with 70-179 g/t Ag (Cerro Rico, Potosi, Bolivia).

ECONOMIC LIMITATIONS: These veins tend to be narrow.

IMPORTANCE: These veins are an important source of cassiterite for economic placer deposits around the world and the lodes have been mined in South America. They are currently attractive only when they carry appreciable Ag. In some deposits Au content is economically significant and Au-rich zones might have been overlooked during past work. Future Sn production from these veins will probably be as a byproduct commodity, and only if cassiterite is the main Sn mineral.

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ALKALIC INTRUSION-ASSOCIATED Au-Ag H08

by Tom G. Schroeter and Robert Cameron

IDENTIFICATION

SYNONYMS: Alkalic epithermal, Au-Ag-Te veins.

COMMODITIES (*BYPRODUCTS*): Au, Ag (*Zn, Pb*).

EXAMPLES (British Columbia - *Canada/International*): Flathead (082GSE070), Howell (082GSE037), Howe (082GSE048); *Cripple Creek (Colorado, USA), Zartman, Landusky, Golden Sunlight (Montana, USA), Golden Reward (South Dakota, USA).*

GEOLOGICAL CHARACTERISTICS

CAPSULE DESCRIPTION: These deposits include quartz veins with pyrite, sphalerite and galena in structural zones and stockworks within alkalic intrusions and/or disseminated pyritic zones in alkalic intrusions, diatremes, coeval volcanics (Cripple Creek) and surrounding sediments. Argillic alteration, +/- silicification, carbonatization, and barite and fluorite veins are common.

TECTONIC SETTINGS: Associated with alkalic intrusive rocks in sedimentary cover rocks above continental crust, generally associated with extensional faulting. Tertiary examples in the USA are related to continental rifting; Rio Grande rift for Cripple Creek, Great Falls tectonic zone for the Montana deposits. Flathead area of British Columbia is in a continental setting but the extensional component is not as apparent.

DEPOSITIONAL ENVIRONMENT / GEOLOGICAL SETTING: Diatreme-intrusive complexes, high-level alkalic plugs, and dikes that intrude Proterozoic to Mesozoic continental clastic and carbonate rocks. Cripple Creek is within a large maar diatreme complex. Flathead intrusions are coeval with chemically similar volcanic rocks, the Crowsnest volcanics, in southern Alberta.

AGE OF MINERALIZATION: Any age; Flathead intrusions are early Cretaceous (98.5 Ma)

HOST/ASSOCIATED ROCK TYPES: (Flathead area): Intrusions include alkali feldspar syenite, foid-bearing syenite (nepheline, leucite, nosean, analcite), mela-syenite and related diatreme breccias with 10 % to 100 % intrusive component. Textures include coarse porphyritic sanidine, micro-syenite, tinguaite. Host sedimentary rocks include clastic rocks, shales and argillites to sandstones, and impure fine-grained carbonaceous limestone and massive calcarenitic limestone. Gold may be present in all rock types.

DEPOSIT FORM: Deposits may be in the form of sheeted veins in structural zones within intrusions (*e.g*, Zortman, Cripple Creek) with dimensions of 50 m to 100 m in width and hundreds of metres in length to, less commonly, large disseminated, diffuse zones within diatremes (*e.g.*, Montana Tunnels, Cripple Creek), volcanic rocks (*e.g.*, Cripple Creek) or stratabound within favourable sedimentary lithologies.

TEXTURE/STRUCTURE: Ore minerals in quartz and quartz-adularia veins, vein stockworks, disseminated zones and minor breccias.

ALKALIC INTRUSION-ASSOCIATED Au-Ag H08

ORE MINERALOGY (Principal and *subordinate*): Fine-grained (auriferous, arsenical?) pyrite, galena, sphalerite, gold tellurides; *chalcopyrite, magnetite, gold, bismuth and tellurium minerals are suspected at Flathead from elevated geochemical values in samples (to 31 ppm Te, 356 ppm Bi).*

GAUNGE MINERALOGY (Principal and *subordinate*): Quartz, calcite; *adularia, barite, fluorite.*

ALTERATION MINERALOGY: Widespread pyrite and carbonate (calcite) alteration of intrusive rocks, silicic and argillic (illite, sericite, jarosite, *roscoelite*) alteration of wallrocks; also albite and adularia.

WEATHERING: Oxidation with limonite, jarosite, hydrozincite.

ORE CONTROLS: Mineralization is controlled by structural zones within or proximal to alkalic intrusions; also in permeable (*e.g.*, sandstone) or chemically favourable units (impure carbonates or bedding contacts) in country rocks. Diatreme breccias are favourable permeable hosts for focused flow of volatiles.

ASSOCIATED DEPOSIT TYPES: Distal base metal mantos are indicated in the Flathead and South Dakota deposit areas. Possible link with porphyry Mo deposits; polymetallic (I05) veins.

COMMENTS: Some authors consider this deposit type to be a subset of the low-sulphidation epithermal suite of precious metal deposits. This deposit model relates to continental rift settings, but related deposit types are present in oceanic arc settings and include Emperor (Fiji), Porgera and Ladolam (Papua New Guinea) deposits. Similar British Columbia settings may include the Quesnel and Stikine Terrane alkalic volcanic belts which host the alkalic porphyry copper-gold deposits (LO3).

EXPLORATION GUIDES

GEOCHEMICAL SIGNATURE: Au, Ag, As, Sb, Pb, Zn, F, Ba, V, Te, Bi

GEOPHYSICAL SIGNATURE: High chargeability (I.P.) will outline pyritic zones; magnetic surveys will outline magnetite-bearing zones.

ECONOMIC FACTORS:

TYPICAL GRADE AND TONNAGE: Highly variable, from very low mineable grades (*e.g.*, 0.53 g/t Au at Zortman) to very high bonanza grades (*e.g.*, 126 g/t Au at the Cresson vug, Cripple Creek). Recovered gold from the Cripple Creek district totals in excess of 600 tonnes. Grades at Howell Creek include 58 m of 1.3 g/t Au in silicified limestone, with grab samples containing up to 184 g/t at Flathead. Tonnages and grades from a number of deposits include:

Cresson deposit, Cripple Creek	70 mt	0.99 g/t Au
Cripple Creek, historical prod'n (1891-1989)	41 mt	17.14 g/t Au
Golden Sunlight (Dec., 1994)	42.8 mt	1.9 g/t
Zortman (Dec., 1994)	55.7 mt	0.68 g/t Au
Montana Tunnels (Dec., 1994)	26.6 mt	0.61 g/T Au

IMPORTANCE: Although these deposits have not been mined in British Columbia, they remain a viable exploration target.

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Au-QUARTZ VEINS — I01

by Chris Ash and Dani Alldrick

IDENTIFICATION

SYNONYMS: Mother Lode veins, greenstone gold, Archean lode gold, mesothermal gold-quartz veins, shear-hosted lode gold, low-sulphide gold-quartz veins, lode gold.

COMMODITIES (*BYPRODUCTS*): Au (Ag, Cu, Sb).

EXAMPLES (British Columbia (MINFILE #) - *Canada/ International*):

- Phanerozoic: Bralorne-Pioneer (092JNE001), Erickson (104P029), Taurus (104P012), Polaris-Taku (104K003), Mosquito Creek (093H010), Cariboo Gold Quartz (093H019), Midnight (082FSW119); *Carson Hill, Jackson-Plymouth, Mother Lode district; Empire Star and Idaho-Maryland, Grass Valley district (California, USA); Alaska-Juneau, Jualin, Kensington (Alaska, USA), Ural Mountains (Russia).*
- Archean: *Hollinger, Dome, McIntyre and Pamour, Timmins camp; Lake Shore, Kirkland Lake camp; Campbell, Madsen, Red Lake camp; Kerr-Addison, Larder Lake camp (Ontario, Canada), Lamaque and Sigma, Val d'Or camp (Quebec, Canada); Granny Smith, Kalgoorlie and Golden Mile (Western Australia); Kolar (Karnataka, India), Blanket-Vubachikwe (Zimbabwe, Africa).*

GEOLOGICAL CHARACTERISTICS

CAPSULE DESCRIPTION: Gold-bearing quartz veins and veinlets with minor sulphides crosscut a wide variety of hostrocks and are localized along major regional faults and related splays. The wallrock is typically altered to silica, pyrite and muscovite within a broader carbonate alteration halo.

TECTONIC SETTINGS:

- Phanerozoic: Contained in moderate to gently dipping fault/suture zones related to continental margin collisional tectonism. Suture zones are major crustal breaks which are characterized by dismembered ophiolitic remnants between diverse assemblages of island arcs, subduction complexes and continental-margin clastic wedges.
- Archean: Major transcrustal structural breaks within stable cratonic terranes. May represent remnant terrane collisional boundaries.

DEPOSITIONAL ENVIRONMENT / GEOLOGICAL SETTING: Veins form within fault and joint systems produced by regional compression or transpression (terrane collision), including major listric reverse faults, second and third-order splays. Gold is deposited at crustal levels within and near the brittle-ductile transition zone at depths of 6-12 km, pressures between 1 to 3 kilobars and temperatures from 200° to 400 °C. Deposits may have a vertical extent of up to 2 km, and lack pronounced zoning.

AGE OF MINERALIZATION: Mineralization is post-peak metamorphism (*i.e.* late syncollisional) with gold-quartz veins particularly abundant in the Late Archean and Mesozoic.

- Phanerozoic: In the North America Cordillera gold veins are post-Middle Jurassic and appear to form immediately after accretion of oceanic terranes to the continental margin. In British Columbia deposits are mainly Middle Jurassic (~ 165-170 Ma) and Late Cretaceous (~ 95 Ma). In the Mother Lode belt they are Middle Jurassic (~ 150 Ma) and those along the Juneau belt in Alaska are of Early Tertiary (~56-55 Ma).
- Archean: Ages of mineralization for Archean deposits are well constrained for both the Superior Province, Canadian Shield (~ 2.68 to 2.67 Ga) and the Yilgarn Province, Western Australia (~ 2.64 to 2.63 Ga).

Au-QUARTZ VEINS I01

HOST/ASSOCIATED ROCK TYPES: Lithologically highly varied, usually of greenschist metamorphic grade, ranging from virtually undeformed to totally schistose.

- Phanerozoic: Mafic volcanics, serpentinite, peridotite, dunite, gabbro, diorite, trondhjemite/plagiogranites, graywacke, argillite, chert, shale, limestone and quartzite, felsic and intermediate intrusions.
- Archean: Granite-greenstone belts - mafic, ultramafic (komaitiitic) and felsic volcanics, intermediate and felsic intrusive rocks, graywacke and shale.

DEPOSIT FORM: Tabular fissure veins in more competent host lithologies, veinlets and stringers forming stockworks in less competent lithologies. Typically occur as a system of en echelon veins on all scales. Lower grade bulk-tonnage styles of mineralization may develop in areas marginal to veins with gold associated with disseminated sulphides. May also be related to broad areas of fracturing with gold and sulphides associated with quartz veinlet networks.

TEXTURE/STRUCTURE: Veins usually have sharp contacts with wallrocks and exhibit a variety of textures, including massive, ribboned or banded and stockworks with anastamosing gashes and dilations. Textures may be modified or destroyed by subsequent deformation.

ORE MINERALOGY: [Principal and *subordinate*]: Native gold, pyrite, arsenopyrite, *galena, sphalerite, chalcopyrite, pyrrhotite, tellurides, scheelite, bismuth, cosalite, tetrahedrite, stibnite, molybdenite, gersdorffite (NiAsS), bismuthimite* (Bi_2S_3), *tetradymite* (Bi_2Te_2S).

GANGUE MINERALOGY: [Principal and *subordinate*]: Quartz, carbonates (ferroan-dolomite, ankerite ferroan-magnesite, calcite, siderite), *albite, mariposite (fuchsite), sericite, muscovite, chlorite, tourmaline, graphite*.

ALTERATION MINERALOGY: Silicification, pyritization and potassium metasomatism generally occur adjacent to veins (usually within a metre) within broader zones of carbonate alteration, with or without ferroan dolomite veinlets, extending up to tens of metres from the veins. Type of carbonate alteration reflects the ferromagnesian content of the primary host lithology; ultramafics rocks - talc, Fe-magnesite; mafic volcanic rocks - ankerite, chlorite; sediments - graphite and pyrite; felsic to intermediate intrusions - sericite, albite, calcite, siderite, pyrite. Quartz-carbonate altered rock (listwanite) and pyrite are often the most prominent alteration minerals in the wallrock. Fuchsite, sericite, tourmaline and scheelite are common where veins are associated with felsic to intermediate intrusions.

WEATHERING: Distinctive orange-brown limonite due to the oxidation of Fe-Mg carbonates cut by white veins and veinlets of quartz and ferroan dolomite. Distinctive green Cr-mica may also be present. Abundant quartz float in overburden.

ORE CONTROLS: Gold-quartz veins are found within zones of intense and pervasive carbonate alteration along second order or later faults marginal to transcrustal breaks. They are commonly closely associated with, late syncollisional, structurally controlled intermediate to felsic magmatism. Gold veins are more commonly economic where hosted by relatively large, competent units, such as intrusions or blocks of obducted oceanic crust. Veins are usually at a high angle to the primary collisional fault zone.

- Phanerozoic: Secondary structures at a high angle to relatively flat-lying to moderately dipping collisional suture zones.

- Archean:. Steep, transcrustal breaks; best deposits overall are in areas of greenstone.

ASSOCIATED DEPOSIT TYPES: Gold placers (C01, C02), sulphide manto Au (J04), silica veins (I07); iron formation Au (I04) in the Archean.

GENETIC MODEL: Gold quartz veins form in lithologically heterogeneous, deep transcrustal fault zones that develop in response to terrane collision. These faults act as conduits for CO_2-H_2O-rich (5-30 mol% CO_2), low salinity (<3 wt% NaCl) aqueous fluids, with high Au, Ag, As, (±Sb, Te, W, Mo) and low Cu, Pb, Zn metal contents. These fluids are believed to be tectonically or seismically driven by a cycle of pressure build-up that is released by failure and pressure reduction followed by sealing and repetition of the process (Sibson *et al.*, 1988). Gold is deposited at crustal levels within and near the brittle-ductile transition zone with deposition caused by sulphidation (the loss of H_2S due to pyrite deposition) primarily as a result of fluid-wallrock reactions, other significant factors may involve phase separation and fluid pressure reduction.

The origin of the mineralizing fluids remains controversial, with metamorphic, magmatic and mantle sources being suggested as possible candidates. Within an environment of tectonic crustal thickening in response to terrane collision, metamorphic devolitization or partial melting (anatexis) of either the lower crust or subducted slab may generate such fluids.

COMMENTS: These deposits may be a difficult deposit to evaluate due to "nugget effect", hence the adage, "Drill for structure, drift for grade". These veins have also been mined in British Columbia as a source of silica for smelter flux.

EXPLORATION GUIDES

GEOCHEMICAL SIGNATURE: Elevated values of Au, Ag, As, Sb, K, Li, Bi, W, Te and B ± (Cd, Cu, Pb, Zn and Hg) in rock and soil, Au in stream sediments.

GEOPHYSICAL SIGNATURE: Faults indicated by linear magnetic anomalies. Areas of alteration indicated by negative magnetic anomalies due to destruction of magnetite as a result of carbonate alteration.

OTHER EXPLORATION GUIDES: Placer gold or elevated gold in stream sediment samples is an excellent regional and property-scale guide to gold-quartz veins. Investigate broad 'deformation envelopes' adjacent to regional listric faults where associated with carbonate alteration. Alteration and structural analysis can be used to delineate prospective ground. Within carbonate alteration zones, gold is typically only in areas containing quartz, with or without sulphides. Serpentinite bodies, if present, can be used to delineate favourable regional structures. Largest concentrations of free gold are commonly at, or near, the intersection of quartz veins with serpentinized and carbonate-altered ultramafic rocks.

ECONOMIC FACTORS

TYPICAL GRADE AND TONNAGE: Individual deposits average 30 000 t with grades of 16 g/t Au and 2.5 g/t Ag (Berger, 1986) and may be as large as 40 Mt. Many major producers in the Canadian Shield range from 1 to 6 Mt at grades of 7 g/t Au (Thorpe and Franklin, 1984). The largest gold-quartz vein deposit in British Columbia is the Bralorne-Pioneer which produced in excess of 117 800 kilograms of Au from ore with an average grade of 9.3 g/t.

ECONOMIC LIMITATIONS: These veins are usually less than 2m wide and therefore, only amenable to underground mining.

IMPORTANCE: These deposits are a major source of the world's gold production and account for approximately a quarter of Canada's output. They are the most prolific gold source after the ores of the Witwatersrand basin.

Au-QUARTZ VEINS 101

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INTRUSION-RELATED Au PYRRHOTITE VEINS I02

by Dani J. Alldrick

IDENTIFICATION

SYNONYMS: Mesothermal veins, extension veins, transitional veins, contact aureole veins.

COMMODITIES (*BYPRODUCTS*): Au, Ag (*Cu*).

EXAMPLES (British Columbia (MINFILE #) - *Canada/International*): Scottie Gold (104B034), Snip (104B250), Johnny Mountain (104B107), War Eagle (082FSW097), Le Roi (082FSW093), Centre Star (082FSW094); *no international examples known.*

GEOLOGICAL CHARACTERISTICS

CAPSULE DESCRIPTION: Parallel tabular to cymoid veins of massive sulphide and/or bull-quartz-carbonate with native gold, electrum and chalcopyrite are emplaced in a set of en echelon fractures around the periphery of a subvolcanic pluton. Many previous workers have included these veins as mesothermal veins.

TECTONIC SETTINGS: Volcanic arcs in oceanic and continental margin settings. Older deposits are preserved in accreted arc terranes.

DEPOSITIONAL ENVIRONMENT / GEOLOGICAL SETTING: The subvolcanic setting for these deposits is transitional between the setting for subvolcanic porphyry copper systems and for subvolcanic epithermal systems.

AGE OF MINERALIZATION: Recognized examples of this 'new' deposit type are all Early Jurassic.

HOST/ASSOCIATED ROCK TYPES: Hostrocks are andesitic tuffs, turbidites or early intrusive phases around the periphery of phaneritic, locally porphyritic, granodiorite stocks and batholiths.

DEPOSIT FORM: At various deposits the form has been described as: planar, en echelon vein sets, shear veins, cymoid veins, cymoid loops, sigmoidal veins, extension veins, tension gashes, ladder veins, and synthetic Reidel shear veins. Veins vary in width from centimetres to several metres and can be traced up to hundreds of metres.

TEXTURE/STRUCTURE: Two vein types may occur independently or together. Veins may be composed of (i) massive fine-grained pyrrhotite and/or pyrite, or (ii) massive bull quartz with minor calcite and minor to accessory disseminations, knots and crystal aggregates of sulphides. These two types of mineralization may grade into each other along a single vein or may occur in adjacent, but separate veins. Some veins have undergone post-ore ductile and brittle shearing that complicates textural and structural interpretations.

ORE MINERALOGY [Principal and *subordinate]*: Native gold, electrum, pyrite, pyrrhotite, sphalerite, galena, chalcopyrite, bornite, argentite, arsenopyrite, *magnetite, ilmenite, tetrahedrite, tennantite, molybdenite, cosalite, chalcocite, tellurobismuthite, hessite, volynskite, altaite, native bismuth.*

GANGUE MINERALOGY (Principal and *subordinate): *Quartz, calcite, ankerite, chlorite, *sericite, rhodochrosite, k-feldspar, biotite.*

ALTERATION MINERALOGY: Chlorite, sericite, pyrite, silica, carbonate, rhodochrosite, biotite, epidote, K-feldspar, ankerite. Alteration occurs as narrow (4 cm) vein selvages and as moderate alteration haloes extending up to several metres into the country rock.

INTRUSION-RELATED Au PYRRHOTITE VEINS I02

ORE CONTROLS: Well defined faults and shears control the mineralization. Veins are peripheral to and spatially associated with porphyritic intrusive rocks which may host porphyry copper mineralization.

GENETIC MODEL: Mineralization is syn-intrusive and synvolcanic and formed along the thermally controlled 'brittle-ductile transition envelope' that surrounds subvolcanic intrusions. Late magma movement caused local shear stress, and resultant en echelon vein sets opened and were filled by sulphides and gangue minerals precipitating from circulating hydrothermal fluids. Subsequent shearing may have superimposed foliation or brecciation onto these early-formed veins.

ASSOCIATED DEPOSIT TYPES: Typical deposits of a volcanic arc, especially those in the subvolcanic setting: porphyry Cu+/-Mo+/-Au (L04), skarns, epithermal veins and breccias (H04, H05), 'transitional' deposits (volcanogenic Cu-As-Sb-Au-Ag, L01) and surficial fumarolic hotspring (H03) and exhalative deposits.

COMMENTS: At least one of these deposits was initially interpreted as a volcanogenic exhalative sulphide lens because a massive sulphide vein was discovered in volcanic rocks with no obvious bedding.

EXPLORATION GUIDES

GEOCHEMICAL SIGNATURE: Elevated values of Au, Ag, Cu. (As, Zn).

GEOPHYSICAL SIGNATURE: Electromagnetic (ABEM and VLF-EM) and magnetometer (negative anomalies or 'magnetic troughs').

OTHER EXPLORATION GUIDES: Intense prospecting swath extending from 100 metres inside the intrusive contact to 1000 metres outside the intrusive contact of a prospective (sub-volcanic Early Jurassic) pluton. Detailed soil geochemistry and detailed ground geophysics could be designed to investigate this same area. Small, 'hairline' mineralized fractures are good proximal indicators of a nearby major vein. Increased alteration intensity could also be a good proximal indicator, but this is a more subtle feature. Once the vein orientation on an initial discovery is determined, additional parallel veins should be anticipated and investigated with fences of drill holes.

ECONOMIC FACTORS

TYPICAL GRADE AND TONNAGE: Gold/silver ratios are close to 1:1. Copper may be a recoverable byproduct. Typical grades are 10 to 20 g/t Au.

IMPORTANCE: The Snip gold mine is currently British Columbia's largest gold producer and the Rossland veins are the province's second largest gold camp.

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TURBIDITE-HOSTED Au VEINS — I03

by R.H. McMillan[1]

IDENTIFICATION

SYNONYMS: Saddle reefs, Bendigo-type.

COMMODITIES (*BYPRODUCTS*): Au (*Ag, W, Sb*).

EXAMPLES (British Columbia (MINFILE #) - *Canada/International*): Frasergold (093A150), Valentine Mountain (092B108), Island Mountain (093H019), Mosquito Creek (093H025), Sheep Creek Deposits - Reno (082FSW036), Queen (082FSW048), Kootenay Belle (082FSW044) and Gold Belt (082FSW040); *Ptarmigan, Burwash, Thompson-Ludmar and other Yellowknife district deposits (Northwest Territories, Canada), Meguma district (Nova Scotia, Canada), Bendigo and Ballarat (Victoria, Australia).*

GEOLOGICAL CHARACTERISTICS

CAPSULE DESCRIPTION: Gold-quartz veins, segregations, lodes and sheeted zones hosted by fractures, faults, folds and openings in anticlines, synclines and along bedding planes in turbidites and associated poorly sorted clastic sedimentary rocks.

TECTONIC SETTING: Hostrocks were deposited in submarine troughs, periarc basins, foreland basins and remnant ocean basins. The sediments were typically formed on continental margins or back-arc basins. Typically these sequences experienced one or two deformational phases with associated metamorphism.

DEPOSITIONAL ENVIRONMENT/GEOLOGICAL SETTING: Thick sediment sequences that have been deformed and metamorphosed; relatively few igneous rocks.

AGE OF MINERALIZATION: Archean to Tertiary; the Bendigo and Meguma districts are underlain by Early Paleozoic strata. The veins are generally considered to be related to later deformational event.

HOST/ ASSOCIATED ROCK TYPES: The predominant rock types are greywackes, siliceous wackes, shales and carbonaceous shales. Bedded cherts, iron formations, fine-grained impure carbonate rocks; minor polymictic conglomerate, tuffaceous members and minor marine volcanic flows may also be part of the stratigraphic sequence. There are younger granitic intrusions in many belts. Metamorphic grade is generally greenschist, but may reach amphibolite rank.

DEPOSIT FORM: Typically deposits are composed of multiple quartz veins up to a few metres in width that are commonly stratabound (either concordant or discordant), bedding-parallel, or discordant, and parallel to fold axial planes. Veins are variably deformed and occur as single strands, as sheeted arrays or as stockworks. Bedding-parallel veins within anticlines and synclines in the Bendigo-Ballarat and Meguma districts are commonly called saddle reefs or saddle troughs.

[1] Consulting Geologist, Saanich, British Columbia

TURBIDITE-HOSTED Au VEINS I03

TEXTURE/STRUCTURE: Veins are well defined with sharp contacts. Bedding veins can be massive or laminated (ribbon texture) with columnar structures or stylolites, while discordant veins are generally massive. Veins can be associated with a variety of structures. Most common are folded veins and saddle reefs related to anticlinal folds. Sheeted, en echelon sigmoidal veins, ladder veins, tension gashes or stockworks may be related to zones of extension or to Reidel shear structures.

ORE MINERALOGY (Principal and *subordinate*): Native gold, pyrite, arsenopyrite, *pyrrhotite, chalcopyrite, sphalerite, galena, molybdenite, bismuth, stibnite, bournonite and other sulphosalt minerals.* Low sulphide content (<2.5%).

GANGUE MINERALOGY (Principal and *subordinate):* Quartz, carbonates (calcite, dolomite or ankerite), *feldspar (albite) and chlorite.*

ALTERATION: Generally not prominent, however, disseminated arsenopyrite, pyrite and tourmaline, and more pervasive silica, sericite and carbonate, may develop in wallrocks adjacent to veins.

WEATHERING: In unglaciated terrains deep weathering and alluvial recycling may produce related rich placer deposits, such as the Bendigo region.

ORE CONTROLS: A strong structural control within dilatent areas in fold crests (saddle and trough reefs), discordant veins and tension gashes. This structural control may extend to district scale alignment of deposits. In some districts the veins appear confined to a specific stratigraphic interval, often near a change in lithologies. In the Meguma district, a more subtle stratigraphic control related to the upper (pelitic) portions of individual bouma cycles as well as regionally to the upper portion of the turbidite section. In the Bendigo district there is a relationship between ore and an abundance of graphite in the adjacent wallrocks.

GENETIC MODEL: Genetic theories range from veins formed by magmatic hydrothermal fluids or metamorphogenic fluids to deformed syngenetic mineralization. Most current workers prefer the metamorphogenic-deformational or lateral secretion theories and interpret the laminations as "crack-seal" phenomena formed during episodic re-opening of the veins during their formation. Workers favoring a syngenetic origin interpret the laminations as primary layering. Structural relationships in the Meguma and Bendigo districts indicate that the veins formed contemporaneously with, or prior to the major deformational event and were metamorphically overprinted during the intrusion of Devonian batholithic granitic rocks. Late post-deformational tension veinlets are generally non-auriferous.

ASSOCIATED DEPOSIT TYPES: Placers (C01), iron formation hosted gold deposits (I04) are also mainly hosted in turbidites - some of the Northwest Territories turbidite-hosted deposits are associated with chemical sediments. In several camps, slate horizons carrying finely disseminated, very low grade gold have been reported.

COMMENTS: Although past classification schemes have not recognized this type of deposit in British Columbia, the Valentine Mountain deposit hosted in Leech River schists and Frasergold hosted in Late Triassic clastic Quesnel River Group can be included. Elsewhere, several important vein gold districts in clastic sedimentary (possibly turbiditic) rocks might also be included. For example, the Sheep Creek camp and some of the Barkerville deposits are hosted in siliceous wackes and phyllites.

EXPLORATION GUIDES

GEOCHEMICAL SIGNATURE: Si, Fe, S, As, B, Au and Ag generally show strong enrichment in the deposits, while Cu, Mg, Ca, Zn, Cd, Pb, Sb, W and Mn generally show moderate enrichment, and Hg, In, Li, Bi, Se, Te, Mo, F, Co and Ni may show low levels of enrichment.

GEOPHYSICAL SIGNATURE: The low sulphide content of the majority of quartz veins renders most geophysical techniques ineffective as direct exploration tools. However, airborne and ground electromagnetic and magnetic surveys and induced polarization surveys can be useful where deposits show an association with iron formation, massive sulphides or graphite.

OTHER EXPLORATION GUIDES: Standard prospecting techniques to trace mineralization directly or in float trains in glacial till, talus or other debris derived from the gold mineralization remains the most effective prospecting tool. Areas where there has been past gold production from placers are good candidates for prospecting.

ECONOMIC FACTORS

TYPICAL GRADE AND TONNAGE: Gold production from the Meguma region has come from 60 deposits at grades ranging from 8 to 50 g/t - a total of 35.13 tonnes has been produced from the district. The Bendigo field is much more significant, having produced a minimum of more than 373.3 t (12 M.oz.) of non-alluvial gold from more than 40 Mt of ore since 1851 - grades ranged from a minimum of approximately 5 g/t to more than 30 g/t. The three Barkerville mines produced an aggregate of 2.75 Mt to yield 38.29 t of gold between 1933 and 1987.

ECONOMIC LIMITATIONS: Deposits such as those in the Bendigo and Barkerville districts constitute attractive exploration targets. Although the hand sorting required to recover gold from the Nova Scotia deposits would probably render them uneconomic today, new techniques such as photometric sorting might improve the economics.

IMPORTANCE: Some districts/deposits, such as Bendigo, rank as world class and remain attractive exploration targets. The limited information available about the immense Muruntau deposit suggest that it may be similar to this type.

TURBIDITE-HOSTED Au VEINS I03

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IRON FORMATION-HOSTED Au[1] I04

by R.H. McMillan[2]

IDENTIFICATION

SYNONYM: Mesothermal veins.

COMMODITIES *(BYPRODUCTS)*: Au *(Ag, Cu)*.

EXAMPLES (British Columbia - *Canada/International*): No B.C. examples; *Lupin and Cullaton Lake B-Zone (Northwest Territories, Canada), Detour Lake, Madsen Red Lake, Pickle Crow, Musselwhite, Dona Lake, (Ontario, Canada), Homestake (South Dakota, USA), Mt. Morgans (Western Australia); Morro Vehlo and Raposos, Mineas Gerais (Brazil); Vubachikwe and Bar 20 (Zimbabwe); Mallappakoda, Kolar District (India).*

GEOLOGICAL CHARACTERISTICS

CAPSULE DESCRIPTION: Gold in crosscutting quartz veins and veinlets or as fine disseminations associated with pyrite, pyrrhotite and arsenopyrite hosted in iron-formations and adjacent rocks within volcanic or sedimentary sequences. The iron-formations may vary between carbonate-oxide iron-formation and arsenical sulphide-silicate iron-formation.

TECTONIC SETTING: In "greenstone belts" believed to be ancient volcanic arcs; and in adjacent submarine troughs.

DEPOSITIONAL ENVIRONMENT/GEOLOGICAL SETTING: Sedimentary and submarine volcanic sequences in a range of mutually overlapping settings ranging from turbiditic clastic sedimentary environments to distal mafic (and komatiitic) environments with associated felsic tuffaceous and intrusive porphyries.

AGE OF MINERALIZATION: Archean to Proterozoic.

HOST/ ASSOCIATED ROCK TYPES: Contained mainly within various facies of Algoma-type iron-formation and cherts, although veins may extend into other units. Associated with variolitic, tholeiitic and komatiitic volcanic and clastic (commonly turbiditic) rocks, rarely felsic volcanic and intrusive rocks. Metamorphic rank ranges from lowest greenschist to upper amphibolite facies. Silicate-facies iron-formations are associated in some cases but are generally not gold-bearing.

[1] This deposit type overlaps with and is gradational into gold-quartz veins (I01) and also the turbidite-hosted gold veins (I03). Some classifications group the three deposit types together as "mesothermal veins".

[2] Consulting Geologist, Saanich, British Columbia

IRON FORMATION-HOSTED Au I04

DEPOSIT FORM: In and near crosscutting structures, such as quartz veins, or stratiform zones within chemical sedimentary rocks. Host strata have generally been folded and deformed to varying degree, consequently the deposits may have developed in axial plane cleavage area or be thickened and remobilized in fold hinges.

TEXTURE/STRUCTURE: Highly variable: gold mineralization may be finely disseminated in sulphide minerals in the stratiform examples or occur as the native mineral or in sulphides in crosscutting quartz veins. Sulphidization features such as pyrite overgrowths on magnetite are present in some deposits.

ORE MINERALOGY (Principal and *subordinate*): Native Au, pyrite, arsenopyrite, magnetite, pyrrhotite, *chalcopyrite, sphalerite, galena, stibnite, rarely gold tellurides.*

GANGUE MINERALOGY (Principal and *subordinate*): Vein quartz, chert, carbonates (calcite, dolomite or ankerite), *graphite, grunerite, stilpnomelane, tourmaline, feldspar (albite).*

ALTERATION: In deposits at low metamorphic rank, carbonatization (generally ankeritic or ferroan dolomite) is generally prominent. Sulphidization (pyritization, arsenopyritization and pyrrhotitization) is common in wallrocks adjacent to crosscutting quartz veins.

WEATHERING: Highly variable: sulphide-rich, carbonate-poor deposits will produce significant gossans.

ORE CONTROLS: Mineralization is within, or near, favourable iron-formations. Most deposits occur adjacent to prominent regional structural and stratigraphic "breaks" and mineralization is often related to local structures. Contacts between ultramafic (commonly komatiitic) rocks and tholeiitic basalts or sedimentary rocks are important. All known deposits occur in Precambrian sequences, however, there are some potentially favourable chemical sediment horizons in Paleozoic rocks. Pinch outs and facies changes within geologically favourable units are important loci for ore deposition.

GENETIC MODELS: One model proposed for iron formation-hosted Au is that the mineralization may form due to deformation focusing metamorphogenic or magmatic hydrothermal fluids, from depth, into a chemically and structurally (brittle-ductile transition zone) favourable depositional environment, late in the orogenic cycle. This theory is consistent with both the crosscutting relationships and radiometric dates for the gold mineralization. Another model emphasizes a syngenetic origin for the widespread anomalous gold values, similarity of the geological environments to currently active submarine exhalative systems, and the association with chemical sedimentary strata. Replacement features could be explained as normal diagenetic features and contact areas between sulphide-rich ore and carbonate wallrock as facies boundaries.

ASSOCIATED DEPOSIT TYPES: Au-quartz veins (I01), turbidite-hosted Au-quartz veins (I03), Algoma-type iron-formations (G01).

COMMENTS: This type of deposit has not been documented in British Columbia. The closest analogy is the 900 zone on the Debbie property (092F331) which contains gold in magnetite-jasper-sulphide-bearing bedded chert, in quartz veins and in stockworks cutting ankeritic aphyric pillow basalt. Some workers consider auriferous stratiform pyrite bodies, such as Bousquet, Doyon, and Agnico Eagle in the Canadian Shield, to be closely related to iron formation-hosted Au.

EXPLORATION GUIDES

GEOCHEMICAL SIGNATURE: Si, Fe, S, As, B, Mg, Ca, Au and Ag generally show strong enrichment in the deposits, while Cu, Zn, Cd, Pb and Mn generally show moderate enrichment.

GEOPHYSICAL SIGNATURE: Airborne and ground electromagnetic and magnetic surveys and induced polarization surveys can be very useful to detect and map the high sulphide and magnetite content of many of the deposits.

OTHER EXPLORATION GUIDES: Standard prospecting techniques to trace mineralization directly or in float trains in glacial till, talus or other debris derived from the gold mineralization remains the most effective prospecting tool. Areas with gold placers are potential targets. Exploration programs should focus on the primary depositional environment for stratiform deposits.

ECONOMIC FACTORS

TYPICAL GRADE AND TONNAGE: The more significant deposits fall in the ranges from 6 to 17 g/t Au and 1 to 5 Mt (Thorpe and Franklin, 1984). At the adjacent properties of Morro Velho and Raposos in Brazil, approximately 10 million ounces of gold have been produced at a grade of between 15 and 16 g/t since 1834. In Ontario, the Detour Lake mine contains a resource of 48 t Au and the Madsen Red Lake deposit produced 75 t, the Pickle Crow Deposits 45 tonnes and the Central Patricia 19 tonnes. At the Lupin mine 6.66 Mt of ore grading 10.63 g/t Au were produced between 1982 and the end of 1993 with remaining reserves of 5.1 Mt averaging 9.11 g/t.

ECONOMIC LIMITATIONS: The narrow veins in some deposits require selective mining techniques which are no longer highly profitable. On the other hand, deposits, such as Lupin, are sufficiently large to be mined very profitably utilizing modern mechanized equipment.

IMPORTANCE: Although attention in recent years has been focused on the large epithermal volcanic-hosted gold deposits of the circum-Pacific Belt and on Carlin-type deposits, iron-formation hosted gold deposits, such as Lupin, rank as world class and remain attractive exploration targets. For example, the Homestake mine has produced approximately 300 t of gold since starting production in 1876.

IRON FORMATION-HOSTED Au

I04

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POLYMETALLIC VEINS Ag-Pb-Zn±Au

I05

by David V. Lefebure and B. Neil Church

B.C. MINERAL DEPOSIT PROFILES

IDENTIFICATION

SYNONYMS: Clastic metasediment-hosted silver-lead-zinc veins, silver/base metal epithermal deposits.

COMMODITIES (BYPRODUCTS): Ag, Pb, Zn (Cu, Au, Mn).

EXAMPLES (British Columbia (MINFILE # - *Canada/International*):

- Metasediment host: Silvana (082FNW050) and Lucky Jim (082KSW023), Slocan-New Denver-Ainsworth district, St. Eugene (082GSW025), Silver Cup (082KNW027), Trout Lake camp; *Hector-Calumet and Elsa,* Mayo *district (Yukon, Canada), Coeur d'Alene district (Idaho, USA), Harz Mountains and Freiberg district (Germany), Příbram district (Czechoslavakia).*
- Igneous host: Wellington (082ESE072) and Highland Lass - Bell (082ESW030, 133), Beaverdell camp; Silver Queen (093L002), Duthie (093L088), Cronin (093L127), Porter-Idaho (103P089), Indian (104B031); *Sunnyside and Idorado, Silverton district and Creede (Colorado, USA), Pachuca (Mexico).*

GEOLOGICAL CHARACTERISTICS

CAPSULE DESCRIPTION: Sulphide-rich veins containing sphalerite, galena, silver and sulphosalt minerals in a carbonate and quartz gangue. These veins can be subdivided into those hosted by metasediments and another group hosted by volcanic or intrusive rocks. The latter type of mineralization is typically contemporaneous with emplacement of a nearby intrusion.

TECTONIC SETTINGS: These veins occur in virtually all tectonic settings except oceanic, including continental margins, island arcs, continental volcanics and cratonic sequences.

DEPOSITIONAL ENVIRONMENT / GEOLOGICAL SETTING:

- Metasediment host: Veins are emplaced along faults and fractures in sedimentary basins dominated by clastic rocks that have been deformed, metamorphosed and intruded by igneous rocks. Veins postdate deformation and metamorphism.
- Igneous host: Veins typically occur in country rock marginal to an intrusive stock. Typically veins crosscut volcanic sequences and follow volcano-tectonic structures, such as caldera ring-faults or radial faults. In some cases the veins cut older intrusions.

AGE OF MINERALIZATION: Proterozic or younger; mainly Cretaceous to Tertiary in British Columbia.

HOST/ASSOCIATED ROCK TYPES: These veins can occur in virtually any host. Most commonly the veins are hosted by thick sequences of clastic metasediments or by intermediate to felsic volcanic rocks. In many districts there are felsic to intermediate intrusive bodies and mafic igneous rocks are less common. Many veins are associated with dikes following the same structures.

DEPOSIT FORM: Typically steeply dipping, narrow, tabular or splayed veins. Commonly occur as sets of parallel and offset veins. Individual veins vary from centimetres up to more than 3 m wide and can be followed from a few hundred to more than 1000 m in length and depth. Veins may widen to tens of metres in stockwork zones.

POLYMETALLIC VEINS Ag-Pb-Zn±Au I05

TEXTURE/STRUCTURE: Compound veins with a complex paragenetic sequence are common. A wide variety of textures, including cockade texture, colloform banding and crustifications and locally druzy. Veins may grade into broad zones of stockwork or breccia. Coarse-grained sulphides as patches and pods, and fine-grained disseminations are confined to veins.

ORE MINERALOGY [Principal and *subordinate*]: Galena, sphalerite, tetrahedrite-tennantite, *other sulphosalts including pyrargyrite, stephanite, bournonite and acanthite, native silver, chalcopyrite, pyrite, arsenopyrite, stibnite*. Silver minerals often occur as inclusions in galena. *Native gold and electrum in some deposits*. Rhythmic compostional banding sometimes present in sphalerite. Some veins contain more chalcopyrite and gold at depth and Au grades are normally low for the amount of sulphides present.

GANGUE MINERALOGY [Principal and *subordinate*]:
- Metasediment host: Carbonates (most commonly siderite with minor dolomite, ankerite and calcite), quartz, *barite, fluorite, magnetite, bitumen*.
- Igneous host: Quartz, carbonate (rhodochrosite, siderite, calcite, dolomite), *sometimes specular hematite, hematite, barite, fluorite*. Carbonate species may correlate with distance from source of hydrothermal fluids with proximal calcium and magnesium-rich carbonates and distal iron and manganese-rich species.

ALTERATION MINERALOGY: Macroscopic wall rock alteration is typically limited in extent (measured in metres or less). The metasediments typically display sericitization, silicification and pyritization. Thin veining of siderite or ankerite may be locally developed adjacent to veins. In the Coeur d'Alene camp a broader zone of bleached sediments is common. In volcanic and intrusive hostrocks the alteration is argillic, sericitic or chloritic and may be quite extensive.

WEATHERING: Black manganese oxide stains, sometimes with whitish melanterite, are common weathering products of some veins. The supergene weathering zone associated with these veins has produced major quantities of manganese. Galena and sphalerite weather to secondary Pb and Zn carbonates and Pb sulphate. In some deposits supergene enrichment has produced native and horn silver.

ORE CONTROLS: Regional faults, fault sets and fractures are an important ore control; however, veins are typically associated with second order structures. In igneous rocks the faults may relate to volcanic centers. Significant deposits restricted to competent lithologies. Dikes are often emplaced along the same faults and in some camps are believed to be roughly contemporaneous with mineralization. Some polymetallic veins are found surrounding intrusions with porphyry deposits or prospects.

GENETIC MODELS: Historically these veins have been considered to result from differentiation of magma with the development of a volatile fluid phase that escaped along faults to form the veins. More recently researchers have preferred to invoke mixing of cooler, upper crustal hydrothermal or meteoric waters with rising fluids that could be metamorphic, groundwater heated by an intrusion or expelled directly from a differentiating magma. Any development of genetic models is complicated by the presence of other types of veins in many districts. For example, the Freiberg district has veins carrying F-Ba, Ni-As-Co-Bi-Ag and U.

COMMENTS: Ag-tetrahedrite veins, such as the Sunshine and Galena mines in Idaho, contain very little sphalerite or galena. These may belong to this class of deposits or possibly the five-element veins. The styles of alteration, mineralogy, grades and different geometries can usually be used to distinguish the polymetallic veins from stringer zones found below syngenetic massive sulphide deposits.

ASSOCIATED DEPOSIT TYPES:
- Metasediment host: Polymetallic mantos (M01).
- Igneous host: May occur peripheral to virtually all types of porphyry mineralization (L01, L03, L04, L05, L06, L07, L08) and some skarns (K02, K03).

EXPLORATION GUIDES

GEOCHEMICAL SIGNATURE: Elevated values of Zn, Pb, Ag, Mn, Cu, Ba and As. Veins may be within arsenic, copper, silver, mercury aureoles caused by the primary dispersion of elements into wallrocks or broader alteration zones associated with porphyry deposit or prospects.

GEOPHYSICAL SIGNATURE: May have elongate zones of low magnetic response and/or electromagnetic, self potential or induced polarization anomalies related to ore zones.

OTHER EXPLORATION GUIDES: Strong structural control on veins and common occurrence of deposits in clusters can be used to locate new veins.

ECONOMIC FACTORS

TYPICAL GRADE AND TONNAGE : Individual vein systems range from several hundred to several million tonnes grading from 5 to 1500 g/t Ag, 0.5 to 20% Pb and 0.5 to 8% Zn. Average grades are strongly influenced by the minimum size of deposit included in the population. For B.C. deposits larger than 20 000 t the average size is 161 000 t with grades of 304 g/t Ag, 3.47 % Pb and 2.66 % Zn. Copper and gold are reported in less than half the occurrences, with average grades of 0.09 % Cu and 4 g/t Au.

ECONOMIC LIMITATIONS: These veins usually support small to medium-size underground mines. The mineralization may contain arsenic which typically reduces smelting credits.

IMPORTANCE: The most common deposit type in British Columbia with over 2 000 occurrences; these veins were a significant source of Ag, Pb and Zn until the 1960s. They have declined in importance as industry focused more on syngenetic massive sulphide deposits. Larger polymetallic vein deposits are still attractive because of their high grades and relatively easy benefication. They are potential sources of cadmium and germanium.

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Cu±Ag QUARTZ VEINS 106

by David V. Lefebure

IDENTIFICATION

SYNONYMS: Churchill-type vein copper, vein copper

COMMODITY (*BYPRODUCTS*): Cu (Ag, rarely Au).

EXAMPLES (British Columbia (MINFILE #) - *Canada/International*): Davis-Keays (094K012, 050), Churchill Copper (Magnum, 094K003), Bull River (082GNW002), Copper Road (092K060), Copper Star (092HNE036), Copper Standard (092HNE079), Rainbow (093L044); *Bruce Mines and Crownbridge (Ontario, Canada), Blue Wing and Seaboard (North Carolina, USA), Matahambre (Cuba), Inyati (Zimbabwe), Copper Hills (Western Australia), Tocopilla area (Chile), Burgas district (Bulgaria), Butte (Montana, USA), Rosario (Chile).*

GEOLOGICAL CHARACTERISTICS

CAPSULE DESCRIPTION: Quartz-carbonate veins containing patches and disseminations of chalcopyrite with bornite, tetrahedrite, covellite and pyrite. These veins typically crosscut clastic sedimentary or volcanic sequences, however, there are also Cu quartz veins related to porphyry Cu systems and associated with felsic to intermediate intrusions.

TECTONIC SETTINGS: A diversity of tectonic settings reflecting the wide variety of hostrocks including extensional sedimentary basins (often Proterozoic) and volcanic sequences associated with rifting or subduction-related continental and island arc settings.

DEPOSITIONAL ENVIRONMENT / GEOLOGICAL SETTING: Veins emplaced along faults; they commonly postdate major deformation and metamorphism. The veins related to felsic intrusions form adjacent to, and are contemporaneous with, mesozonal stocks.

AGE OF MINERALIZATION: Any age; can be much younger than hostrocks.

HOST/ASSOCIATED ROCK TYPES: Cu±Ag quartz veins occur in virtually any rocks although the most common hosts are clastic metasediments and mafic volcanic sequences. Mafic dikes and sills are often spatially associated with metasediment-hosted veins. These veins are also found within and adjacent to felsic to intermediate intrusions.

DEPOSIT FORM: The deposits form simple to complicated veins and vein sets which typically follow high-angle faults which may be associated with major fold sets. Single veins vary in thickness from centimetres up to tens of metres. Major vein systems extend hundreds of metres along strike and down dip. In some exceptional cases the veins extend more than a kilometre along the maximum dimension.

TEXTURE/STRUCTURE: Sulphides are irregularly distributed as patches and disseminations. Vein breccias and stockworks are associated with some deposits.

ORE MINERALOGY (Principal and *subordinate*):

- Metasediment and volcanic-hosted: Chalcopyrite, pyrite, chalcocite; *bornite, tetrahedrite, argentite, pyrrhotite, covellite, galena.*
- Intrusion-related: Chalcopyrite, bornite, chalcocite, pyrite, pyrrhotite; *enargite, tetrahedrite-tennantite, bismuthinite, molybdenite, sphalerite, native gold and electrum.*

GANGUE MINERALOGY (Principal and *subordinate*): Quartz and carbonate (calcite, dolomite, ankerite or siderite); *hematite, specularite, barite.*

Cu±Ag QUARTZ VEINS I06

ALTERATION MINERALOGY: Wallrocks are typically altered for distances of centimetres to tens of metres outwards from the veins.

- Metasediment and volcanic-hosted: The metasediments display carbonatization and silicification. At the Churchill and Davis-Keays deposits, decalcification of limy rocks and zones of disseminated pyrite in roughly stratabound zones are reported. The volcanic hostrocks exhibit abundant epidote with associated calcite and chlorite.
- Intrusion-related: Sericitization, in places with clay alteration and chloritization.

WEATHERING: Malachite or azurite staining; silicified linear "ridges".

ORE CONTROLS: Veins and associated dikes follow faults. Ore shoots commonly localized along dilational bends within veins. Sulphides may occur preferentially in parts of veins which crosscut carbonate or other favourable lithologies. Intersections of veins are an important locus for ore.

GENETIC MODEL: The metasediment and volcanic-hosted veins are associated with major faults related to crustal extension which control the ascent of hydrothermal fluids to suitable sites for deposition of metals. The fluids are believed to be derived from mafic intrusions which are also the source for compositionally similar dikes and sills associated with the veins. Intrusion-related veins, like Butte in Montana and Rosario in Chile, are clearly associated with high-level felsic to intermediate intrusions hosting porphyry Cu deposits or prospects.

ASSOCIATED DEPOSIT TYPES:

- Metasediment and volcanic-hosted: Possibly related to sediment-hosted Cu (E04) and basaltic Cu (D03).
- Intrusion-related: High sulphidation (H04), copper skarns (K01), porphyries (L01?, L03, L04) and polymetallic veins (I05).

COMMENTS: Cu±Ag quartz veins are common in copper metallogenetic provinces; they often are more important as indicators of the presence of other types of copper deposits.

EXPLORATION GUIDES

GEOCHEMICAL SIGNATURE: High Cu and Ag in regional silt samples. The Churchill-type deposits appear to have very limited wallrock dispersion of pathfinder elements; however, alteration halos of silica and carbonate addition or depletion might prove useful. Porpyhyry-related veins exhibit many of the geochemical signatures of porphyry copper systems.

GEOPHYSICAL SIGNATURE: Large veins with conductive massive sulphides may show up as electromagnetic conductors, particularly on ground surveys. Associated structures may be defined by ground magnetic, very low frequency or electromagnetic surveys. Airborne surveys may identify prospective major structures.

OTHER EXPLORATION GUIDES: Commonly camp-scale or regional structural controls define a dominant orientation for veins.

ECONOMIC FACTORS

GRADE AND TONNAGE: Typically range from 10 000 to 100 0000 t with grades of 1 to 4% Cu, nil to 300 g/t Ag. The Churchill deposit has reserves of 90 000 t of 3 % Cu and produced 501 019 t grading 3% Cu and the Davis-Keays deposit has reserves of 1 119 089 t grading 3.43 % Cu. The Big Bull deposit has reserves of 732 000 t grading 1.94% Cu. The intrusion-related veins range up to millions of tonnes with grades of up to 6% Cu. The Butte veins in Montana have produced several hundred million tonnes of ore with much of this production from open-pit operations.

ECONOMIC LIMITATIONS: Currently only the large and/or high-grade veins (usually associated with porphyry deposits) are economically attractive.

Cu±Ag QUARTZ VEINS 106

IMPORTANCE: From pre-historic times until the early 1900s, high-grade copper veins were an important source of this metal. With hand sorting and labour-intensive mining they represented very attractive deposits.

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SILICA-CARBONATE Hg

108

by Chris Ash

IDENTIFICATION

SYNONYMS: Serpentinite-type, listwanite-type.

COMMODITIES (*BYPRODUCTS*): Hg (Sb, Ag, Au).

EXAMPLES (British Columbia (MINFILE #) - *Canada/International*): Pinchi (093K049), Bralorne Takla (093N008), Eagle Mercury (092JNE062), Silverquick (092O017), Manitou (092O023); *New Almaden, New Idria (California, USA).*

GEOLOGICAL CHARACTERISTICS

CAPSULE DESCRIPTION: Cinnabar occurs associated with quartz and carbonate alteration in zones of intense brittle fracturing at relatively shallow levels along major fault zones. Commonly occur in areas of active geothermal systems.

TECTONIC SETTING: Within orogenic belts.

DEPOSITIONAL ENVIRONMENT / GEOLOGICAL SETTING: At shallow levels within high-angle, regional-scale, deep crustal faults marked by the presence of ophiolitic ultramafic rocks. Typically at brittle faulted contacts between competent lithologies, *e.g.* carbonate-altered ultramafics, limestone, etc. Locally associated with recent volcanism and hotspring activity. Mercury deposits in B.C. are concentrated along several north to northwest-trending, high-angle transcurrent fault zones which border oceanic terranes. These include the Pinchi, Yalakom and Germansen faults.

AGE OF MINERALIZATION: Eocene to Recent?

HOST/ASSOCIATED ROCK TYPES: Serpentinite, limestone, siltstone, graywacke, conglomerate, mafic volcanic rocks.

DEPOSIT FORM: Deposits are typically highly irregular within major fault zones.

TEXTURE/STRUCTURE: Thin discontinuous stringers or fracture and cavity coatings in areas of shattering and brecciation along major faults.

ORE MINERALOGY [Principal and *subordinate*]: Cinnabar, *native mercury (quicksilver), metacinnabar, livingstonite* ($HgSb_4S_9$).

GANGUE MINERALOGY: Pyrite, marcasite, quartz, carbonate, limestone, serpentinite.

ALTERATION MINERALOGY: "Silica-carbonate rock" or "listwanite/listvenite", magnesite, ankerite, dolomite, quartz, chalcedony, kaolinite, sericite (fuchsite/mariposite).

WEATHERING: Mineralized areas display distinctive limonite stain due to the presence of iron carbonates.

ORE CONTROLS: High-angle fault zones marginal to accreted oceanic terranes. In general, grade of ore increases with fracture density in the hostrock.

GENETIC MODELS: Deposits form where relatively low temperature (between 100° and 200°C) CO_2-H_2O aqueous fluids (< 2 wt. % chlorine), charged with Hg migrate upward along permeable fault zones and precipitate cinnabar in fractured hostrocks at shallow levels due to cooling and mixing with meteoric water. At this stage a vapour phase evolves which emanates from hotsprings at surface.

SILICA-CARBONATE Hg I08

ASSOCIATED DEPOSIT TYPES: Sb veins.

COMMENTS: Due to the liquid state of this metal, mercury is generally measured in "flasks" and quoted in dollar value per flask. Flasks are standard steel containers that hold 76 lb (about 2.5 L) of the liquid metal.

EXPLORATION GUIDES

GEOCHEMICAL SIGNATURE: Hg, Sb (Cu, Zn).

GEOPHYSICAL SIGNATURE: Not generally applicable.

OTHER EXPLORATION GUIDES: Soil, stream sediment and geobotanical sampling for Hg has proven successful. The spatial association of hotsprings with major fault zones associated with ophiolitic ultramafic rocks.

ECONOMIC FACTORS

TYPICAL GRADE AND TONNAGE: Deposits of this type are typically less than 1 Mt, but may be up to several million tonnes with mercury grades averaging 0.5% and ranging from 0.2 to 0.8%.

ECONOMIC LIMITATIONS: The low grade of these deposits relative to other mercury deposit types, extreme fluctuations in the price of the metal, and inherent pollution problems are all factors in the economics of this deposit type.

IMPORTANCE: Although historically significant as a source of mercury, these deposits are not currently mined due to their low grades and small size relative to the much larger and richer Almaden-type mercury deposits. The only significant past-producing mines in B.C. include the Pinchi and Bralorne Takla. Both deposits are along the Pinchi fault.

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STIBNITE VEINS and DISSEMINATIONS

by Andre Panteleyev

IDENTIFICATION

SYNONYMS: Quartz-stibnite, simple antimony, syntectonic stibnite, mesothermal Sb-Au.

COMMODITIES (*BYPRODUCTS*): Sb (*Au*).

EXAMPLES (British Columbia (MINFILE #) - *Canada/International*): a) Veins - Minto (092JNE075) and Congress (092JNE029), Bridge River area; Snowbird (093K036); *Becker-Cochran (Yukon, Canada), Lake George (New Brunswick, Canada), Beaver Brook (Newfoundland, Canada), Murchison Range deposits (South Africa), Caracota and numerous other deposits in the Cordillera Occidental (Bolivia).* b) Disseminated - *Caracota and Espiritu Santo (Bolivia), many deposits (Turkey).*

GEOLOGICAL CHARACTERISTICS

CAPSULE DESCRIPTION: Stibnite veins, pods, disseminations and stibnite-bearing quartz and quartz-carbonate veins occur in, or adjacent to, shears, fault zones and brecciated rocks in sedimentary or metasedimentary sequences.

TECTONIC SETTING: Any orogenic area, particularly where large-scale fault structures are present

DEPOSITIONAL ENVIRONMENT / GEOLOGICAL SETTING: Fault and shear zones, notably in fault splays and fault-related breccias in which shallow to intermediate-depth hydrothermal systems have been operative.

AGE OF MINERALIZATION: Deposits range from Paleozoic to Tertiary age.

HOST/ASSOCIATED ROCK TYPES: Any faulted lithologies with a wide variety of rock types; sedimentary and metasedimentary rocks are commonly present. British Columbia deposits tend to be near major fault zones with attendant serpentinized mafic and ultramafic rocks.

DEPOSIT FORM: Stibnite occurs in veins; also as fine to coarse grains in sheared or brecciated rocks. Some stibnite is disseminated in carbonate-altered wallrocks surrounding structures and may form within pressure shadows at crests of folds. Massive stibnite-pyrite replacements which may form pods or lenses up to tens of metres long, are relatively uncommon, but are sources of rich ore.

TEXTURE/STRUCTURE: Veins have fine to coarse-grained, commonly euhedral bladed crystals of stibnite, quartz and carbonate in masses of stibnite. Quartz and quartz-carbonate gangue minerals range from fine to coarse grained, commonly with white 'bull quartz" present.

ORE MINERALOGY [Principal and *subordinate*]: Stibnite, pyrite, arsenopyrite; *sphalerite, galena, tetrahedrite, marcasite, chalcopyrite, jamesonite, berthierite, gold, cinnabar, scheelite, argentite and sulphosalt minerals. Other than stibnite, the overall sulphide content of the veins is low.*

GANGUE MINERALOGY [Principal and *subordinate*]: Quartz, calcite, dolomite; *chalcedony, siderite, rare barite and fluorite.*

ALTERATION MINERALOGY: Quartz-carbonate envelopes on veins; some silicification, sericite, and intermediate argillic alteration. Chlorite, serpentinization and 'listwanite' (quartz-carbonate-talc-chromian mica-sulphide minerals) green-coloured alteration may be present when mafic and untramafic rocks are involved.

WEATHERING: Stibnite weathers to various oxides of yellowish (kermsite) or whitish (cerrantite or stibiconite) colour.

STIBNITE VEINS and DISSEMINATIONS I09

ORE CONTROLS: Fissure, shear zones and breccia associated with faults. Some open-space filling in porous rocks and structurally induced openings (joints, saddle reefs, ladder veins). Minor replacement in limestones.

GENETIC MODEL: The origin is not well documented. Deposits are spatially closely associated with, and in many ways resemble, low-sulphide gold-quartz (mesothermal) veins. Their (mutual) origin is thought to be from dilute, CO_2 rich fluids generated by metamorphic dehydration. Structural channelways focus the hydrothermal fluids during regional deformation. Some deposits are associated with felsic intrusive bodies, for example a Tertiary rhyolite plug at Becker-Cochran deposit, Yukon, and with porphyry W-Mo mineralization in granitic rocks at the Lake George Sb deposit, New Brunswick.

ASSOCIATED DEPOSIT TYPES: Quartz-carbonate gold (low-sulphide gold-quartz vein or I01), polymetallic vein Ag-Pb-Zn (I05), epithermal Au-Ag: low sulphidation (H05), hotspring Au-Ag (H03), Sn-W vein (??), W-Mo porphyry (L07); silica-carbonate Hg (I08), placer gold (C01, C02); possibly Carlin-type sediment-hosted Ag-Ag (E03).

COMMENTS: Occurrences of typical stibnite veins in the Bridge River gold camp in British Columbia were thought to be part of a regional deposit zoning pattern. The deposits are now known to be younger than the gold deposits by about 15-20 Ma. Farther north, the Snowbird deposit near Stuart Lake, has been shown to be Middle Jurassic in age by radiometric dating and is interpreted to be related to large-scale crustal structures. This deformation possibly involves the Pinchi fault system in which the largest known mercury deposits in the province are found.

EXPLORATION GUIDES

GEOCHEMICAL SIGNATURE: Sb, As, Au, Ag, Pb, Zn; locally W or Hg.

GEOPHYSICAL SIGNATURE: VLF surveys may detect faults.

ECONOMIC FACTORS

TYPICAL GRADE AND TONNAGE: Veins typically have high grade but small ore shoots; the disseminated deposits are also relatively small. Grade-tonnage data from 81 "typical" vein deposits (predominately, hand-sorted ore from USA mines) is 180 t with 35 % Sb; 10 % of the deposits contained > 1 g/t Au and > 16 g/t Ag. The disseminated deposits average 88 000 t with an average grade of 3.6 % Sb.

ECONOMIC LIMITATIONS: Antimony is a low-priced metal so only high-grade deposits are mined. Deposits (veins and disseminations) containing gold offer the best potential.

IMPORTANCE: Bolivia, Turkey and China dominate the antimony market; Cordilleran production will likely be only as a byproduct from precious metal bearing deposits.

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VEIN BARITE I10

by Z.D. Hora

IDENTIFICATION

SYNONYM: Epigenetic vein barite.

COMMODITIES (BYPRODUCTS): Barite (*Ag, Pb, Zn, Cu*).

EXAMPLES (British Columbia (MINFILE #) - Canada/International): Parson (082N002), Brisco (082KNE013), Fireside (094M003); *Matchewan (Ontario, Canada), Lake Ainslie (Nova Scotia, Canada), Collier Cove (Newfoundland, Canada), Nevada, Montana, Virginia, Pennsylvania, Georgia in USA; Bonarta, Jbel Ighoud (Morocco); Wolfach, Bad Lauterberg (Germany); Roznava (Slovakia), China.*

GEOLOGICAL CHARACTERISTICS

CAPSULE DESCRIPTION: Barite in fissure-filling voids resulting from mechanical deformation, including dilatant zones along faults and folds, gash fractures, joints and bedding planes; also in shear and breccia zones along faults.

TECTONIC SETTINGS: Highly varied, frequently but not exclusively at or near the margins of basins with sedex or Kuroko type deposits, or abrupt deep basin-platform sedimentation facies change.

DEPOSITIONAL ENVIRONMENT / GEOLOGICAL SETTING: Highly varied; almost any type of sedimentary, metamorphic or intrusive rocks. Veins associated with regional faults and lineaments, also the breccia zones along the margins of rift basins. In carbonate rocks, barite may fill karst cavities and collapse structures and forms manto-like replacement orebodies.

AGE OF MINERALIZATION: Precambrian to Tertiary.

HOST/ASSOCIATED ROCK TYPES: Any sedimentary, metamorphic or even igneous rocks.

DEPOSIT FORM: Tabular/lenticular bodies and breccias, collapse breccias and related cavity fills, veins with manto-type orebodies in carbonate hostrocks. The veins are several hundreds up to over 1000 m in length and sometimes up to 20 m thick. Some veins are mined to the depth of 500 m from surface.

TEXTURE/STRUCTURE: Massive, banded, brecciated. Texture typical of high-level veins, occasional druzy textures.

ORE MINERALOGY [Principal and *subordinate*]: Barite, *fluorspar, siderite, Pb-Zn-Cu sulphides.*

GANGUE MINERALOGY: (Principal and *subordinate*): *Quartz, calcite, siderite, witherite, barytocalcite, cinnabar, pyrite.*

ALTERATION MINERALOGY: Insignificant.

WEATHERING: Barite float and detrital fragments as a result of physical weathering.

ORE CONTROLS: Dominant structural control with veins along faults, fractures, and shear zones, sometimes related to dilatant zones in major fault systems.

VEIN BARITE I10

GENETIC MODEL: Epithermal barite veins, with or without sulphides, are common at and near the margins of rift basins, both in continental and continental margin settings. The veins and orebodies occur as open-space fillings in high-angle faults or fractures in sedimentary rocks or adjacent crystalline rocks, sills, and irregular and stratabound collapse structures or mantos. The source fluids are inferred to have been brines of moderate salinity (10 to 16 equivalent weight percent NaCl) and temperatures of 100° to 250° C. Pre-existing fractures and faults are apparently important in localizing the veins and orebodies. Multiple mineralizing episodes and several pulses of fluid migration are evident in many of the vein systems.

ASSOCIATED DEPOSIT TYPES: Polymetallic veins (I05) and replacement deposits (J01, E10-E12), sedex (E14) and Kuroko massive sulphide (G06) deposits, carbonatites (N03).

COMMENTS: This type of barite vein is distinct from barite associated with fluorspar veins. These (fluorspar-barite) veins may have, at least in part, a different barium source and are closely associated with Mississippi Valley type deposits.

EXPLORATION GUIDES

GEOCHEMICAL SIGNATURE: Ba, Sr, sometimes Hg, Ag, Pb, Zn and Cu anomalies in soils and silts.

GEOPHYSICAL SIGNATURE: Linear gravity highs over large veins.

OTHER EXPLORATION GUIDES: Clastic barite in stream sediments, both in sand and silt fractions.

ECONOMIC FACTORS

TYPICAL GRADE AND TONNAGE: Most deposits in production are selectively mining high-grade orebodies with over 80% barite. The deposit size varies from a few thousand up to some 3 Mt. Brisco mine produced approximately 250,000 tonnes during its life; Parson is expected to produce close to 1 Mt.

ECONOMIC LIMITATIONS: Dependant on the end use. White, high-purity barite is suitable for filler and chemical applications and can be mined from even very small deposits. Drilling mud is a lower priced grade and, if processing is required to reach the required 4.2 specific gravity, only large deposits can be operated successfully. Even a small amount of contamination by siderite or witherite may make the barite unusable in drilling mud applications. Barite which is contaminated with small quantities (ppm) of heavy metals like Pb, Zn, Cu and Hg may result in environmental problems with disposal of spent drilling mud.

END USES: Drilling muds, fillers, chemicals, radiation shields, speciality glass and ceramics.

IMPORTANCE: Probably the main source of barite worldwide, but in North America very subordinate to bedded barite deposits.

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VEIN FLUORITE-BARITE I11

by Z.D. Hora

IDENTIFICATION

SYNONYM: Epigenetic fluorite/barite vein.

COMMODITIES (BYPRODUCTS): Fluorite, sometimes barite (occasionally Pb, Zn, and Cu. Some fluorites contain the recoverable Be minerals bertrandite and phenacite.

EXAMPLES (British Columbia (MINFILE #) - *Canada/International*): Rock Candy (082ESE070), Eaglet (093A046), Rexspar (82M007); *Madoc (Ontario, Canada); St. Lawrence (Newfoundland, Canada); Nevada, Utah, New Mexico (USA); Nabburg-Woelsendorf, Ilmenau, Schoenbrunn (Germany); Torgola, Prestavel, Gerrai (Italy); Auvergne, Morvan (France); Mongolia, China.*

GEOLOGICAL CHARACTERISTICS

CAPSULE DESCRIPTION: Fluorite and barite fill dilatant shear and breccia zones along faults and folds, gash fractures, joints and bedding planes as well as stockworks. In carbonate rocks, the fissure veins are frequently associated with replacement bodies and mantos. Fluorite veins commonly show affinities with barite veins and may grade into polymetallic veins with barite gangue.

TECTONIC SETTINGS: Highly varied - but in terrains underlain by sialic crust. In young orogenic belts: postorogenic and lateorogenic granite intrusions or rift-related alkaline rocks (from syenites to nepheline syenites to carbonatites) may be associated with fluorite veins. In old orogenic belts: proximity of major tectonic zones, grabens, tensional rifts and lineaments.

DEPOSITIONAL ENVIRONMENT / GEOLOGICAL SETTING: Highly varied, sometimes linked to volatile-rich intrusives of alkaline to granite composition. In the Cordillera, topaz rhyolites, particularly, are associated with many fluorite veins.

AGE OF MINERALIZATION: Precambrian to Tertiary; in B.C. Devono-Mississippian (Rexspar), Cretaceous (Eaglet) and Tertiary (Rock Candy).

HOST/ASSOCIATED ROCK TYPES: Any sedimentary, metamorphic or igneous rock; in volcanic environment usually associated with topaz rhyolite.

DEPOSIT FORM: Tabular or lenticular bodies and breccias or stockworks and breccia pipes. The veins are usually 1-5 m thick and may be over a 1000 m long. Some particularly large veins in Sardinia are 3 km in length; the Torgola vein is reported to be 20 m thick. Some vein deposits were mined up to 500 m below surface, however the usual mining depth is 200 to 300 m down the dip from the outcrop.

TEXTURE/STRUCTURE: Massive, banded, brecciated. Drusy textures are common, fluorspar may be coarse grained or fine grained with radiating texture. Banding of different colour varieties of fluorspar is very common (coontail type). Bands of barite in fluorite, or young silica replacement of fluorspar along the cleavage and crystal borders are common features.

ORE MINERALOGY [Principal and *subordinate*]: Fluorite, barite, *celestite, barytocalcite, galena, sphalerite, chalcopyrite, pyrite, adularia or K-feldspar, red jasper. Dark purple fluorite may contain uraninite. Bertrandite and other Be minerals are sometimes accessory components.* Fluorite is often the main or even only vein mineral.

GANGUE MINERALOGY: (Principal and *subordinate)* Gangue may be a variety of minerals such as quartz, chalcedony, jasper, barite and Ca-Fe-Mg carbonates. Barite commonly varies in colour from yellow to pink or red; jasper may have a red colour due to finely dispersed haematite.

VEIN FLUORITE-BARITE I11

ALTERATION MINERALOGY: Kaolinization and/or silicification of wallrocks, sometimes pervasive potassic alteration (Eaglet, Rexspar); occasionally montmorillonite in wallrocks.

WEATHERING: Physical weathering mostly; in high-sulphide environment fluorspar may be dissolved by sulphuric acid. Floats of vein quartz with voids after weathered out fluorspar crystals are a common feature.

ORE CONTROLS: Faults, fractures, shear zones. Vertical zoning of veins is a common feature, but not very well understood.

GENETIC MODEL: Fluorite veins are generally found in the proximity of continental rifts and lineaments. In young orogenic belts fluorite can be linked to late or postorogenic granitic intrusions, particularly in areas of sialic crust. Rift-related alkaline intrusions are also linked to some fluorite veins. In old orogenic belts, fluorite veins are also in fracture zones within major faults and graben structures which facilitated circulation of mineralized fluids far from original fluorine source. Fluorite is precipitated from fluids by cooling low-pH solutions or by an increase in the pH of acid ore fluids. The fluids usually have a high Na/K ratio.

ASSOCIATED DEPOSIT TYPES: Pb-Zn veins (I05), carbonatite plugs, dikes and sills with Nb-REE (N02); Sn-W greisen (I13), F/Be deposits (Spor Mountain), Pb-Zn mantos (J01) and Mississippi Valley type deposits (E10, E11, E12).

COMMENT: End uses of fluorine chemicals in aluminium and chemical industries are very sensitive to P and As contents of only a few ppm.

EXPLORATION GUIDES

GEOCHEMICAL SIGNATURE: F in stream waters.

GEOPHYSICAL SIGNATURE: Sometimes gamma radiometric anomalies as an expression of potassic alteration or uranium content in certain types of fluorite.

OTHER EXPLORATION GUIDES: Fault control in some districts; regional silicified zones and major quartz veins.

ECONOMIC FACTORS

TYPICAL GRADE AND TONNAGE: Past producers reported grades in general between 30% and 60% fluorite, with occasional higher grade orebodies. The deposit size varies; up to 6 Mt. In B.C., Eaglet reported 1.8 million tonnes of 15% CaF_2, Rexspar 1.4 million tonnes of 23% CaF_2.

ECONOMIC LIMITATIONS: In recent years, shipments of high quality fluorspar from China, at very low prices, resulted in the collapse of most fluorspar production centres worldwide.

END USES: Metallurgy of aluminum and uranium, fluorine chemicals, flux in iron and steel metallurgy, glass and ceramics.

IMPORTANCE: Main source of fluorspar worldwide. In B.C., the Rock Candy mine produced 51,495 t of 68% CaF_2 between 1918 and 1929.

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FIVE-ELEMENT VEINS Ag-Ni-Co-As±(Bi,U) I14

by David V. Lefebure

IDENTIFICATION

SYNONYMS: Five-element (Ni-Co-As-Ag-Bi) veins, nickel-cobalt-native silver veins, Cobalt-type silver-sulpharsenide veins, Ni-Co-Bi-Ag-U (As) association, Ag-As (Ni,Co,Bi) veins, Schneeberg-Joachimsthal-type.

COMMODITY (*BYPRODUCTS*): Ag, U, Ni, Co, Bi (barite).

EXAMPLES (British Columbia - *Canada/International*): No B.C. examples; *Beaver and Timiskaming, Cobalt camp, Silver Islet, Thunder Bay district (Ontario, Canada), Echo Bay and Eldorado (Port Radium, Northwest Territories, Canada), Black Hawk district (New Mexico, USA), Batopilas district (Mexico), Johanngeogenstadt, Freiberg and Jachymov, Erzgebirge district (Germany), Konsberg-Modum (Norway).*

GEOLOGICAL CHARACTERISTICS

CAPSULE DESCRIPTION: Native silver occurs in carbonate veins associated with a variety of mineral assemblages that are rare in other settings, such as Ni-Co-Fe arsenides, Ni-Co-Fe-Sb sulpharsenides and bismuth minerals. In many cases only some of these minerals are present, although the best examples of this deposit type typically contain significant Ag-Ni-Co. In some deposits uraninite (pitchblende) is an important ore mineral.

TECTONIC SETTINGS: Virtually all occur in areas underlain by continental crust and are generally believed to have formed late or post-tectonically. In some cases the veins appear related to basinal subsidence and continental rifting.

DEPOSTIONAL ENVIRONMENT/GEOLOGICAL SETTING: Veins are believed to be emplaced at shallow depths in a continental setting along high-angle fault systems.

AGE OF MINERALIZATION: Proterozoic or younger, can be much younger than hostrocks.

HOST/ASSOCIATED ROCK TYPES: Found in a wide variety of hostrocks, although metasediments, metamorphosed intrusive rocks and granitic sequences are the most common. Diabase sills are an important host in the Cobalt camp and a number of the deposits in the Thunder Bay region are within a gabbro dike.

DEPOSIT FORM: Simple veins and vein sets. Veins vary from centimetre to metre thicknesses, typically changing over distances of less than tens of metres. Most vein systems appear to have limited depth extent, although some extend more than 500 m.

TEXTURE/STRUCTURE: Commonly open space filling with mineral assemblages and textures commonly due to multiple episodes of deposition. Sulphides are irregularly distributed as massive pods, bands, dendrites, plates and disseminations. The mineralization is more common near the interesections of veins or veins with crosscutting faults. Fragments of wallrock are common in some veins. Faults may be filled with graphite-rich gangue, mylonite or breccia.

FIVE-ELEMENT VEINS Ag-Ni-Co-As±(Bi,U) I14

ORE MINERALOGY (Principal and *subordinate*): Native silver associated with Ni-Co arsenide minerals (rammelsbergite, safflorite, niccolite, cloanthite, maucherite), sulpharsenides of Co, Ni, Fe and Sb, native bismuth, bismuthinite, argentite, ruby silver, pyrite and uraninite (pitchblende). *Chalcopyrite, bornite and chalcocite are common, but minor, constituents of ore. Minor to trace galena, tetrahedrite, jamesonite, cosalite, sphalerite, arsenopyrite and rare pyrrhotite.* In many deposits only a partial mineral assemblage occurs containing a subset of the many elements which may occur in these veins. These veins are characterized by the absence of gold.

GANGUE MINERALOGY (Principal and *subordinate*): Calcite and dolomite are usually associated directly with native silver mineralization; quartz, *jasper, barite and fluorite are less common.* The carbonate minerals are common in the cores of some veins.

ALTERATION MINERALOGY: Not conspicuous or well documented. In the Cobalt camp calcite and chlorite alteration extends 2-5 cm from the vein, approximately equivalent in width to the vein.

WEATHERING: No obvious gossans because of the low sulphide content; locally "cobalt bloom".

ORE CONTROLS: Veins occupy faults which often trend in only one or two directions in a particular district. Ore shoots may be localized at dilational bends within veins. Intersections of veins are an important locus for ore. Possibly five-element veins are more common in Proterozoic rocks.

GENETIC MODEL: In regions of crustal extension, faults controled the ascent of hydrothermal fluids to suitable sites for deposition of metals at depths of approximately 1 to 4 km below surface. The fluids were strongly saline brines at temperatures of 150° to 250°C, which may have been derived from late-stage differentiation of magmas, convective circulation of water from the country rocks driven by cooling intrusive phases or formation brines migrating upwards or towards the edge of sedimentary basins. Sulphide-rich strata (including Fahlbands) and carbonaceous shales in the stratigraphy are potential sources of the metals. Deposition occurs where the fluid encounters a reductant or structural trap.

ASSOCIATED DEPOSIT TYPES: 'Classical' U veins (I15), polymetallic veins (I05). In the Great Bear Lake area there are associated "giant" quartz veins with virtually no other minerals.

COMMENTS: Several Co-Ag±Ni±Bi veins are found in the Rossland Camp in British Columbia. These may be five-element veins, however, they also contain the atypical elements Au and Mo.

EXPLORATION GUIDES

GEOCHEMICAL SIGNATURE: The rare association of anomalous values of Ag with Ni, Co, Bi, U and As in rock samples is diagnostic.

GEOPHYSICAL SIGNATURE: Associated structures may be defined by ground magnetic or VLF-EM surveys. Airborne surveys may identify prospective major structures. Gamma ray scintillometers and spectrometers can be used to detect the uraninite-bearing veins in outcrop or in float trains in glacial till, frost boils, talus or other debris.

OTHER EXPLORATION GUIDES: Commonly camp or regional structural controls will define a dominant orientation for veins.

ECONOMIC FACTORS

GRADE AND TONNAGE: Typically range from tens of thousands of tonnes to a few hundreds of thousands of tonnes with very high grades of silver (more than 1000 g/t Ag for Canadian mines, with grades up to 30 000 g/t Ag).

IMPORTANCE: There has been no significant production from a native silver vein in British Columbia, however, these veins have historically been an important Canadian and world source of Ag and U with minor production of Co. More recently the narrow widths and discontinuous nature of these veins has led to the closure of virtually all mines of this type.

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"CLASSICAL" U VEINS — I15

by R.H. McMillan[1]

IDENTIFICATION

SYNONYMS: Pitchblende veins, vein uranium, intragranitic veins, perigranitic veins.

COMMODITIES (*BYPRODUCTS*): U (Bi, Co, Ni, As, Ag, Cu, Mo).

EXAMPLES (British Columbia - *Canada/International*): In the Atlin area structurally controlled scheelite-bearing veins host uranium at the Purple Rose, Fisher, Dixie, Cy 4, Mir 3 and IRA occurrences; *Ace Fay-Verna and Gunnar, Beaverlodge area (Saskatchewan, Canada), Christopher Island-Kazan-Angikuni district, Baker Lake area (Northwest Territories, Canada), Millet Brook (Nova Scotia, Canada), Schwartzwalder (Colorado, USA), Xiazhuang district (China), La Crouzille area, Massif Central and Vendee district, Armorican Massif, (France), Jachymov and Pribram districts (Czeck Republic), Shinkolobwe (Shaba province, Zaire).*

GEOLOGICAL CHARACTERISTICS

CAPSULE DESCRIPTION: Pitchblende (Th-poor uraninite), coffinite or brannerite with only minor amounts of associated metallic minerals in a carbonate and quartz gangue in veins. These deposits show affinities with, and can grade into, five-element veins which have significant native silver, Co-Ni arsenides, Bi or other metallic minerals.

TECTONIC SETTING: Postorogenic continental environments, commonly associated with calcalkaline felsic plutonic and volcanic rocks. "Red beds" and sediments of extensional successor basins are common in the host sequence. The economic deposits appear confined to areas underlain by Proterozoic basement rocks.

DEPOSITIONAL ENVIRONMENT: Ore is deposited in open spaces within fracture zones, breccias and stockworks commonly associated with major or subsidiary, steeply dipping fault systems.

AGE OF MINERALIZATION: Proterozoic to Tertiary. None are older than approximately 2.2 Ga, the time when the atmosphere evolved to the current oxygen-rich condition.

HOST/ ASSOCIATED ROCK TYPES: A wide variety of hostrocks, including granitic rocks, commonly peraluminous two-mica granites and syenites, felsic volcanic rocks, and older sedimentary and metamorphic rocks. The uranium-rich veins tend to have an affinity to felsic igneous rocks. Some veins are closely associated with diabase and lamprophyre dikes and sills.

DEPOSIT FORM: Orebodies may be tabular or prismatic in shape generally ranging from centimetres up to a few metres thick and rarely up to about 15 m. Many deposits have a limited depth potential of a few hundred metres, however, some deposits extend from 700 m up to 2 km down dip. Disseminated mineralization is present within the alteration envelopes in some deposits.

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"CLASSICAL" U VEINS I15

TEXTURE/STRUCTURE: Features such as drusy textures, crustification banding, colloform, botryoidal and dendritic textures are common in deposits which have not undergone deformation and shearing. The veins typically fill subsidiary dilatant zones associated with major faults and shear zones. Mylonites are closely associated with the St. Louis fault zone at the Ace-Fay-Verna mines.

ORE MINERALOGY (Principal and *subordinate*): Pitchblende (Th-poor uraninite), coffinite, *uranophane, thucolite, brannerite, iron sulphides, native silver, Co-Ni arsenides and sulpharsenides, selenides, tellurides, vanadinites, jordesite, chalcopyrite, galena, sphalerite, native gold and platinum group elements.* Some deposits have a "simple" mineralogy of with only pitchblende and coffinite. Those veins with the more complex mineralogy are often interpreted to have had the other minerals formed at an earlier or later stage.

GANGUE MINERALOGY (Principal and *subordinate*): Carbonates (calcite and dolomite), quartz (often chalcedonic), hematite, *K-feldspar, albite, muscovite, fluorite, barite.*

ALTERATION: Chloritization, hematization, feldspathization. A few of the intrusive-hosted deposits are surrounded by desilicated, porous feldspar-mica rock called "episyenite" in the La Crouzille area of France and "sponge-rock" at the Gunnar mine in Saskatchewan. In most cases the hematization is due to oxidation of ferrous iron bearing minerals in the wallrocks during mineralization. The intense brick-red hematite adjacent to some high-grade uranium ores is probably due to loss of electrons during radioactive disintegration of uranium and its daughter products.

WEATHERING: Uranium is highly soluble in the +6 valence state above the water table. It will re-precipitate as uraninite and coffinite below the water table in the +4 valence state in the presence of reducing agents such as humic material or carbonaceous "trash". Some uranium phosphates, vanadinites, sulphates, silicates and arsenates are semi-stable under oxidizing conditions, consequently autunite, torbernite, carnotite, zippeite, uranophane, uranospinite and numerous other secondary minerals may be found in the zone of oxidation , particularly in arid environments.

ORE CONTROLS: Pronounced structural control related to dilatant zones in major fault systems and shear zones. A redox control related to the loss of electrons associated with hematitic alteration and precipitation of uranium is evident but not completely understood. Many deposits are associated with continental unconformities and have affinities with unconformity-associated U deposits (I16).

GENETIC MODEL: Vein U deposits are generally found in areas of high uranium Clarke, and generally there are other types of uranium deposits in the vicinity. The veins might be best considered polygenetic. The U appears to be derived from late magmatic differentiates of granites and alkaline rocks with high K or Na contents. Uranium is then separated from (or enriched within) the parent rocks by aqueous solutions which may originate either as low-temperature hydrothermal, connate or meteoric fluids. Current opinion is divided on the source of the fluids and some authors prefer models that incorporate mixing fluids. Studies of carbon and oxygen isotopes indicate that the mineralizing solutions in many cases are hydrothermal fluids which have mixed with meteoric water. In some cases temperatures exceeding 400 °C were attained during mineralization. The uranium minerals are precipitated within faults at some distance from the source of the fluids. Wallrocks containing carbonaceous material, sulphide and ferromagnesian minerals are favourable loci for precipitation of ore. Radiometric age dating indicates that mineralization is generally significantly younger than the associated felsic igneous rocks, but commonly close to the age of associated diabase or lamprophyre dikes.

ASSOCIATED DEPOSIT TYPES: Stratabound, disseminated and pegmatitic occurrences of U are commonly found in older metamorphic rocks. Sandstone-hosted U deposits (D05) are commonly found in associated red-bed supracrustal strata, and surficial deposits (B08) in arid or semi-arid environments.

COMMENTS: The Cretaceous to Tertiary Surprise Lake batholith in the Atlin area hosts several fracture-controlled veins with zeunerite, kasolite, autunite and Cu, Ag, W, Pb and Zn minerals. These include the Purple Rose, Fisher, Dixie, Cy 4, Mir 3 and IRA. Southwest of Hazelton, Th-poor uraninite associated with Au, Ag, Co-Ni sulpharsenides, Mo and W is found in high-temperature quartz veins within the Cretaceous Rocher Déboulé granodiorite stock at the Red Rose, Victoria and Rocher Deboule properties. Although the veins are past producers of Au, Ag, Cu and W, no U has been produced.

EXPLORATION GUIDES

GEOCHEMICAL SIGNATURE: Uranium and sometimes any, or all, of Ni, Co, Cu, Mo, Bi, As and Ag are good pathfinder elements which can be utilized in standard stream silt, lake bottom sediment and soil surveys. Stream and lake bottom water samples can be analyzed for U and Ra. In addition, the inert gases He and Ra can often be detected above a U-rich source in soil and soil gas surveys, as well as in groundwater and springs.

GEOPHYSICAL SIGNATURE: Standard prospecting techniques using sensitive gamma ray scintillometers and spectrometers to detect U mineralization in place or in float trains in glacial till, frost boils, talus or other debris remains the most effective prospecting methods. Because most deposits do not contain more than a few percent metallic minerals, electromagnetic and induced polarization surveys are not likely to provide direct guides to ore. VLF-EM surveys are useful to map the fault zones which are hosts to the veins. Magnetic surveys may be useful to detect areas of magnetite destruction in hematite-altered wallrocks.

OTHER EXPLORATION GUIDES: Secondary uranium minerals are typically yellow and are useful surface indicators.

ECONOMIC FACTORS

TYPICAL GRADE AND TONNAGE: Individual deposits are generally small (< 100 000 t) with grades of 0.15% to 0.25% U, however districts containing several deposits can aggregate considerable tonnages. The large Ace-Fay-Verna system produced 9 Mt of ore at an average grade of 0.21% U from numerous orebodies over a length of 4.5 km. and a depth of 1500 m. Gunnar produced 5 Mt of ore grading 0.15% U from a single orebody. The Schwartzwalder mine in Colorado was the largest “hardrock” uranium mine in the United States, producing approximately 4 300 tonnes U, and contains unmined reserves of approximately the same amount.

ECONOMIC LIMITATIONS: The generally narrow mining widths and grades of 0.15% to 0.25% U rendered most vein deposits uneconomic after the late 1960s discovery of the high-grade unconformity-type deposits.

"CLASSICAL" U VEINS I15

IMPORTANCE: This type of deposit was the source of most of the world's uranium until the 1950s. By 1988, significant production from veins was restricted to France, with production of 3 372 tonnes U or 9.2% of the world production for that year.

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CRYPTOCRYSTALLINE ULTRAMAFIC-HOSTED MAGNESITE VEINS[1] — I17

by S. Paradis[2] and G.J. Simandl

IDENTIFICATION

SYNONYMS: Cryptocrystalline or microcrystalline magnesite, "Kraubath-type" magnesite, "Bone magnesite", "amorphous magnesite".

COMMODITY: Magnesite.

EXAMPLES (British Columbia (MINFILE #) - *Canada/International*): Sunny (092O014), Pinchi Lake (093K065); *Chalkidiky area (Greece); Kraubath (Austria); Eskisehir and Kutaya (Turkey).*

GEOLOGICAL CHARACTERISTICS

CAPSULE DESCRIPTION: Cryptocrystalline magnesite deposits are related to faults cutting ultramafic rocks. Individual deposits may consist of two styles of mineralization. Steeply dipping magnesite veins, up to several metres thick, pass gradually upward into magnesite stockworks or breccias cemented by magnesite.

TECTONIC SETTINGS: Typically in allochthonous serpentinized ophiolitic sequences or along structural breaks within ultramafic layered complexes; however, other settings containing ultramafic rocks are also favourable.

DEPOSITIONAL ENVIRONMENT / GEOLOGICAL SETTING: The veins are emplaced along steep faults in near surface environments.

AGE OF MINERALIZATION: Post-date ultramafic hostrock that is Archean to Paleogene in age.

HOST/ASSOCIATED ROCK TYPES: Serpentinite, peridotite; other olivine-rich rocks of the typical ophiolitic sequence and layered ultramafic complexes.

DEPOSIT FORM: Stockworks, branching veins, single veins up to several metres in thickness, and less frequently, irregular masses. The maximum reported vertical extent is 200 m. The footwall of the deposits is commonly sharp and slickensided and coincides with a fault zone. The hangingwall of the fault contains magnesite veins and/or magnesite-cemented breccias.

TEXTURE/STRUCTURE: Magnesite is commonly cryptocrystalline and massive with microscopic "pinolite" texture; rarely granular, fibrous, or "cauliflower-like".

ORE MINERALOGY: Magnesite.

GANGUE MINERALOGY [Principal and *subordinate*]: Serpentine, chlorite, talc, iron oxides, dolomite, hydromagnesite, calcite, sepiolite, quartz, opal, chalcedony and quartz in vugs.

ALTERATION MINERALOGY: Ultramafic rocks hosting magnesite are typically, but not always, intensely serpentinised. Alteration minerals are dolomite, quartz, montmorillonite, sepiolite, talc, goethite and deweylite.

WEATHERING: Varies with climatic environment, gangue mineralogy and iron content in the crystal structure of magnesite.

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[1] Geological Survey of Canada contribution number 45295

[2] Pacific Geoscience Centre, Geological Survey of Canada, Sidney

CRYPTOCRYSTALLINE ULTRAMAFIC-HOSTED MAGNESITE VEINS I17

ORE CONTROLS: Tectonic boundaries or major fault breaks, secondary fault zones parallel to major breaks cutting ultramafic rocks. The large magnesite-cemented breccias are commonly located below paleoerosional or erosional surfaces. Most contacts between the magnesite and country rock are sharp and irregular.

GENETIC MODEL: Two hypothesis competing to explain the origin of these deposits are:

1) hypogene low-temperature, CO_2-metasomatism of ultramafic rocks (Pohl, 1991):
2) low-temperature descending, meteoric waters containing biogenic CO_2 and enriched in Mg^{2+} (Zachmann and Johannes, 1989).

ASSOCIATED DEPOSIT TYPES: Lateritic deposits, chromite deposits and platinum deposits occur in the same geological environment but are not genetically related. The ultramafic-hosted talc deposits (M07) may be genetically related.

EXPLORATION GUIDES

GEOCHEMICAL SIGNATURE: May contain above average Hg.

GEOPHYSICAL SIGNATURE: N/A

OTHER EXPLORATION GUIDES: Favourable lithologic and structural setting. Commonly underlying unconformities. Near-surface (or paleosurface) magnesite deposits may be capped by stratiform magnesite, dolomite-quartz (chalcedony) or chert zones. Some of these deposits are overlain by laterites. Boulder tracing in glaciated areas.

ECONOMIC FACTORS

TYPICAL GRADE AND TONNAGE: For stockwork (upper) portions of the deposits the grades vary from 20 to 40% magnesite and reserves ranging from hundreds of thousands to several millions tonnes are typical. The deeper vein portions of these deposits have higher grades and may be almost monomineralic. A representative specimen of Greek cryptocrystalline magnesite is reported to contain 46.6 % MgO, 49.9 % CO_2, 0.70 % SiO_2, 1.35 % CaO, 0.85% Fe_2O_3 and Al_2O_3 combined (Harben and Bates, 1990).

ECONOMIC LIMITATIONS: These deposits compete for markets with sediment-hosted sparry magnesite deposits and seawater or brine-derived magnesia compounds. In the past, European refractory producers preferred cryptocrystalline magnesite over sparry magnesite, because of its higher density and lower iron, manganese and boron content. Recently this advantage was largely lost by availability of excellent quality sparry magnesite exports and by new technical developments in the refractory industry. Natural magnesite-derived compounds in general have to compete with seawater and brine-derived magnesia compounds.

END USES: Source of wide variety of magnesia products used mainly in refractories, cements, insulation, chemicals, fertilizers, fluxes and environmental applications.

IMPORTANCE: These deposits are substantially smaller and, in the case of stockwork-type portions, lower grade than sparry magnesite deposits.

COMMENTS: Stockworks and adjacent ultramafic hostrock are capped in some cases by sediments that may contain nodular magnesite concretions or magnesite/hydromagnesite layers and/or dolomite, quartz or chert. It is not well established if sediments are of sabkha /playa affinity or directly linked to fluids that formed stockworks and veins.

CRYPTOCRYSTALLINE ULTRAMAFIC-HOSTED MAGNESITE VEINS I17

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POLYMETALLIC MANTOS Ag-Pb-Zn[1] J01

by J.L. Nelson

IDENTIFICATION

SYNONYM: Polymetallic replacement deposits.

COMMODITIES (*BYPRODUCTS*): Ag, Pb, Zn (Au, Cu, Sn, Bi).

EXAMPLES (British Columbia (MINFILE #) - *Canada/International*): Midway (104O038) and Bluebell (082ENW026); *Sa Dena Hes (Yukon, Canada), Prairie Creek (Northwest Territories, Canada), Leadville District (Colorado, USA), East Tintic District (Utah, USA), Eureka District (Nevada, USA), Santa Eulalia, Naica, Fresnillo, Velardena, Providencia (Mexico).*

GEOLOGICAL CHARACTERISTICS

CAPSULE DESCRIPTION: Irregularly shaped, conformable to crosscutting bodies, such as massive lenses, pipes and veins, of sphalerite, galena, pyrite and other sulphides and sulphosalts in carbonate hosts; distal to skarns and to small, high-level felsic intrusions.

TECTONIC SETTING: Intrusions emplaced into miogeoclinal to platformal, continental settings.

DEPOSITIONAL ENVIRONMENT / GEOLOGICAL SETTING: In northern Mexico, most are hosted by Cretaceous limestones. In Colorado, the principal host is the Devonian-Mississippian Leadville limestone; in Utah, the Permian Torweap Formation hosts the Deer Trail deposit. The most favourable hosts in the Canadian Cordillera are massive Lower Cambian and Middle Devonian limestones, rather than impure carbonates and dolostone-quartzite units.

AGE OF MINERALIZATION: Canadian Cordilleran examples are Cretaceous to Eocene age; those in the southern Cordillera are typically Tertiary.

HOST/ASSOCIATED ROCK TYPES: Hosted by limestone and dolostone. The carbonates are typically within a thick sediment package with siliciclastic rocks that is cut by granite, quartz monzonite and other intermediate to felsic hypabyssal, porphyritic lithologies. There may be volcanic rocks in the sequence, or more commonly above, which are related to the intrusive rocks.

DEPOSIT FORM: Irregular: mantos (cloak shaped), lenses, pipes, chimneys, veins; in some deposits the chimneys and/or mantos are stacked.

TEXTURE/STRUCTURE: Massive to highly vuggy, porous ore. In some cases fragments of wallrock are incorporated into the ore. Some deposits have breccias: fragments of wallrock and also of sulphide ore within a sulphide matrix.

ORE MINERALOGY (Principal and *subordinate*): Sphalerite, galena, pyrite, chalcopyrite, marcasite; *arsenopyrite, pyrargyrite/proustite, enargite, tetrahedrite, geocronite, electrum, digenite, jamesonite, jordanite, bournonite, stephanite, polybasite, rhodochrosite, sylvanite, calaverite.* Chimneys may be more Zn-rich, Pb-poor than mantos.

GANGUE MINERALOGY (Principal and *subordinate*): Quartz, barite, gypsum; minor *calc-silicate minerals.*

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[1] Manto is a Spanish mining term denoting a blanket-shaped orebody which is widely used for replacement deposits found in Latin America. It has been used to describe the orientation of individual lenses and also to describe a class of orebodies.

POLYMETALLIC MANTOS Ag-Pb-Zn J01

ALTERATION MINERALOGY: Limestone wallrocks are commonly dolomitized and/or silicified, whereas shale and igneous rocks are argillized and chloritized. Jasperoid occurs in some U.S. examples.

WEATHERING: In some cases, a deep oxidation zone is developed. Mexican deposits have well developed oxide zones with cassiterite, hematite, Cu and Fe carbonates, cerusite and smithsonite.

ORE CONTROLS: The irregular shapes of these deposits and their occurrence in carbonate hosts emphasize the importance of ground preparation in controlling fluid channels and depositional sites. Controlling factors include faults, fault intersections, fractures, anticlinal culminations, bedding channelways (lithologic contrasts), karst features and pre-existing permeable zones. In several districts karst development associated with unconformities is believed to have led to development of open spaces subsequently filled by ore. Some deposits are spatially associated with dikes.

GENETIC MODEL: Manto deposits are high-temperature replacements as shown by fluid inclusion temperatures in excess of 300 °C, high contents of Ag, presence of Sn, W and complex sulphosalts, and association with skarns and small felsic intrusions. They are the product of pluton-driven hydrothermal solutions that followed a variety of permeable pathways, such as bedding, karst features and fracture zones.

ASSOCIATED DEPOSIT TYPES: There is probably an overall outward gradation from granite-hosted Mo-Cu porphyries (L04), endoskarns (K) and possibly W- and Sn mineralization (L06?), through exoskarns (K01, K02) and into Ag-Pb-Zn veins (I05), mantos (J01) and possibly Carlin-type sediment-hosted Au-Ag deposits (E03). Only some, or possibly one, of these types may be manifest in a given district. Ag-Pb-Zn vein, manto and skarn deposits belong to a continuum which includes many individual occurrences with mixed characteristics.

COMMENTS: In the Canadian Cordillera, most mantos are located in the miogeocline (western Ancestral North America, Cassiar and Kootenay terranes) because of the essential coincidence of abundant carbonate and presence of felsic intrusions. There is one known example in Upper Triassic limestone on Vancouver Island, which probably formed distal to skarn mineralization related to a mid-Jurassic intrusion. Most mantos in the Canadian Cordillera are Late Cretaceous to Eocene, coinciding with the age of youngest, F-rich intrusions of the A-type (anorogenic) granite suite. In Mexico, mantos are associated with Early to mid-Tertiary volcanic rocks and cogenetic intrusions. The Colorado deposits may be associated with Tertiary sills, and the Deer Trail deposit in Utah has given a 12 Ma sericite age.

EXPLORATION GUIDES

GEOCHEMICAL SIGNATURE: B.C.: Ag, Pb, Zn, Sn in stream silts, F in waters. U.S.: Districts show outward zoning from Cu-rich core through broad Ag-Pb zone to Zn-Mn fringe. Locally Au, As, Sb, Bi. Jasperoid contains elevated Ba + Ag.

GEOPHYSICAL SIGNATURE: Subsurface granite associated with Midway deposit has negative magnetic signature.

OTHER EXPLORATION GUIDES: Concentration of Ag-Pb-Zn vein deposits in or near carbonates.

POLYMETALLIC MANTOS Ag-Pb-Zn J01

ECONOMIC FACTORS

TYPICAL GRADE AND TONNAGE: Individual deposits average about a million tonnes grading tens to hundreds of grams/tonne Ag and approximately 5 to 20% combined Pb-Zn. Mexico: Santa Eulalia district produced about 24 Mt in this century, grading about 300 g/t Ag, 8% Pb, 9% Zn. U.S.: Leadville deposit mined 30 Mt 70-130 g/t Ag, 12-15% Pb-Zn. B.C.: Midway geological resource is 1 Mt grading 400 g/t Ag 7% Pb, 9.6% Zn. In many mining districts the early production came from oxidized ore zones that can have higher grades and be easier to mine.

ECONOMIC LIMITATIONS: Generally, although not always, these deposits tend to be small, highly irregular and discontinuous. The Mexican deposits have yielded large quantities of ore because, due to low labour costs, mining provided an effective and low-cost exploration tool.

IMPORTANCE: As sources of base metals, manto deposits are overshadowed on a world scale by the giant syngenetic classes such as sedimentary exhalitive and volcanogenic massive sulphides. However, because of their high precious metal contents; they provide exciting targets for small producers.

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MANTO AND STOCKWORK Sn[1] J02

by W. David Sinclair[2]

IDENTIFICATION

SYNONYMS: Replacement Sn, distal Sn skarn, Renison-type.

COMMODITIES (*BYPRODUCTS*): Sn (*Cu, Zn, Pb, Ag, Sb, Cd, Bi, In*).

EXAMPLES (British Columbia - *Canada/International*): *Renison Bell, Cleveland and Mt. Bischoff (Tasmania, Australia), Dachang and Gejiu districts (China).*

GEOLOGICAL CHARACTERISTICS

CAPSULE DESCRIPTION: Disseminated cassiterite occurs in massive sulphide replacement bodies in carbonate rocks and in associated veins, stockworks and breccias. Felsic intrusions are nearby, or adjacent to the deposits and may also be mineralized.

TECTONIC SETTING: Postorogenic underlain by cratonic crust containing carbonate rocks.

DEPOSITIONAL ENVIRONMENT / GEOLOGICAL SETTING: Carbonate rocks intruded by epizonal felsic intrusive rocks.

AGE OF MINERALIZATION: Mainly Paleozoic to Mesozoic, but other ages possible.

HOST/ASSOCIATED ROCK TYPES: Mainly limestone or dolomite; chert, pelitic and Fe-rich sediments, and volcanic rocks may also be present. Genetically-related granitic plutons and associated felsic dikes are typically F and/or B rich. They are commonly porphyritic.

DEPOSIT FORM: Variable: massive, lensoid to tabular, concordant sulphide-rich bodies in carbonate rocks; veins and irregular stockwork zones in associated rocks.

TEXTURE/STRUCTURE: Massive sulphide-rich bodies tend to follow bedding in host carbonate rocks; associated veins and stockworks include mineralized fractures, veinlets, quartz veins and breccias.

ORE MINERALOGY [Principal and *subordinate*]: Cassiterite, chalcopyrite, sphalerite and galena; *stannite, stibnite, bismuth, bismuthinite* and a wide variety of sulphosalt minerals including *jamesonite, bournonite, franckeite, boulangerite, geocronite, matildite and galenobismutite* may also be present.

GANGUE MINERALOGY [Principal and *subordinate*]: Pyrrhotite (often predominant sulphide) and/or pyrite, arsenopyrite, quartz, calcite, siderite, rhodochrosite, flourite and tourmaline.

ALTERATION MINERALOGY: Dolomite near massive sulphide bodies is typically altered to siderite, and, to a lesser extent, talc, phlogopite and quartz. Rocks hosting vein or stockwork zones may be tourmalinized. Greisen-type alteration, characterized by flourite and/or topaz, F-bearing micas and tourmaline, is best developed in and around genetically related felsic intrusive rocks.

WEATHERING: Oxidation of pyrite and pyrrhotite produces limonitic gossans. Deep weathering and erosion may result in residual concentrations of cassiterite *in situ* or in placer deposits downslope or downstream.

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[1] Geological Survey of Canada contribution number 16395
[2] Geological Survey of Canada, Ottawa

MANTO AND STOCKWORK Sn J02

ORE CONTROLS: Carbonate rocks in the vicinity of F and B rich felsic intrusive rocks; faults and fracture zones in the carbonates and associated rocks provide channelways and also alternate sites of deposition for ore-forming fluids.

GENETIC MODEL: Magmatic-hydrothermal. Magmatic, highly saline aqueous fluids strip Sn and other ore metals from temporally- and genetically related magma. Early Sn deposition is dominantly from these magmatic fluids, mainly in response to increase in pH due to carbonate replacement. Mixing of magmatic with meteoric water during waning stages of the magmatic-hydrothermal system may result in deposition of Sn and other metals in late-stage veins and stockworks.

ASSOCIATED DEPOSIT TYPES: Sn-W skarn deposits (K06, K05), Sn-W vein deposits, Sb-Hg veins, placer deposits (C01, C02).

EXPLORATION GUIDES

GEOCHEMICAL SIGNATURE: Sn, Cu, Pb, Zn, As, Ag, Sb, Hg, F, W, Bi and In may be anamalously high in hostrocks adjacent to and overlying mineralized zones; Sb and Hg anomalies may extend as much as several hundred metres. Sn, W, F, Cu, Pb and Zn may be anomalously high in stream sediments and Sn, W, and B (tourmaline) may be present in heavy mineral concentrates.

GEOPHYSICAL SIGNATURE: Massive pyrrhotite may be detected by magnetic surveys; massive sulphide zones may also be detected by electromagnetic and resistivity surveys.

OTHER EXPLORATION GUIDES: Deposits commonly occur in zoned, polymetallic districts; Sn and base metal bearing skarns and veins occur close to related intrusive rocks, carbonate-hosted Sn mantos and stockworks are at intermediate distances from the intrusive rocks, and Sb and Hg veins are the outermost deposits. Genetically related felsic intrusive rocks typically have high contents of silica (>74% SiO_2) and F (>0.1% F); tourmaline may also be present.

ECONOMIC FACTORS

TYPICAL GRADE AND TONNAGE: Deposits are large and high grade, containing millions to tens of millions of tonnes averaging about 1% Sn. The following figures are for production plus reserves:

Renison Bell (Australia): 27 Mt at 1.1% Sn (Newnham, 1988)
Cleveland (Australia): 5.3 Mt at 0.5% Sn, 0.2% Cu (Cox and Dronseika, 1988)
Mt. Bischoff (Australia): 6.1 Mt at 0.49% Sn (Newnham, 1988)
Dachang (China): 100 Mt at 1% Sn, 3-5% combined Cu, Pb, Zn and Sb (Fu *et al.*, 1993)
Gejiu (China): 100 Mt at 1% Sn, 2-5% Cu, 0.5% Pb (Sutphin *et al.*, 1990)

IMPORTANCE: The large tonnage and relatively high grade of these deposits makes them attractive for exploration and development.The Renison Bell deposit in Australia and the Dachang and Gejiu deposits in China are currently major producers of tin on a world scale.

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PODIFORM CHROMITE M03

by Chris Ash

IDENTIFICATION

SYNONYMS: Alpine type; ophiolite hosted chromite.

COMMODITIES (*BYPRODUCTS*): Chromite (may contain platinum group elements Os, Ir and Ru).

EXAMPLES (British Columbia (MINFILE #) - *Canada/International*): Castle Mountain Nickel (082ESE091) and Scottie Creek (092INW001); *Guleman ore field (Turkey); Kalimash - Kukes-Tropoje district, Bulquize and Todo Manco - Bater-Martanesh district (Mirdita ophiolite, Albania); Tiébaghi ophiolite and Massif du Sud (New Caledonia), Acoje and Masinloc-Coto (Zambales range/ophiolite, Luzon, Phillipines); Batamshinsk, Stepninsk, Tagashaisai and Main SE ore fields (Kempirsai massif, Southern Urals, Russia); Xeraivado and Skoumtsa mines (Vourinos ophiolite, Greece); Semail ophiolite (Oman); Luobusa, Donqiao, Sartohay, Yushi, Solun, Wudu and Hegenshan deposits (China) all > 1.5 Mt.*

GEOLOGICAL CHARACTERISTICS

CAPSULE DESCRIPTION: Deposits of massive chromitite occur as pods, lenses or layers within ophiolitic ultramafic rocks.

TECTONIC SETTING: Obducted fragments of oceanic, lower crustal and upper mantle ultramafic rocks within accreted oceanic terranes.

DEPOSITIONAL ENVIRONMENT / GEOLOGICAL SETTING: Formed as a primary magmatic differentiate during early olivine and chrome-spinel crystal fractionation of basaltic liquid at an oceanic spreading centre; (1) as massive to disseminated pods and lenses of chrome-spinel surrounded by a dunite envelope within depleted mantle harzburgite; or (2) as massive to disseminated cumulate layers in dunite at the base of the crustal plutonic section.

AGE OF MINERALIZATION: Mesozoic and younger.

HOST/ASSOCIATED ROCK TYPES: Variably serpentinized peridotite; residual mantle harzburgite; cumulate dunite.

DEPOSIT FORM: Podiform, tabular lenses, irregular masses, cumulate layers. Pods and lenses typically occur in clusters of variable size.

TEXTURE/STRUCTURE: Massive to disseminated, nodular (*syn*. leopard, grape, bean or shot ore), chromite net, occluded silicate, orbicular.

ORE MINERALOGY: Chromite.

GANGUE MINERALOGY [Principal and *subordinate*]: Variably serpentinized olivine and orthopyroxene, magnetite, *iddingsite*.

WEATHERING: Black, no noticeable affects resulting from surface oxidation.

ORE CONTROLS: Proximity to the crust-mantle transition zone. Restricted to dunite bodies in tectonized harzburgite below this transition, or lower dunitic portions of ultramafic cumulate section above it.

PODIFORM CHROMITE M03

GENETIC MODEL: Early fractional crystallization of chromite from a basaltic liquid either (1) just below the crust-mantle transition (syn. petrological MOHO) in small magma pockets or possibly conduits within the residual mantle harzburgite; or (2) immediately above the crust-mantle transition as cumulate layers within dunite at the base of the axial magma chamber. Pods and lenses in harzburgite obtain their diagonistic shape as a result subsolidus to hypersolidus ductile deformation due to mantle convection.

COMMENTS: Ophiolites of suprasubduction zone affinity with harzburgite mantle sections appear to be the only ophiolite type to host economic deposits of podiform chromite. A lack of any sizable chromite occurrence in British Columbia may reflect the fact that most ophiolitic complexes in the province are of mid-ocean ridge affinity. Occurrences of podiform chromite are found in ophiolitic ultramafic rocks in the Slide Mountain, Cache Creek and Bridge River terranes. Most of these known occurrences have been reviewed by Hancock (1990).

EXPLORATION GUIDES

GEOCHEMICAL SIGNATURE: Cr

GEOPHYSICAL SIGNATURE: Gravity anomaly.

OTHER EXPLORATION GUIDES: Found in rocks formed near or within the ophiolitic crust-mantle transition zone.

ECONOMIC FACTORS

TYPICAL GRADE AND TONNAGE: Grades range from 20 to 60% Cr_2O_3 and are a function of the texture of the chromite; *i.e.* amount of chromite relative to gangue serpentinite. Tonnages are variable, ranging from several thousand tonnes to several million tonnes.

ECONOMIC LIMITATIONS: The complex structure and irregular distribution make exploration and development difficult.

END USES: Chromium has a wide range of uses in the iron and steel industry which accounts for over 75% of its use. Chromite is also used in making refractory bricks for furnace linings.

IMPORTANCE: An important source of metallurgical-type chromite ores (45-60% Cr_2O_3: Cr/Fe = 2.8-4.3). Podiform chromite is the only source of refractory-type ore (min. 25% Al_2O_3: min. 60% $Cr_2O_3 + Al_2O_3$: max. 15% FeO). Historically podiform-type ore fields account for 57% of all chromite produced.

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ALASKAN-TYPE Pt±Os±Rh±Ir M05

by Graham T. Nixon

IDENTIFICATION

SYNONYMS: Zoned ultramafic, Uralian-type, Alaskan-type.

COMMODITIES (*BYPRODUCTS*): Pt (*Ir, Os, Rh, magnetite*).

EXAMPLES (British Columbia - *Canada/International*): Tulameen Complex and associated placers; magnetite plus trace platinum group elements (PGE) -Lodestone Mountain (092HSE034), Tanglewood Hill (092HSE035); chromite - Grasshopper Mountain (092HNE011); olivine - Grasshopper Mountain Olivine (092HNE1890); *Red Mountain, Goodnews Bay (Alaska, USA), Tin Cup Peak (Oregon, USA), Ural Mountains and Aldan Shield (Russia), Fifield district (NSW, Australia)*

GEOLOGICAL CHARACTERISTICS

CAPSULE DESCRIPTION: Ultramafic intrusive complexes, commonly zoned, forming sills, stocks or intrusive bodies with poorly known external geometry. Subeconomic platinum group elements in lode occurrences are associated with:

1) thin (centimetre-scale), disrupted chromitite layers,
2) thick (metre-scale) concentrations of cumulus magnetite or
3) clinopyroxenite.

Economic placer deposits appear to be derived predominantly from chromitite-hosted PGE occurrences.

TECTONIC SETTINGS: Traditionally subdivided into orogenic (unstable) and platformal (stable) environments. In British Columbia, Alaskan-type complexes were emplaced during an episode of Cordillera-wide, subduction-related arc magmatism followed by an episode of orogenic compression.

DEPOSITIONAL ENVIRONMENT / GEOLOGICAL SETTING: Zoned to crudely layered ultramafic-mafic intrusive complexes with rarely preserved (or poorly documented) metamorphic aureoles. Intrusive margins are commonly faulted. Traditionally viewed as deep-seated cumulates diapirically re-emplaced at high levels in the crust. In British Columbia, at least, most intrusions appear to represent cumulate deposition in upper crustal (subvolcanic?) magma chambers and the diapiric re-emplacement model lacks definitive supporting evidence.

AGE OF MINERALIZATION: Precambrian to late Mesozoic; most Alaskan-type complexes in British Columbia appear to be mid-Triassic to late Early Jurassic in age.

HOST/ASSOCIATED ROCK TYPES: Predominantly dunite, wehrlite, olivine clinopyroxenite, clinopyroxenite, hornblende clinopyroxenite, clinopyroxene hornblendite, hornblende- and/or clinopyroxene-bearing gabbro/diorite. Minor lithologies include chromitite, magnetitite, olivine-hornblende clinopyroxenite, and hornblendite. Associated feldspar-bearing lithologies include gabbro/diorite, monzonite, monzodiorite and minor alkali-feldspar syenite and hornblende-feldspar ± quartz ± biotite pegmatite.

DEPOSIT FORM: Lode occurrences of PGEs are primarily controlled by magmatic cumulate stratigraphy: 1) chromitites are restricted to dunites where they form thin discontinuous layers or schlieren, pods and nodular masses seldom more than a metre in length; 2) magnetitites and concentrations of cumulus magnetite form well bedded, locally continuous layers up to six m thick intercalated with hornblende clinopyroxenite; 3) lenses and vein-like bodies of relatively coarse-grained or "pegmatoid", biotite and magnetite-poor, PGE-bearing clinopyroxenites are enclosed by finer grained, biotite and magnetite-rich, PGE-poor clinopyroxenites.

ALASKAN-TYPE Pt±Os±Rh±Ir M05

TEXTURE/STRUCTURE: Cumulus and intercumulus textures are most common; poikilitic textures may predominate locally, especially in hornblende-bearing lithologies. Comparatively rare macroscopic layering. Euhedral to subhedral chromite concentrations form networks around olivine or discrete wispy or thin layers in dunite. Chromitites typically form schlieren and nodular masses due to syndepositional remobilization. Magnetite-rich accumulations usually form thin to thick bedded layers in hornblende clinopyroxenite. Tectonic deformation, commonly in the form of ductile shear fabrics, is locally superimposed on magmatic textures, and is especially prevalent at intrusive contacts.

ORE MINERALOGY (Principal and *subordinate*): Three types of PGE mineral (PGM) associations are recognized in lode occurrences: 1) chromitite-PGM association, principally chromite and Pt-Fe(-Cu-Ni) alloys (e.g. tetraferroplatinum, isoferroplatinum, rare *native platinum, tulameenite*) and minor *Os-Ir* and *Pt-Ir alloys, Rh-Ir sulpharsenides (hollingworthite-irarsite* series), *sperrylite* ($PtAs_2$), *geversite* ($PtSb_2$), and *laurite* (RuS_2); 2) magnetitite-PGM association (not well documented), principally magnetite (Ti-V-rich in certain cases) and Pt-Fe and Os-Ir alloys, and rare *cooperite* (PtS); 3) clinopyroxenite-PGM association (known from a single locality - Fifield, NSW, Australia), principally Pt-Fe alloys (isoferroplatinum-tetraferroplatinum), erlichmanite (OsS_2), cooperite, and sperrylite-geversite. Minor amounts of *base metal sulphides (chalcopyrite, pentlandite, pyrrhotite, pyrite, bornite, violarite, bravoite, millerite, heazlewoodite*) generally accompany the PGM in all three associations.

GANGUE MINERALOGY (Principal and *subordinate*): The principal gangue minerals include olivine, chrome spinel, clinopyroxene, and hornblende in ultramafic rocks; hornblende, clinopyroxene and plagioclase in gabbroic/dioritic rocks; and hornblende, quartz (rare) and alkali feldspar in leucocratic differentiates. Orthopyroxene is characteristically absent as a cumulus phase but may form very rare intercumulus grains. Accessory magnetite and apatite are generally common, and locally abundant in hornblende clinopyroxenite; sphene and zircon occur in felsic differentiates; phlogopite-biotite is particularly widespread as an accessory phase in British Columbia.

ALTERATION MINERALOGY: Secondary PGM are minor and closely associated with the primary PGM alloys. Remobilization of PGE is believed to be extremely limited and may be commonly related to postmagmatic serpentinizaton processes acting during regional metamorphism and deformation.

WEATHERING: It has been argued by some that the PGE found in placer occurrences may owe their origin to the hydromorphic dispersion and precipitation of PGE during normal weathering processes. The debate continues, but it is clear from a variety of textural, mineralogical and isotopic (Re-Os) data that the common placer PGE occurrences are the products of mechanical degradation of magmatic lode occurrences and not surficial remobilization processes.

ORE CONTROLS: The PGM appear to be restricted to chromitite, magnetite-rich or clinopyroxenite layers which formed by primary magmatic crystallization processes. The chromite is typically associated with dunite whereas the magnetite is found with clinopyroxenite.

GENETIC MODEL: The origin of the PGE in Alaskan-type deposits is magmatic with very limited low-temperature remobilization. A low sulphidation, relatively high oxidation magmatic environment (subduction-related?) appears to be an important genetic control. The chromitites in dunite and, to a much lesser extent, the magnetite-rich layers in clinopyroxenite, appear to be the ultimate source of the placer PGE.

ASSOCIATED DEPOSIT TYPES: Placer deposits (C01, C02) are extremely important since they have been the only significant economically recoverable source of PGE associated with Alaskan-type complexes. Some lode deposits have been worked in Russia but their documentation is extremely poor.

ALASKAN-TYPE Pt±Os±Rh±Ir M05

COMMENTS: All of the world's most important Alaskan-derived placers appear to be related to concentrations of PGE in chromitites. Gold in these placers appears to have been derived from a separate source. Magnetite accumulations in clinopyroxenites of the Tulameen Complex have been explored for magnetite.

EXPLORATION GUIDES

GEOCHEMICAL SIGNATURE: Primarily Pt, with subsidiary Os, Rh and Ir; other elements such as Cu, Ni, and Cr may be locally important. Geochemical pathfinder elements for PGE, such as As and Sb, may also be important.

GEOPHYSICAL SIGNATURE: Primarily magnetic; gravity may be important.

OTHER EXPLORATION GUIDES: Stream sediment sampling of heavy mineral concentrates for PGE is a key exploration tool; in favourable circumstances PGE geochemistry and platinum nugget mineralogy can uniquely distinguish an Alaskan-type heritage from all other common PGE environments.

ECONOMIC FACTORS

TYPICAL GRADE AND TONNAGE: PGE concentrations in grab samples from lode deposits are extremely spotty such that reliable tonnages and grades are not available. The associated placer deposits are likewise extremely variable. Maximum grade of Pt from the Goodnews Mining Company records, Alaska (1957) was approximately "$37 per cubic yard" at February 1993 prices. Placers in the Tulameen district reportedly yielded some 620 kg of impure platinum between 1889 and 1936. Some of the placer deposits in the former Soviet Union have yielded exceptional platinum nuggets of up to 11.3 kg.

ECONOMIC LIMITATIONS: The chromitite-PGE association appears to be the most important in British Columbia; without exception, all of these chromitite occurrences are small, dispersed throughout a dunite host, and all have been remobilized soon after deposition within the high-temperature magmatic environment. A small open pit operation appears to be the only potentially economic method of PGE extraction. The occurrence of the PGE as small micrometre-size inclusions in refractory chromite poses problems for processing.

END USES: PGE are primarily used as high-temperature catalysts in a variety of industries, perhaps the most familiar being platinum for automobile catalytic converters. Other uses include medical and electronic (fuel cells, thermocouples), and platinum is used in jewelry.

IMPORTANCE: PGE are classed as a strategic commodity. The most important producers are South Africa and Russia.

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ALASKAN-TYPE Pt±Os±Rh±Ir M05

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BROKEN HILL-TYPE Pb-Zn-Ag±Cu S01

By Trygve Höy

IDENTIFICATION

SYNONYMS: Shuswap-type, Ammeburg-type Zn-Pb, Jervois-type.

COMMODITIES (*BY-PRODUCTS*): Pb, Zn, Ag, *(Cu, Au, barite)*.

EXAMPLES (British Columbia (MINFILE #) - *Canada/International*): Cottonbelt (082M086), River Jordan (082M001), Ruddock Creek (082M082-084), Big Ledge? (082LSE012), Colby? (082ESW062); *Broken Hill and Pinnacles (New South Wales, Australia); Broken Hill and Black Mountain, Aggeneys district and Gammsberg area (South Africa), Knalla and Nygruvan, Bergslaggen district (Sweden).*

GEOLOGICAL CHARACTERISTICS

CAPSULE DESCRIPTION: Deposits comprise massive to semimassive galena, sphalerite, pyrrhotite and pyrite and/or magnetite layers or stacked lenses hosted by thin-bedded, commonly calcareous paragneiss successions. A complex gangue mineralogy includes a variety of calcsilicate minerals. These stratabound deposits are typically thin, but laterally extensive and were deformed and metamorphosed together with their hostrocks.

TECTONIC SETTING: In strongly deformed and metamorphosed supracrustal rocks commonly referred to as 'mobile belts' which probably originated in an intracratonic rift or possibly continental margin setting.

DEPOSITIONAL ENVIRONMENT/GEOLOGICAL SETTING: Marine sediments and associated minor bimodal (?) volcanics (often felsic, possibly alkalic) reflect active extensional tectonics. Host successions include inferred evaporites and are generally interpreted as shallow marine. Underlying gneissic successions suggest some deposits formed on or along margins of tectonic highs. However, intense deformation and metamorphism have commonly masked relationships.

AGE OF MINERALIZATION: Commonly Lower and Middle Proterozoic; some British Columbia deposits may be hosted by Late Proterozoic to Cambrian rocks.

HOST/ASSOCIATED ROCK TYPES: Hosted by thin-bedded calcareous schists, impure marble, quartzites and, less commonly, graphitic schists. A common and important host rock is garnet quartzite which occurs as envelopes to the sulphide bodies; associated with well layered and heterogenous successions of quartzite, crystalline marble, quartzo-feldspathic gneiss, hornblende gneiss, and abundant pelitic and calcareous schist and gneiss; locally associated carbonatite and amphibolite. Banded iron formations, chert, gahnite quartzites and tourmalinites are common in the host stratigraphic succession as distal facies or in the footwall successions. Scapolite-rich units and sulphur isotopes suggest associated evaporites. Metamorphic grades vary from amphibolite to granulite.

DEPOSIT FORM: Stacked sulphide or sulphide/magnetite lenses are common; they are thin, irregular, discontinuous, strongly deformed massive sulphide bodies. Thickening in fold hinges is often critical to make economic thicknesses. Individual lenses vary from less than a metre to tens of metres and may extend hundreds of metres often grading laterally into quartzite, quartz gahnite, garnet quartzite or pyrite/pyrrhotite disseminated units that may persist for tens of kilometres.

TEXTURE/STRUCTURE: Mineralization occurs as discontinuous massive to semimassive sulphide lenses or as disseminated stratabound sulphides. Sulphides are massive to irregular banded, with locally coarse "skarn" textures; locally well layered or laminated sulphides and silicates occur. They are commonly medium to coarse grained and intimately intergrown with gangue calcsilicate minerals, quartz or magnetite; as well, there are occasional thin monominerallic sulphide layers. Disseminated sulphides are common in granular marble. Pegmatitic zones are present in some ore zones.

BROKEN HILL-TYPE Pb-Zn-Ag±Cu S01

ORE MINERALOGY (Principal and *subordinate*): Galena, sphalerite, magnetite, pyrrhotite, pyrite; *chalcopyrite, tetrahedrite, molybdenite, arsenopyrite, löllingite*. In some deposits magnetite makes up more than 40% of the ore. Some deposits display zoning from siliceous Zn-rich to distal carbonate-silicate Pb-Ag rich ore.

GANGUE MINERALOGY (Principal and *subordinate*): Quartz, garnet, calcite, rhodonite, magnetite, siderite, pyroxenes and amphiboles, commonly manganiferous, fluorite; *Mn olivine, apatite, gahnite, plagioclase, biotite, chlorite, ankerite, epidote, graphite, barite, hematite, wollastonite, sillimanite, staurolite, vesuvianite*. The complex gangue mineralogy is a characteristic of Broken Hill-type deposits.

ALTERATION MINERALOGY: Original alteration assemblages are replaced by a complex variety of metamorphic minerals. Alteration envelopes and deposit zoning are common in larger deposits, but are generally not recognized in smaller ones. Footwall alteration pipes are generally not recognized, except for some of the Cu-rich deposits, which complicates their interpretation. Typically the alteration reflects enrichment of Fe, Si, Mn, Ca, P, F, K and CO_3 and includes metamorphic silicates including amphiboles, olivine, biotite, phlogopite, sillimanite, orthoclase and clinozoisite as well as carbonates, fluorite and a variety of other minerals. Spessartine-quartz halos surround many deposits, with more regional silicification (quartz) and K (sillimanite) enrichment. In the Broken Hill area, Australia, with increasing intensity of mineralization, Fe-Si-Mn systems (typical of metamorphosed iron formations) are overprinted by extreme Ca-Mn-F enrichment with calcsilicate assemblages.

WEATHERING: Large gossans are not common; however, pyrrhotite and pyrite in some deposits locally produce rusted outcrops. Some Australian deposits have deep weathered zones: gossanous quartz-garnet-gahnite rocks, with abundant Mn and Fe oxides at surface, and secondary Ag enrichment at depths associated with oxides (goethite and coronadite) and carbonates (dolomite, cerussite and smithsonite). Leached sulphides mark the transition into underlying sulphide ore.

ORE CONTROLS: Not well understood; deposits appear to be restricted to Proterozoic "mobile belts", generally interpreted to be intracratonic rifts. Oxidized shallow-marine basins, possibly developed due to extensional faulting above basement highs, and associated bimodal (?) volcanism are local controls.

GENETIC MODEL: Difficult to interpret due to high metamorphic grades. A sedimentary exhalite origin, with sulphide deposition in rapidly deepening rifts, is preferred because the deposits are associated with iron formations, chert and Mn-rich iron oxide facies. This environment, dominated by oxidized facies, contrasts with reduced, anoxic basins that commonly host sedex deposits. However, associated bimodal volcanics, ore and gangue chemistry and sulphide textures suggest similarities with volcanogenic massive sulphide deposition. Some workers have supported replacement models for the mineralization.

ASSOCIATED DEPOSIT TYPES: Sedimentary exhalative Pb-Zn deposits (E14), carbonatites (N01), nepheline syenites, polymetallic veins (I05) and W-Mo veins.

COMMENTS: Broken Hill-type deposits are a difficult exploration target due to their setting in strongly metamorphosed and deformed rocks.

EXPLORATION GUIDES

GEOCHEMICAL SIGNATURE: Anomalous enrichments of Mn, Cu, Au, Bi, Sb, W, Co and As in the ore and some proximal exhalative units; high Ag:Pb ratios, Mn and K enrichment (with muscovite, K-feldspars and sillimanite) in alteration halos; elevated base metal values (particularly Zn) and Mn in more regional iron formations. In silt samples expect anomalous Pb, Zn, Ag, Mn and Ba.

GEOPHYSICAL SIGNATURE: Deposits with associated magnetite produce strong magnetic anomalies. Electromagnetic and induced polarization surveys may detect those deposits with pyrrhotite and pyrite massive sulphides lenses. Associated graphite in some (*e.g.*, Big Ledge) may provide local targets.

OTHER EXPLORATION GUIDES: Main exploration guide is appropriate sedimentary/tectonic environment - thin-bedded succession of paragneisses with abundant carbonate. The mineralization may occur at, or near, the transition from quartzo-feldspathic basement rocks to fine-grained clastic metasediments. Rapid lithologic facies changes in the vicinity of deposits may indicate local hydrothermal systems. Associated volcanism is indicative of extension or rifting. In closer proximity to deposits, unusual mineral assemblages include garnet quartzites, gahnite quartzites and Mn-rich calcsilicates with skarn textures.

ECONOMIC FACTORS

TYPICAL GRADE AND TONNAGE: Deposits frequently occur in clusters with numerous small, uneconomic deposits. Broken Hill-type targets average less than 5 to 20 Mt, but may be in excess of 100 Mt (Broken Hill, Australia: 280 Mt containing 10.0% Pb, 8.5% Zn and 148 g/t Ag, including approximately 150 Mt of more that 20% Pb+Zn). Grades are variable, commonly with 2 to 10 % Pb, 2 to 8% Zn and 10 to 150 g/t Ag. Some deposits contain no byproduct copper, others have 0.1 to 1% Cu. In British Columbia, known deposits range in size from less than one million to 6.5 Mt; geological reserves may be considerably larger. Grades range from approximately 2 to 5 % Zn and 2.5 to 6.5 % Pb with up to 50 g/t Ag. Ruddock Creek contains 5 Mt with 7.5% Zn, 2.5% Pb and Jordan River, 2.6 Mt with 5.6% Zn, 5.1% Pb and 35 g/t Ag.

ECONOMIC LIMITATIONS: Structural thickening is often critical to the genesis of economic deposits. Broken Hill-type deposits have not been mined in British Columbia, due mainly to their form - thin, though laterally persistent layers - and their location in remote, mountainous terrains.

IMPORTANCE: These deposit are an important source for lead, zinc and silver, and remain an attractive exploration target in British Columbia.

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Grade and Tonnage Data for Selected Deposit Types

compiled by

Eric Grunsky, David Lefebure and Larry Jones

Grade and Tonnage Data for Selected Deposit Types

INTRODUCTION

A key element in many mineral resource assessments is quantitative data which defines the grade and tonnage characteristics of known deposits. This information is required to assist with the definition of the probable size and value of the undiscovered resources in any tract. The data can also be used to help identify specific deposit types as exploration targets because they potentially have the required grades and tonnages to provide an economic return on investment.

The USGS published the first comprehensive set of grade and tonnage curves for 60 deposit types in Bulletin 1693 (Cox and Singer, 1986). The actual data for 50 of these deposit types is available as a digital file (Singer, D.A., Mosier, D.L. and Menzie, W.D., 1993). During the British Columbia mineral potential project data from provincial deposits for more than 25 deposit types was collected. In this Open File data for twenty-one is presented.

DATA SOURCES

The original grade and tonnage data was assembled by Ron McMillan and Nick Carter who were contracted in 1993 to audit the reserves and production figures for significant producers, past producers and deposits in British. Columbia. They selected 526 deposits (Carter and McMillan, personal communication, 1993) with:

- more than 100 000 tonnes past production or reserves,
- greater than 10 000 tonnes of production in any one year
- entries on Map 1992-1 (Faulkner *et al.*, 1992).

The information for the production was derived from government records in BC METAL, except for current producers where company annual reports and other published sources were used. Reserve figures were initially derived from the provincial MINFILE database which was followed up by referring to company annual reports and Mine Development Assessment stage I and stage II reports. They took particular care to rationalize reserve figures with production data.

The final objective of the McMillan and Carter audit was to determine a "global resource total" for deposits by adding production and ore reserves (Carter and McMillan, personal communication, 1993). Subsequently their data set was reviewed by BC Geological Survey staff for accuracy and to evaluate their designation as to deposit type. At this stage some deposits were added, including some figures for deposits from outside British Columbia. As well, any deposits which were controversial with respect to deposit type were removed. A final check of the data was made in March, 1995 using the information in the MINFILE database.

Data presented in the following tables are the cumulative or global resource total based on published figures. If you are interested in the grade and tonnage figures for a particular deposit, it is best to refer directly to MINFILE where there is data for each zone with complete information concerning category of reserves and year of production.

In the tables the status of the deposit, and the source of the data used to determine the global resource total for British Columbia deposits are denoted by the following abbreviations:

PROD	- producer
PAPR	- past producer
DEPR	- deposit
P	- production data
R	- reserve data
RP	- production and reserve data

Unfortunately cutoff grades have not been reported for many deposits and therefore, this information has not been catalogued. Cutoff grades used for individual deposits with diffuse grade boundaries can change over time and vary considerably. The total reserves quoted for any of these deposits will depend on the date when the calculations were made and the organization which completed them.

DATA QUALITY

Considerable effort has been made to ensure that grade and tonnage figures are accurate. However, the BC Geological Survey does not certify the accuracy of the data or assume any responsibility for it. Current and complete figures are maintained in the MINFILE database. Since reported grades and tonnages are strongly influenced by cutoff grades, commodity prices, degree of definition by drilling and development workings, mining methods, completeness of production records, percentage recovery and other factors, these numbers should be treated only as an approximation of the in-situ resource. As with the deposit profile descriptions, readers are encouraged to submit comments and data.

In the following tables, there are numerous deposits for which grades are given as zero for commodities that are undoubtedly present. In some cases these were commodities which were not economically recoverable at the time of mining. For example, zinc grades for many sulphide deposits which were mined in the early part of the century are often not reported.

DIGITAL DATA

A complete digital file is available from BCGS by contacting:

Profile Grade and Tonnage data
MINFILE
BC Geological Survey
5th Floor - 1810 Blanshard Street
Victoria, B.C.
V8V 1X4
tel: (604) 952-0386
fax: (604) 952-0381
email: ljones@galaxy.gov.bc.ca

The digital file includes not only all the data listed here, but also the source references.

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Singer, D.A., Menzie, W.D., DeYoung, J.H., Jr., Sander, M. and Lott, A. (1980): Grade and Tonnage Data Used to Construct Models for the Regional Alaskan Mineral Resource Assessment Program, *U.S. Geological Survey*, Open-File Report 80-799, 58 pages.

Singer, D.A., Mosier, D.L. and Menzie, W.D. (1993): Digital Grade and Tonnage Data for 50 Types of Mineral Deposits; *U.S. Geological Survey*, Open File 93-280, digital file.

Table 1. Grade and Tonnage Data for Basaltic Cu - D03[1]

Deposit Name	MINFILE #	Status		Tonnes	Cu %	Ag g/t	Au g/t
Copper Cliff	092K 012	PAPR -	RP	4740	2.92	11.40	0
Cincinatti	092HNE084	DEPR -	R	54000	0.88	0	0
Copper Road	092K 060	PAPR -	RP	156081	3.37	13.90	0.15
Alvija	103I 085	DEPR -	R	181400	4	69	0
Pomeroy 3, 4	092K 071	PAPR -	RP	194206	0.78	3.10	0
Regal	092HSE078	DEPR -	R	200000	0.5	0	0
Spokane	092N 001	DEPR -	R	335000	1.35	6.20	0.27
Porcupine	092ISE054	DEPR -	R	578729	1.92	0	0
Megabucks	093A 078	DEPR -	R	725000	0.15	0	1.30
Driftwood	093M 117	DEPR -	R	900000	2	0	0
Kelly Creek	103I 092	DEPR -	R	2267950	1.03	18.50	0
Sustut	094D 063	DEPR -	R	54400000	1.25	0	0

Table 2. Grade and Tonnage Data for Basal-type U - D04

Deposit Name	MINFILE #	Status		Tonnes	U %
Fuki	082ENE015	DEPR -	R	500000	0.025
Haynes Lake	082ENW051	DEPR -	R	2000000	0.017
Blizzard	082ENE046	DEPR -	R	2200000	0.183
Cup Lake	082ENE041	DEPR -	R	2250270	0.037
Hydraulic Lake	082ENW053	DEPR -	R	3055697	0.026

Table 3. Grade and Tonnage Data for Mississippi Valley-type Pb-Zn - E12

Deposit Name	MINFILE #	Status		Tonnes	Pb %	Zn %	Cu %	Ag g/t
Silver Giant	082KNE018	PAPR -	P	841058	3.5	0.38	0.03	23.00
Monarch/Kicking Horse	082N 019	PAPR -	P	1490000	4.67	5.1	0	27.40
Paradise	082KSE029	PAPR -	P	1510000	2.65	5.05	0	0
Mineral King	082KSE001	PAPR -	P	2175405	1.8	4.3	0.03	27.70
Robb Lake	094B 005	DEPR -	R	5500000	1.5	5.8	0	0

Mosier and Briskey (1986) have compiled a larger data set for these deposits.

Mosier, D.L. and Briskey, J.A. (1986): Grade and Tonnage Model of Southeast Missouri Pb-Zn and Appalachian Zn Deposits; *in* Cox, D.P. and Singer, D.A., Editors, Mineral Deposit Models, *U.S. Geological Survey*, Bulletin 1693, pages 224-226.

[1] *For complete and current data for the deposits listed in these tables please refer to the provincial MINFILE database.*

Table 4. Grade and Tonnage Data for Irish-type Carbonate-hosted Zn-Pb - E13[1]

Deposit Name	MINFILE # or Country	Status		Tonnes	Zn %	Pb %	Ag g/t	Au g/t	Cu %
Ferguson	094C 002	DEPR -	R	23000	6.1	9.8	120.0	0	0
Mastadon	082M 005	PAPR -	P	28975	9.25	0.28	6.6	0.01	0
Abbott	082KNW056	DEPR -	RP	210393	7.48	4.88	157.0	0.70	0
Maybe	093A 110	DEPR -	R	400000	3	1	0	0	0
Wigwam	082KNW068	PROS	R	632000	3.54	2.14	0	0	0
Big Showing	082KNW078	DEPR -	R	679587	0	0	577	0	0
Annex	082FSW219	PAPR -	P	763314	5.59	0.94	44.6	0	0
Jackpot Main	082FSW012	DEPR -	R	943240	2.32	2.32	0	0	0
Reeves Macdonald	082FSW026	PAPR -	P	5848021	3.38	0.99	3.4	0	0
HB	082FSW004	PAPR -	RP	6656101	4.03	0.77	4.7	0	0
Galmoy	Ireland	DEPR		6700000	11	1	0	0	0
Jersey	082FSW009	PAPR -	P	7336344	3.59	1.66	3.0	0	0
Tynagh	Ireland	PAPR		7400000	3	4	42	0	0
Duncan	082KSE023	DEPR -	R	9000000	2.9	2.7	0	0	0
Lisheen	Ireland	DEPR		9300000	13	2	31	0	0
Silvermines	Ireland	PAPR		17000000	7	3	26	0	0
Navan	Ireland	PROD		69900000	10	3	0	0	0

The data for the five Irish deposits is from Goodfellow *et al.* (1993).

Goodfellow, W.D., Lydon, J.W. and Turner, R.J.W. (1993): Geology and Genesis of Stratiform Sediment-hosted (SEDEX) Zinc-lead-silver sulphide Deposits; in Kirkham, R.V., Sinclair, W.D., Thorpe, R.I. and Duke, J.M., Editors, Mineral Deposit Modeling, Geological Association of Canada, Special Paper 40, pages 201-251.

[1] *For current data for all the British Columbia deposits listed in this table please refer to the provincial MINFILE database.*

Table 5. Grade and Tonnage Data for Sedimentary Exhalative Zn-Pb-Ag - E14[1]

Deposit Name	MINFILE # or Country	Status		Tonnes	Zn %	Pb %	Ag g/t	Au g/t	Cu%
Driftpile	094K 066	DEPR -	R	2440000	12	3	0	0	0
Swim	Yukon	DEPR -	R	4300000	4.7	3.8	42	0	0
Bend 1 Canyon Zone	083D 001	DEPR -	R	5000000	2.3	0.6	7.0	0	0
Vangorda	Yukon	PAPR -		7100000	4.3	3.4	48.0	0	0
Jason	Yukon	DEPR -	R	10100000	7	7	80	0	0
Tom	Yukon	DEPR -	R	16000000	6	4	40	0	0
Dy	Yukon	DEPR -	R	21000000	6.7	5.5	84.0	0.95	0.12
Grum	Yukon	PROD -	R	31000000	4.9	3.1	49.0	0	0
Cirque	094F 008	DEPR -	R	32000000	7.9	2.2	48.0	0	0
Faro	Yukon	PAPR -	RP	58000000	4.7	3.4	36.0	0	0
Sullivan	082FNE052	PROD -	RP	151000000	5.54	5.82	63.3	0	0
Howard's Pass	Yukon	DEPR -	R	550000000	5	2	9	0	0

The reserve figures for the Driftpile deposit are for the lower mineralized unit of the Main zone (Nelson *et al.*, 1995), not the lower grade, but much larger reserve figure for multiple zones often quoted. The data for the Yukon deposits are from MacIntyre (1991; Swim, Vangorda, Dy, Grum, Faro) and Goodfellow *et al.* (1993; Jason, Tom, Howard's Pass).

The USGS data set for sedimentary exhalative Zn-Pb deposits (Menzie and Mosier, 1986) includes a number of deposits which are classified as different types of deposits by the BCGS.

Goodfellow, W.D., Lydon, J.W. and Turner, R.J.W. (1993): Geology and Genesis of Stratiform Sediment-hosted (SEDEX) Zinc-lead-silver sulphide Deposits; *in* Kirkham, R.V., Sinclair, W.D., Thorpe, R.I. and Duke, J.M., Editors, Mineral Deposit Modeling, *Geological Association of Canada*, Special Paper 40, pages 201-251.

MacIntyre, D.G. (1991): SEDEX - Sedimentary Exhalative Deposits; *in* McMillan, W.J., Höy, T., MacIntyre, D.G., Nelson, J.L., Nixon, G.T., Hammock, J.L., Panteleyev, A., Ray, G.E. and Webster, I.C.L., Ore Deposits, Tectonics and Metallogeny of the Canadian Cordillera, *B. C. Ministry of Energy, Mines and Petroleum Resources*, Paper 1991-4, pages 25-70.

Menzie, W.D., and Mosier, D.L. (1986): Grade and Tonnage Model of Sedimentary Exhalative Zn-Pb; *in* Cox, D.P. and Singer, D.A., Editors, Mineral Deposit Models, *U.S. Geological Survey*, Bulletin 1693, pages 212-215.

Nelson, J., Paradis, S. and Farmer, R. (1995): Geology of the Driftpile Stratiform, Sediment-hosted Ba-Zn-Pb Deposit, Northern British Columbia (94K/4); *B. C. Ministry of Energy, Mines and Petroleum Resources*, Geological Fieldwork 1994, Paper 1995-1, pages 261-268.

[1] *For current data for all the British Columbia deposits listed in this table please refer to the provincial MINFILE database.*

Table 6. Grade and Tonnage Data for Besshi Massive Sulphide - G04

Deposit Name	MINFILE # or Country	Status		Tonnes	Cu%	Zn %	Ag g/t	Au g/t
Noji	Japan			11000	0.7	0	0	0
Hirabaya	Japan			14000	0.5	0	0	0
Nakayama	Japan			14600	2.5	0	3	0
Akinokawa (Onishi)	Japan			16600	2.4	0	0	0
Asakawa	Japan			19000	5.4	0	0	0
Chushiro	Japan			20000	0.5	0	0	0
Kamegamori	Japan			23000	1.2	0	0	0
Nii	Japan			23000	2	0	0	0
Nanogawa	Japan			25000	2.8	0	37	2
Yoshimoto	Japan			30000	2.6	0	0	0
Ryuo	Japan			33000	1.4	0	0	0
Choja	Japan			36000	0.6	0	0	0
Machimi	Japan			45000	0.5	0	0	0
Kanayama	Japan			65000	2.8	0	0	0
Miyoshi	Japan			68000	3.8	0	0	0
Naruyasu	Japan			70000	0.6	0	0	0
Imade + Ouchi	Japan			76000	1.1	0	8	1
Izushi	Japan			99000	1	0	0	0
Ehime	Japan			103000	1.5	0	0	0
Iyo	Japan			123000	3.2	0	0	0
Shiiba Takaragi	Japan			131000	1.7	0	0	0
Hirota	Japan			143000	2.8	0	0	0
Shimokawa (Kouchi)	Japan			146000	0.8	0	0	0
Omine	Japan			160000	0.5	0	0	0
Nonowaki	Japan			161000	1.7	0	0	0
Minawa	Japan			170000	2.7	0	0	0
Yuryo	Japan			183000	0.9	0	0	0
Nishinokawa	Japan			200000	1	0	0	0
Terano	Japan			250000	0.4	0	0	0
Takaura	Japan			286000	1.1	0	6	1
Higashiyame	Japan			355000	3.5	0	0	0
Motoyasu	Japan			372000	1.4	0	4	0
Shinga	Japan			504000	1.2	0	4	0
Okuki	Japan			789000	2.8	1	18	1
Gorob	Namibia			1100000	3	0	0	0
Hixbar	Philippines			1100000	1	1	14	2
Stone Hill	USA			1300000	1	1	0	0
Ore Knob	USA			1500000	3	1	16	0
Tisova	Czech Republic			1500000	0.7	0	0	0
Kotsu	Japan			1780000	1.4	0	0	0
Goldstream	082M 141	PROD -	RP	2490198	3.91	1.56	4	0
Matchless	Namibia			2700000	2	0	0	0
Elizabeth	USA			2900000	2	1	0	0
Killingdal	Norway			3000000	2	6	23	1

Table 6. Grade and Tonnage Data for Besshi Massive Sulphide - G04

Deposit Name	MINFILE # or Country	Status	Tonnes	Cu%	Zn %	Ag g/t	Au g/t
Folldal	Norway		3000000	2	3	0	0
Hersjo	Norway		3200000	1	1	0	0
Rapu-Rapu	Philippines		3200000	2	3	40	3
Kune	Japan		3370000	3.17	0	0	0
Green Mountain	USA		3600000	1	1	0	0
Sazare	Japan		4160000	1.7	0.4	7	0
Denali	USA		4500000	2	0	0	0
Sherridon	Canada		4800000	3	3	33	1
Imori	Japan		4900000	1.17	0	0	0
Shirataki	Japan		4960000	1.3	0.3	4	0
Makimine Hibira	Japan		5200000	1.8	0	6	0
Soucy	Canada		5400000	2	2	14	2
Beatson	USA		6000000	2	0	9	0
Shimokawa	Japan		8000000	2.28	1.34	10	1
Otjihase	Namibia		17000000	2	0	9	0
Tverfjell	Norway		19000000	1	1	13	0
Kilembe	Uganda		19000000	2	0	0	0
Liwu	China		20000000	2	0	30	0
Arinteiro	Spain		23000000	1	0	0	0
Yanahara	Japan		25000000	1.2	0	58	1
Granduc	104B 021	PAPR - RP	26000000	1.44	0	8	0
Hitachi	Japan		29000000	1.39	0.65	5	0
Besshi	Japan		30000000	2.45	0.3	6.6	0.2
Windy Craggy[1]	114P 002	DEPR - R	297000000	1.38	0	4	0.2

The provincial dataset is augmented by the USGS dataset of Besshi deposits from Japan that are greater than 10 000 tonnes (Singer, 1986, Singer *et al*, 1993) and deposits identified by Slack (1993). Slack's data is limited to deposits exceeding 1 million tonnes.

Singer, D.A. (1986): Grade and Tonnage Model of Besshi Massive Sulfide Deposits; in Cox, D.P. and Singer, D.A., Editors, Mineral Deposit Models, *U.S. Geological Survey*, Bulletin 1693, pages 136-138.

Singer, D.A., Mosier, D.L. and Menzie, W.D. (1993): Digital Grade and Tonnage Data for 50 Types of Mineral Deposits; *U.S. Geological Survey*, Open File 93-280, digital file.

Slack, J.F. (1993): Descriptive and Grade-tonnage Models for Besshi-type Massive Sulphide Deposits; *in* Kirkham, R.V., Sinclair, W.D., Thorpe, R.I. and Duke, J.M., Editors, Mineral Deposit Modeling, *Geological Association of Canada*, Special Paper 40, pages 343-371.

[1] Note that the gold and silver values for the Windy Craggy deposit are for the North Zone only which forms approximately 2/3 of the deposit (Slack, 1993).

Table 7. Grade and Tonnage Data for Cyprus Massive Sulphide Cu (Zn) - G05

Deposit Name	MINFILE # or Country	Status	Tonnes	Cu%	Zn %	Ag g/t	Au g/t
Rendall-Jackson	Newfoundland		11000	3.45	0	0	0
Ambelikou	Cyprus		15000	1	0	0	0
Platies	Cyprus		45000	3	0	0	0
Kapedhes	Cyprus		50000	0.5	0	0	0
Bongbongan	Phillipines		90000	1.18	0	0	0
Peravasa	Cyprus		90000	0.76	0	0	0
Big Mike	Nevada, USA		100000	10	0	0	0
Carmel	Phillipines		108000	1.48	0	0	0
Betts Cove	Newfoundland		119000	10	5	27.0	0.9
Carawison	Phillipines		170000	2.8	0	0	0
York Harbour	Newfoundland		243000	2.4	7	0	0
Svano	Norway		250000	0.84	1	0	0
Troulli	Cyprus		270000	1	0	0	0
Wayside (New Discovery)	092JNE121	DEPR - R	283891	2	2.5	0	0.3
Sha	Cyprus		320000	0.6	0	0	0
Lorraine	Phillipines		450000	4.5	0	0	0
Kynousa	Cyprus		560000	2.04	1.7	0	0
Oxec	Guatemala		762000	3	0	0	0
Colchester	Newfoundland		910000	1.3	0	0	0
Kokkinoyia	Cyprus		910000	1.5	0.2	0	0
Bayda	Oman		1000000	2	0	0	0
Fornas	Spain		1000000	1.33	0	0	0
Chu Chua	092P 140	DEPR - R	1043257	2.98	0.3	10.3	0.6
Agrokipia	Cyprus		1420000	1.7	1.09	0	0
Apliki	Cyprus		1500000	1.8	0	0	0
Huntingdon	Quebec		1815000	0.9	0	0.6	0.1
Barlo	Phillipines		2050000	1.9	2.22	2.7	0
Hand Camp	Newfoundland		2270000	2.62	0	56.0	13.4
Ny Sulitjelma	Norway		2300000	2	0.55	0	0
Mathiati North	Cyprus		2500000	0.24	0.1	0	0
Little Bay	Newfoundland		2950000	1.36	0	0	0
Aarja	Cyprus		3000000	2	0	0	0
Rua Cove	Alaska, USA		3200000	1.1	0	0	0
Turner-Albright	Oregon, USA		4000000	3.4	7.2	51.1	5.9
Limni	Cyprus		4220000	1.4	0	0	0
Kure (Bakibaba)	Turkey		4400000	2.2	0	0	1.0
Whalesback-Little Deer	Newfoundland		4890000	1.05	0	0	0

Table 7. Grade and Tonnage Data for Cyprus Massive Sulphide Cu (Zn) - G05

Deposit Name	MINFILE # or Country	Status		Tonnes	Cu%	Zn %	Ag g/t	Au g/t
Kokkinopezoula	Cyprus			5000000	0.5	0	0	0
Skouriotissa	Cyprus			5400000	2.35	0.5	69.0	11.0
Mousoulos-Kalavasos	Cyprus			6916000	1	0.5	6.1	1.7
Skorovass	Norway			10000000	1	1.5	10.0	0.1
Arinteiro	Spain			11000000	0.9	0	0	0
Tilt Cove	Newfoundland			12000000	1.82	0	0.9	0.8
Kure (Asikoy)	Turkey			14000000	2.17	0.01	11.0	2.2
Mavrovouni	Cyprus			15000000	4	0.5	39.0	0.3
Lasail	Oman			16000000	2	0	0	0
Bama	Spain			20000000	0.55	0	0	0
Ana Yatak Ergani	Turkey			24000000	2.94	0	18.7	1.1
Lokken	Norway			25000000	2.1	1.9	19.0	0.3
Siirt Madenkoy	Turkey			26000000	1.55	0	0	0
Anyox Camp	103P 021	PAPR-	RP	43000000	1.05	0	18.3	0.45

The provincial dataset is augmented by the USGS dataset (Singer and Mosier, 1986, Singer *et al.*, 1993) which is restricted to massive sulphide deposits hosted only by mafic or ultramafic rocks with either pillow basalts or diabase dikes in the sequence.

Singer, D.A., and Mosier, D.L. (1986): Grade and Tonnage Model of Cyprus Massive Sulfide Deposits: *in* Cox, D.P. and Singer, D.A., Editors, Mineral Deposit Models, *U.S. Geological Survey*, Bulletin 1693, pages 131-135.

Singer, D.A., Mosier, D.L. and Menzie, W.D. (1993): Digital Grade and Tonnage Data for 50 Types of Mineral Deposits; *U.S. Geological Survey*, Open File 93-280, digital file.

Table 8. Grade and Tonnage Data for Noranda/Kuroko Cu-Pb-Zn - G06[1]

Deposit Name	MINFILE #	Status		Tonnes	Cu%	Zn %	Pb %	Ag g/t	Au g/t
Bowler Creek	082M 138	DEPR -	R	312000	0.2	2.58	3.37	52.4	0
Rea Gold	082M 191	DEPR -	R	376000	0.33	2.3	2.2	69.4	6.10
Lara	092B 129	DEPR -	R	528839	1.01	5.87	1.22	100.1	4.70
Rock and Roll	104B 377	DEPR -	R	580600	0.64	3	1	336	2
Lenora	092B 001	PAPR -	RP	594967	2.46	3.85	0.37	117.0	4.20
Homestake	082M 025	PAPR -	RP	1470962	0.55	3.99	2.5	244.8	0.01
Seneca	092HSW013	DEPR -	RP	1506499	0.63	3.57	0	41.1	0.82
Ecstall	103H 011	DEPR -	R	6900000	0.6	0	2.5	17.1	0.50
Tulsequah Chief	104K 002	PAPR -	RP	8733570	1.57	6.45	1.21	110.3	2.80
Kutcho Creek	104I 060	DEPR -	R	17000000	1.62	2.3	0.06	29.2	0.30
Myra Falls camp	092F 330	PROD -	RP	29000000	1.96	6.38	0.57	53.7	2.20
Britannia	092GNW003	PAPR -	RP	49000000	1.1	0.25	0.03	3.7	0.31

Two grade and tonnage models for Kuroko massive sulphide deposits have been published by the USGS, a more general one (Singer and Mosier, 1986) and a specific model for Sierran deposits (Singer, 1992).

Singer, D.A., and Mosier, D.L. (1986): Grade and Tonnage Model of Kuroko Massive Sulfide Deposits: *in* Cox, D.P. and Singer, D.A., Editors, Mineral Deposit Models, *U.S. Geological Survey*, Bulletin 1693, pages 190-197.

Singer, D.A., 1992, Grade and Tonnage Model of Sierran Kuroko Deposits; *in* Bliss, J.D., Editor, Developments in Deposit Modeling, *U.S. Geological Survey,* Bulletin 2004, pages 29-32.

[1] *For current data for all the British Columbia deposits listed in this table please refer to the provincial MINFILE database.*

Table 9. Grade and Tonnage Data for Epithermal Au-Ag: Low Sulphidation - H05[1]

Deposit Name	MINFILE #	Status		Tonnes	Au g/t	Ag g/t	Cu%	Pb %	Zn %
Dusty Mac	082ESW078	PAPR -	P	93392	6.50	113.0	0	0	0
Baker	094E 026	PAPR -	RP	120449	17.90	269.7	0	0	0
Mets	094E 093	DEPR -	R	144000	11.30	0	0	0	0
Vault	082ESW173	DEPR -	R	152000	14.00	0	0	0	0
Goldwedge	104B 105	PAPR -	R	329000	24.90	201.2	0	0	0
Blackdome	092O 053	PAPR -	RP	398123	21.50	78.9	0	0	0
Golden Stranger	094E 076	DEPR -	R	500000	2.70	0	0	0	0
Lawyers	094E 066	PAPR -	P	528337	8.40	168.3	0	0	0
Shasta	094E 050	PAPR -	RP	1122533	4.10	217.5	0	0	0
Sulphurets	104B 189	DEPR -	R	1437000	11.50	783.6	0	0	0
Silbak Premier	104B 054	PROD -	RP	7065528	9.00	188.9	0.03	0.4	0.14
Cinola	103F 034	DEPR -	RP	24000000	2.50	3.1	0	0	0

Mosier, D.L., Singer, D.A., and Berger, B.R. (1986): Grade and Tonnage Model of Comstock Epithermal Vein Deposits; *in* Cox, D.P. and Singer, D.A., Editors, Mineral Deposit Models, *U.S. Geological Survey*, Bulletin 1693, pages 151-153.

Mosier, D.L., Singer, D.A., Sato, T., and Page, N.J. (1986): Relationship of Grade, Tonnage, and Basement Lithology in Volcanic-hosted Epithermal Precious- and Base-metal Quartz-adularia-type Districts, *Mining Geology*, volume 36, pages 245-264.

Mosier, D.L., Menzie, W.D., and Kleinhampl (1986): Geologic and Grade-tonnage Information on Tertiary Epithermal Precious- and Base-metal Vein Districts Associated with Volcanic Rocks: *U.S. Geological Survey*, Bulletin 1666, 39 pages.

[1] *For complete and current data for the British Columbia deposits listed in this table please refer to the provincial MINFILE database.*

Table 10. Grade and Tonnage Data for Au-quartz Veins - I01[1]

Deposit Name	MINFILE #	Status	Tonnes	Au g/t	Ag g/t	Cu%	Pb %	Zn %
Valentine Mountain	092B 108	DEPR - RP	30706	14.7	0.80	0	0	0
Athasbasca	082FSW168	PAPR - RP	59924	13.1	4.80	0	0.02	0.03
Cariboo Hudson	093A 071	PAPR - RP	66640	13.6	15.20	0	0	0
Mt. Zeballos	092L 012	PAPR - P	74268	12.8	6.00	0	0.02	0
Bayonne	082FSE030	PAPR - P	81903	16.0	45.80	0	0.05	0.03
Meridian	082KNW064	PAPR - P	88762	6.1	1.90	0	0	0
Hunter	103H 034	PAPR - RP	94003	1.2	0	0	0	0
Central Zeballos	092L 212	PAPR - RP	104381	12.1	24.60	0.01	0.01	0.14
Morning Star	082ESW006	PAPR - P	110273	3.9	43.00	0.01	0.08	0
Cariboo-Amelia	082ESW020	PAPR - P	124451	20.4	8.10	0	0.04	0.07
Wayside	092JNE030	PAPR - RP	137069	4.3	0.67	0	0	0
Reliance	092JNE033	DEPR - R	410916	6.0	0	0	0	0
Banbury	092HSE046	PAPR - RP	174360	10.2	2.30	0.01	0	0
Granite-Poorman	082FSW086	PAPR - P	181118	11.2	5.30	0	0.01	0.01
Congress	092JNE029	PAPR - RP	193581	9.2	1.40	0	0	0
Alpine	082FNW127	PAPR - RP	206251	14.4	14.10	0	0.31	0.02
Snowbird	093K 036	PAPR - RP	226000	6.9	0	0	0	0
Gold Belt	082FSW044	PAPR - P	236502	10.6	4.50	0	0	0
Congress (Howard)	092JNE132	DEPR - R	267505	11.3	0	0	0	0
Georgia River	103O 013	PAPR - RP	290751	28.8	22.50	0.73	0	0
Dome Mountain	093L 276	PAPR - RP	256385	12.5	67.40	0	0	0
Kootenay Belle	082FSW046	PAPR - P	305608	11.5	4.30	0	0.02	0.02
Spud Valley Roper	092L 013	PAPR - R	414754	12.0	3.00	0	0	0
Taurus	104P 012	PAPR - RP	436315	7.2	1.00	0	0	0
Reno/Nugget/Motherlode	082FSW036	PAPR - P	455208	17.7	8.10	0	0.02	0.02
Debbie	092F 079	PAPR - RP	472321	6.2	0	0	0	0
Privateer Prident	092L 008	PAPR - RP	527311	16.2	7.70	0.01	0.02	0
Tamarac	082FSW072	PAPR - RP	560046	4.5	0	0	0	0
Queen	082FSW048	PAPR - P	653160	14.5	4.80	0	0	0
Erickson/Table Mountain	104P 029	PAPR - RP	861843	16.0	4.00	0	0	0
CPW	093A 043	DEPR - RP	838004	2.0	0	0	0	0
Surf Inlet	103H 027	PAPR - RP	973427	13.3	7.00	0.33	0	0
Island Mountain	093H 006	PAPR - RP	1011875	12.1	1.80	0	0	0
Edye Pass & Surf Point	103J 015	PAPR - P	1443182	7.0	3.70	0.01	0	0
Stemwinder-Fairview	082ESW007	PAPR - RP	1549675	3.8	40.80	0	0.01	0
Carolin	092HNW007	PAPR - RP	2718425	2.8	0.11	0	0	
Cariboo Gold Quartz	093H 019	PAPR - RP	3548340	13.3	1.40	0	0	0

[1] *For complete and current data for the British Columbia deposits listed in this table please refer to the provincial MINFILE database.*

Table 10. Grade and Tonnage Data for Au-quartz Veins - I01

Deposit Name	MINFILE #	Status		Tonnes	Au g/t	Ag g/t	Cu%	Pb %	Zn %
Polaris-Taku	104K 003	PAPR -	RP	3283357	13.7	0.11	0	0	0
Golden Bear	104K 079	PAPR -	RP	4312866	12.7	0.03	0	0	0
Bralorne/Pioneer	092JNE001	PAPR -	RP	9080490	16.7	3.40	0	0	0
Frasergold	093A 150	DEPR -	R	12000000	1.9	0	0	0	0

Bliss, J.D. (1986): Grade and Tonnage Model of Low-sulfide Au-quartz Veins; *in* Cox, D.P. and Singer, D.A., Editors, Mineral Deposit Models, *U.S. Geological Survey,* Bulletin 1693, pages 239-243.

Table 11. Grade and Tonnage Data for Intrusion-related Au Pyrrhotite Veins - I02[1]

Deposit Name	MINFILE #	Status		Tonnes	Au g/t	Ag g/t	Cu%
Velvet	082FSW162	PAPR -	P	88800	7.0	7.48	1.30
Golden Crown	082ESE032	PAPR -	RP	92500	15.3	28.10	1.53
Scottie Gold	104B 034	PAPR -	RP	182000	19.3	8.91	0.00
Johnny Mountain	104B 107	PAPR -	RP	205000	12.7	19.20	0.49
War Eagle	082FSW097	PAPR -	P	300000	18.9	40.10	1.67
Josie	082FSW147	PAPR -	P	569000	17.2	27.30	1.40
Snip	104B 250	PROD -	RP	1225488	28.1	0	0
Le Roi	082FSW093	PAPR -	P	1790000	13.4	21.00	1.19
Centre Star	082FSW094	PAPR -	RP	2340000	15.4	12.40	0.65

[1] *For complete and current data for the British Columbia deposits listed in this table please refer to the provincial MINFILE database.*

Table 12. Grade and Tonnage Data for Polymetallic Veins Ag-Pb-Zn+/-Au - I05[1]

Deposit Name	MINFILE #	Status	Tonnes	Ag g/t	Pb %	Zn %	Cu%	Au g/t
Virginia Silver	093M 021	PAPR - RP	20060	2950	4.4	2.19	0	1
Howard	082FSW199	PAPR - P	20091	81	5.27	1.71	0	11
Sunrise Silver	093M 043	PAPR - P	20527	295	14.83	4.95	0	0
Richmond-Eureka	082FNW054	PAPR - P	36650	681	6.34	2.08	0	0
Noble Five	082FNW037	PAPR - P	39812	376	5.45	3.99	0	0
Ivanhoe	082FNW057	PAPR - P	40293	353	5.87	0.82	0	0
Teddy Glacier	082KNW069	DEPR - RP	44005	161	7.9	6.8	0	5
Surprise	082FNW021	PAPR - P	44384	1348	12.63	7.97	0	0
Dunwell	103P 052	PAPR - P	46689	220	1.8	2.38	0.03	7
Emerald Glacier	093E 001	PAPR - RP	49142	348	6.73	9.69	0.02	1.
Center Star	082FSW066	PAPR - P	51460	57	1.88	0.92	0	8
Mamie	093L 091	PAPR - R	55340	141	0	112	9	33
Skylark	082ESE011	PAPR - RP	57913	593	0.41	0.15	0.04	3
Ruth-Hope	082FNW052	PAPR - P	60605	1271	16.55	2.65	0	0
Bosun	082FNW003	PAPR - P	63222	1098	7.76	4.98	0	0
Enterprise	092ISE028	PAPR - P	71304	109	1.46	0.33	0.07	4
Cronin	093L 127	PAPR - RP	73048	388	7.04	7.25	0.12	1
Galena Farm	082FNW067	PAPR - P	84098	209	3.4	5.52	0	0
Spokane	082FNE028	PAPR - P	85360	53	5.02	1.83	0	0
Highland	082FNE015	PAPR - P	89228	118	10.5	0.43	0	0
Duthie	093L 088	PAPR - RP	93862	631	4.84	4.76	0.02	2
Wagner	082KNW212	DEPR - RP	99901	418	8.79	3.78	0	0
Hewitt	082FNW065	PAPR - P	108554	550	1.59	2.49	0	0
Estella	082GNW008	PAPR - P	109518	58	4.73	8.98	0	0
Silver Tunnel	092JW 003	DEPR - RP	111400	382	0.17	0.39	0	6
Atlin Ruffner	104N 011	PAPR - RP	116260	600	5		0	0
Tedi	092JW 001	PAPR - RP	138210	78	1.81	2.7	0.59	1
Payne	082KSW006	PAPR - P	140604	837	12.36	2.34	0	0
Victor (L. 4565)	082FNW204	PAPR - P	149425	864	14.55	9.52	0	1
Spider	082KNW045	PAPR - RP	153465	391	8.09	8.56	0.06	3
Molly Gibson	082FNW121	PAPR - P	160185	551	3.34	2.07	0	0
Treasure Mtn	092HSW016	PAPR - RP	160987	858	4.83	5.01	0	0
Union	082ENE003	PAPR - P	171165	251	0.1	0.17	0.01	1
Grouse Mountain 2	093L 251	PAPR - R	181443	20	0	4.5	0.53	0
Arlington	082FSW205	PAPR - RP	182826	62	0.75	0.65	0	11
Rambler	082KSW018	PAPR - P	189564	560	5.56	1.4	0	0
Cork Province	082FNW094	PAPR - P	193244	86	3.06	4.84	0	0
Silver Standard	093M 049	PAPR - P	205033	1158	3.88	5.99	0.1	2
Chaput	082LSE006	PAPR - RP	509911	7	0.03	0.02	0	4
Zone 3	092ISE129	DEPR - R	258847	12	1.69	4.8	0.18	0
Silver King	082FSW176	PAPR - RP	277050	579	0.25	0	2.99	0

[1] *For complete and current data for the British Columbia deposits listed in this table please refer to the provincial MINFILE database.*

Table 12. Grade and Tonnage Data for Polymetallic Veins Ag-Pb-Zn+/-Au - I05

Deposit Name	MINFILE #	Status	Tonnes	Ag g/t	Pb %	Zn %	Cu%	Au g/t
Van Roi	082FNW064	PAPR - P	284705	304	2.84	2.67	0	0
Ymir	082FSW074	PAPR - P	327647	44	1.46	0.25	0	10
Silversmith	082FNW053	PAPR - P	355047	656	9.07	3.36	0.33	0
Wolf	103P 198	DEPR - R	392200	305	0.59	0.12	0	0
Highlander	082FNE030	PAPR - P	396927	67	5.55	1.31	0	0
Horn Silver	082ESW002	PAPR - P	433177	294	0.08	0.09	0.01	1
Whitewater	082KSW033	PAPR - P	471063	231	2.96	4.91	0	0
Silvana	082FNW050	PAPR - RP	564653	467	5.49	5.04	0	0
Northair	092JW 012	PAPR - RP	536569	52	1.12	3.35	0.08	11
Snowflake	082N 003	PAPR - P	660697	91	2.26	1.15	0	0
New Moon	093E 011	DEPR - R	688712	59	.2	6	0	1
Standard	082FNW180	PAPR - P	745418	373	5.31	6.62	0	0
Porter-Idaho	103P 089	PAPR - RP	853729	733	3.07	1.94	0.97	1
Lucky Jim	082KSW023	PAPR - P	1065798	17	0.35	7.49	0	0
Grouse Mountain 1	093L 026	PAPR - RP	1100003	19	0	2	0.4	0
Beaverdell	082ESW030	PAPR - P	1198829	877	0.93	1.16	0	0
Dundee Yankee Girl	082FSW067	PAPR - RP	1245334	14	5.78	6	0	0
Vine	082GSW050	DEPR - R	1300000	36	3.12	0.76	0.11	2
St.Eugene	082GSW025	PAPR - P	1475266	124	7.66	0.98	0	0
Silver Queen	093L 002	PAPR - RP	1907643	304	0.04	5.87	0.02	3

As mentioned by Bliss and Cox (1986), these deposits display some of the complexities in dealing with published production and reserve data. For example, "the zinc grades are subject to considerable uncertainty because smelters in the past penalized producers for ore containing zinc which in turn caused mine operators to avoid zinc-bearing ore in their mining and milling". Therefore, the reported zinc grades for some deposits are likely to be low and tonnages may also be under estimated.

The USGS have also published a descriptive model for Creede epithermal veins (Mosier *et al.*, 1986a) with an associated grade and tonnage model (Mosier *et al.*, 1986b). One of the principal distinctions between the Creede epithermal veins and the USGS polymetallic veins is the host lithologies - volcanic versus sedimentary. The BCGS have combined the base metal-rich Creede-type veins, as exemplified by Silver Queen and Duthie in British Columbia, with examples of Bliss and Cox's polymetallic veins, for example the Slocan veins, to form one composite deposit type.

Bliss, J.D. and Cox, D.P. (1986): Grade and Tonnage Model of Polymetallic Veins; *in* Cox, D.P. and Singer, D.A., Editors, Mineral Deposit Models, *U.S. Geological Survey*, Bulletin 1693, pages 125-129.

Menzie, W.D., Singer, D.A., and Mosier, D.L. (1992): Grade and Tonnage Data for Climax Mo and Creede Epithermal Vein Deposit Models; *U.S. Geological Survey*, Open-File Report 92-248, 3 pages.

Mosier, D.L., Sato, T., Page, N.J., Singer, D.A. and Berger, B.R. (1986a): Descriptive Model of Creede Epithermal Vein Deposits; *in* Cox, D.P. and Singer, D.A., Editors, Mineral Deposit Models, *U.S. Geological Survey*, Bulletin 1693, pages 146-149.

Mosier, D.L., Sato, T., and Singer, D.A. (1986b): Grade and Tonnage Model of Creede Epithermal Vein Deposits; *in* Cox, D.P. and Singer, D.A., Editors, Mineral Deposit Models, *U.S. Geological Survey*, Bulletin 1693, pages 146-149.

Table 13. Grade and Tonnage Data for Silica-carbonate Hg - I08[1]

Deposit Name	MINFILE #	Status		Tonnes	Hg %
Bralorne Takla	093N 008	PAPR -	P	10308	0.58
Eagle Mercury	092JNE062	PAPR -	RP	1658126	0.2
Pinchi Lake Mercury	093K 049	PAPR -	RP	2797439	0.34

Rytuba, J.J. and Cargill, S.M. (1986): Grade and Tonnage Model of Silica-carbonate Hg; in Cox, D.P. and Singer, D.A., Editors, Mineral Deposit Models, *U.S. Geological Survey*, Bulletin 1693, pages 181-182.

Table 14. Grade and Tonnage Data for Cu Skarns - K01

Deposit Name	MINFILE #	Status		Tonnes	Cu%	Au g/t	Ag g/t
Lily	103B 028	PAPR -	RP	36085	2.56	3.80	64.3
Queen Victoria	082FSW082	PAPR -	P	45352	1.48	0.17	21.0
Oro De Noro	082ESE063	PAPR -	P	124001	1.36	0.94	7.7
Yreka	092L 052	PAPR -	P	145334	2.71	0.34	31.2
Emma	082ESE062	PAPR -	P	241538	0.97	0.88	10.1
Little Billie	092F 105	PAPR -	RP	245133	1.81	10.10	30.3
Blue Grouse	092C 017	PAPR -	P	249298	2.73	0	10.1
Marble Bay	092F 270	PAPR -	P	286028	2.37	5.40	44.1
Indian Chief	092E 011	PAPR -	RP	1973608	1.5	0.31	23.2
Oldsport, Benson Lake	092L 035	PAPR -	P	2721980	1.56	1.40	4.5
Mother Lode/Greyhound	082ESE034	PAPR -	RP	5457201	0.7	1.00	4.3
London	092JSE001	DEPR -	R	6500000	0.66	0	0
Phoenix, Knobhill	082ESE020	PAPR -	P	23000000	1.09	1.40	8.5
Craigmont	092ISE035	PROD -	RP	34000000	1.2	0	0.01

The USGS subdivided Cu skarns into two deposit types with two different grade and tonnage data sets (Jones and Menzie, 1986; Singer, 1986). These two USGS deposit types are combined as one deposit profile.

Jones, G.M., and Menzie, W.D. (1986): Grade and Tonnage Model of Cu Skarn Deposits; *in* Cox, D.P. and Singer, D.A., Editors, Mineral Deposit Models, *U.S. Geological Survey*, Bulletin 1693, pages 86-89.

Singer, D.A. (1986): Grade and Tonnage Model of Porphyry Cu, Skarn-related Deposits; *in* Cox, D.P. and Singer, D.A., Editors, Mineral Deposit Models, *U.S. Geological Survey*, Bulletin 1693, pages 82-85.

[1] *For complete and current data for the British Columbia deposits listed in this table please refer to the provincial MINFILE database.*

Table 15. Grade and Tonnage Data for Zn-Pb Skarns - K02

Deposit Name	MINFILE # or Country	Status		Tonnes	Zn %	Pb %	Cu%	Ag g/t	Au g/t
Caledonia	092L 061	DEPR -	RP	68001	7.45	0.06	6.04	704.1	0.01
McDame Belle	104P022	DEPR -	R	32652	2.70	3.70	0.3	288	0
Smith Copper (Main)	092L 208	DEPR -	R	83906	12.5	3.7	1.69	64.7	0
Dolores	Mexico			91000	3	2	0	480	0
Yangchiachangtze	China			136000	5	4	0	0	0
Kennecott	New Mexico, USA			136077	15	0	0	0	0
Rajabasa	Indonesia			250000	4	0	0	0	0
Aravipa	Arizona, USA			272000	5	6	0	45	0
Uchucchacua	Peru			354000	2	2	0	573	0
Washington Camp	Arizona, USA			454000	9	3	2	137	0
Garpenberg Norra	Sweden			490000	2	1	0	156	0
Nyseter	Norway			560000	5	0	0	0	0
Kalvbacken	Sweden			600000	8	4	0	100	0
Black Hawk	New Mexico, USA			677500	10	3	2	105	0
Svardsjo	Sweden			973000	5	2	1	111	1
Ryllshyttan	Sweden			1000000	14	6	0	54	0
Ulchin	South Korea			1270000	6	2	0	0	0
Shuihoushan	China			1500000	20	17	0	3	0
Parroquia-Magistral	Mexico			1850000	6	1	0	195	0
Stollberg	Sweden			2615000	3	3	0	0	0
Groundhog	New Mexico, USA			2700000	12	4	1	69	0
Tienpaoshan	China			3000000	6	5	2	0	0
Aguilar	Argentia			3600000	16	11	0	309	0
Meat Cove	Nova Scotia			3992000	4	0	0	0	0
Yeonhwa II	South Korea			4500000	4	1	0	0	0
Saxberget	Sweden			6579000	6	2	1	42	0
Ammeberg	Sweden			6762000	10	2	0	54	0
El Mochito	Honduras			7260000	8	4	0	137	0
Yeonhwa I	South Korea			7600000	6	2	0	0	0
Sala	Sweden			8000000	2	4	0	350	0
Garpenberg Odal	Sweden			9600000	5	4	0	86	1
Tetyukhe	Russia			18600000	6	5	0	0	0
Langban	Sweden			20000000	5	3	1	0	0

All the data for deposits from outside British Columbia listed in the table is from Singer *et al.* (1993) which was originally complied by Mosier (1986).

Mosier, D.L. (1986a): Grade and Tonnage Model of Zn-Pb Skarn Deposits; *in* Cox, D.P. and Singer, D.A., Editors, Mineral Deposit Models, *U.S. Geological Survey*, Bulletin 1693, pages 90-93.

Singer, D.A., Mosier, D.L. and Menzie, W.D. (1993): Digital Grade and Tonnage Data for 50 Types of Mineral Deposits; *U.S. Geological Survey*, Open File 93-280, digital file.

Table 16. Grade and Tonnage Data for Fe Skarns - K03[1]

Deposit Name	MINFILE #	Status		Tonnes	Fe %	Au g/t	Ag g/t	Cu%
Hiller 8-12	092L 301	DEPR -	R	180000	35	0	0	0
Apex	103B 008	DEPR -	R	272180	50	0	0	1
Glengarry	092E 001	PAPR -	RP	383699	36.4	0	0	0
Rose	103B 029	PAPR -	R	509000	40	0	0	0
Iron Duke	103B 001	DEPR -	R	528500	33	0	0	0
Magnet	103B 034	DEPR -	R	615070	43.4	0	0	0
Artlish	092L 068	DEPR -	R	635000	44.1	0	0	0.08
Iron Mike	092K 043	PAPR -	RP	864735	45.18	0	0	0
Churchill	092L 031	DEPR -	R	925700	45	0	0	0
Mac	103B 019	DEPR -	R	1360800	45	0	0	0
Ford	092L 028	PAPR -	P	1739892	44.22	0	0	0
Iron Crown	092L 034	PAPR -	P	2175683	37.54	0	0	0
Merry Widow & Kingfisher	092L 044	PAPR -	P	3643967	27.36	0.07	0	0.12
Jedway (Jessie)	103B 026	PAPR -	P	4200000	52.42	0	0	0
Bugaboo	092C 022	DEPR -	R	4815000	55.2	0	0	0
Iron Hill	092F 075	PAPR -	RP	5155793	32.6	0	0	0
Wedeene	103I 014	DEPR -	R	5355028	22.1	0	0	0
Little Lake	092L 003	DEPR -	R	5921248	38.5	0	0	0.03
Jib	103B 020	DEPR -	R	7438220	49.45	0	0	0.02
Brynnor	092F 001	PAPR -	P	8480917	55.68	0	0	0
Max	104B 013	DEPR -	R	11000000	45	0	0	0
Texada	092F 106	PAPR -	P	20000000	33.03	0.04	1.2	0.12
Tasu	103C 003	PAPR -	RP	23000000	30.62	0.06	2.3	0.25

Mosier, D.L.,, and Menzie, W.D. (1986): Grade and Tonnage Model of Fe Skarn Deposits; *in* Cox, D.P. and Singer, D.A., Editors, Mineral Deposit Models, *U.S. Geological Survey*, Bulletin 1693, pages 94-97.

[1] *For complete and current data for the deposits listed in this table please refer to the provincial MINFILE database.*

Table 17. Grade and Tonnage Data for Au Skarns - K04[1]

Deposit Name	MINFILE # or Country	Status		Tonnes	Au g/t	Ag g/t	Cu%
Silverado	092E 017	PAPR -	P	130	43.0	79.2	0.07
Marshall	082ESE031	PAPR -	P	190	77.0	92.8	0.24
Molly B	103P 085	PAPR -	P	290	2.0	4.5	0.13
Good Hope	092HSE060	PAPR -	RP	11400	15.6	10.5	0.01
Discovery	103G 025	DEPR -	R	38000	17.0	0	0
French	092HSE059	PAPR -	RP	82045	19.9	2.6	0.03
Dividend-Lakeview	082ESW001	PAPR -	P	111252	4.5	0.8	0.06
Tillicum	082FNW234	DEPR -	RP	1309726	9.3	0.0	0
Fortitude	Nevada, USA	PAPR -		5100000	14.0	27.8	0.2
Buckhorn Mountain	Washington, USA			7200000	4	0	0
Nickel Plate	092HSE038	PROD -	RP	13400000	5	1	0
McCoy	Nevada, USA	PROD -		15000000	2	30	0.1

The data for the deposits located in the United States was provided by Gerry Ray (personal Communication).

[1] *For current data for the British Columbia deposits listed in this table please refer to the provincial MINFILE database.*

Table 18. Grade and Tonnage Data for Alkalic Porphyry Cu-Au - L03[1]

Deposit Name	MINFILE #	Status		Tonnes	Cu %	Au g/t	Ag g/t	Mo %
Iron Mask	092INE010	PAPR -	P	165555	1.48	0.71	2.8	0
Voight	092HSE020	DEPR -	RP	220394	0.5	1.80	0	0
Col	093N 101	DEPR -	R	2032000	0.6	0	0	0
Misty	093N 001	DEPR -	R	3000000	0.6	0	0	0
Galaxy	092INE007	PAPR -	RP	3174898	0.65	0.21	0	0
Rainbow	092INE028	DEPR -	R	4467000	0.66	0	4	0
Virginia	092HSE242	PAPR -	R	6260000	0.36	0.17	0	0
Tam	093N 093	DEPR -	R	7000000	0.6	0	0	0
Rondah	093N 005	DEPR -		9072000	0.7	0	0	0
Lorraine	093N 002	DEPR -	R	10000000	0.67	0.21	0	0
Alabama	092HSE013	DEPR -	R	20000000	0.31	0.16	0	0
Primer (North Zone)	092HNE056	DEPR -	R	23000000	0.2	0	0	0
Copper Mountain	092HSE001	PROD -	RP	32000000	0.75	1.20	17.0	0
Copper Canyon	104G 017	DEPR -	R	32400000	1	1	17	0
Ingerbelle	092HSE004	PROD -	RP	43000000	0.37	0.17	0.7	0
Chuchi	093N 159	DEPR -	R	50000000	0.22	0.25	0	0
Afton/Pothook/Ajax	092INE023	PAPR -	P	54900000	0.63	0.47	2.1	0
Axe	092HNE040	DEPR -	R	58000000	0.5	0	0	0
Mount Polley	093A 008	DEPR -	R	81500000	0.31	0.41	0	0
Galore Creek	104G 090	DEPR -	R	125000000	1.06	0.40	7.7	0
Mount Milligan	093N 194	DEPR -	R	329000000	0.22	0.45	0	0

Alkalic porphyry deposits were first identified in British Columbia as a distinct deposit type (Barr *et al.*, 1976). Some of these deposits, such as Copper Mountain, do include mineralization which has been called skarn by some geologists.

Barr, D.A., Fox, P.E., Northcote, K.E. and Preto, V.A. (1976): The Alkaline Suite Porphyry Deposits - A Summary; *in* Porphyry Deposits of the Canadian Cordillera, Sutherland Brown, A., Editor, *Canadian Institute of Mining and Metallurgy*, Special Volume 15, pages 359-367.

[1] *For complete and current data for the British Columbia deposits listed in this table please refer to the provincial MINFILE database.*

Table 19. Grade and Tonnage Data for Porphyry Cu±Mo±Au - L04[1]

Deposit Name	MINFILE #	Status		Tonnes	Cu %	Mo %	Au g/t	Ag g/t
Taseko (Empress)	092O 033	DEPR -	R	9501800	0.58	0	1	2
Ide - Am	092ISE088	DEPR -	R	11000000	0.23	0.01	0	0
Krain	092INE038	DEPR -	R	14000000	0.56	0.01	0	0
Ox Lake	093E 004	DEPR -	R	17000000	0.33	0.04	0	0
Big Onion	093L 124	DEPR -	R	18000000	0.36	0	0	0
Nanika	093E 055	DEPR -	R	18000000	0.44	0.009	0.21	0.4
Rey	092ISE160	DEPR -	R	21000000	0.23	0.02	0	0
Red Dog	092L 200	DEPR -	R	25000000	0.35	0	0.44	0
Eagle	104I 008	DEPR -	R	30000000	0.41	0.01	0.20	2.7
Gnat Pass	104I 001	DEPR -	R	30000000	0.39	0	0	0
Swan	093N 073	DEPR -	R	36000000	0.2	0	0	0
Dorothy	093M 009	DEPR -	R	41000000	0.25	0.01	0	0
Ann	092ISE152	DEPR -	R	43300000	0.27	0	0	0
Louise Lake	093L 079	DEPR -	R	50000000	0.3	0.02	0.30	0
Granisle	093L 146	PAPR -	RP	66000000	0.42	0	0.13	1.3
Hi-Mars	092F 292	DEPR -	R	82000000	0.3	0	0	0
Morrison	093M 007	DEPR -	R	86000000	0.42	0	0.34	3.4
Huckleberry	093E 037	DEPR -	R	91200000	0.52	0.014	2.80	0.1
Gambier Island	092GNW025	DEPR -	R	114000000	0.29	0.01	0	1.0
Kemess North	094E 021	DEPR -	R	173000000	0.18	0	0.34	0.0
Whiting Creek	093E 112	DEPR -	R	124000000	0.06	0.03	0	0
Highmont	092ISE013	PAPR -	RP	125000000	0.22	0.02	0	0
Bethlehem	092ISE001	PAPR -	P	134000000	0.44	0	0.01	0.7
Kerr	104B 191	DEPR -	R	135000000	0.76	0	0	0
Catface	092F 120	DEPR -	R	138000000	0.46	0	0.05	0
Bell Copper	093M 001	PAPR -	RP	143000000	0.42	0	0.20	0.5
Poplar	093L 239	DEPR -	R	144000000	0.37	0.02	0	0
O.K.	092K 008	DEPR -	R	155000000	0.39	0.02	0	0
Poison Mountain	092O 046	DEPR -	R	159000000	0.33	0.01	0.31	0
Hushamu	092L 240	DEPR -	R	173000000	0.27	0.01	0.34	0
Maggie	092INW015	DEPR -	RP	181000000	0.28	0.03	0	0
Brenda	092HNE047	PAPR -	P	183000000	0.25	0.04	0.01	1.1
Kemess South	094E 094	DEPR -	R	200000000	0.22	0	0.63	0
Berg	093E 046	DEPR -	R	238000000	0.39	0.03	0.05	2.8
Ja	092ISE149	DEPR -	R	260000000	0.43	0.02	0	0
Island Copper	092L 158	PROD -	RP	373000000	0.37	0.017	0.11	0.9
Gibraltar	093B 012	PROD -	RP	965000000	0.32	0.01	0.07	0.2
Fish Lake	092O 041	DEPR -	R	976000000	0.25	0	0.48	0
Schaft Creek + Nabs	104G 015	DEPR -	R	1000000000	0.3	0.02	0.14	1.2
Highland Valley Copper	092ISW012	PROD -	RP	1200000000	0.372	0.01	0.005	1.7

[1] *For complete and current data for the British Columbia deposits listed in this table please refer to the provincial MINFILE database.*

Table 19. Grade and Tonnage Data for Porphyry Cu±Mo±Au - L04

Gold recoveries for these deposits are moderate, therefore, production grades are typically significantly lower than reserve grades. Unlike some of the deposits in the USGS dataset which include parts "which could be considered skarn", the British Columbia porphyry Cu±Mo±Au (L04) deposits do not contain significant amounts of skarn ore.

Relatively few of the province's porphyry deposits are overlain by significant weathering profiles with significant supergene or oxidized ore zones because most of British Columbia has been glaciated. The principle exceptions are Berg, South Kemess, Gibraltar, Bell, Krane and Afton. Therefore, the BCGS dataset contrasts markedly with the grade and tonnages for deposits from the southwest United States (Singer, D.A., Mosier, D.L. and Cox, D.P., 1986) which do include substantial resources of supergene or oxidized ore. More recently Menzie and Singer (1993) have published a grade and tonnage model for porphyry copper deposits in British Columbia and Alaska.

Singer, D.A., Mosier, D.L. and Cox, D.P. (1986): Grade and Tonnage model of Porphyry Cu; *in* Cox, D.P. and Singer, D.A., Editors, Mineral deposit models, *U.S. Geological Survey,* Bulletin 1693, pages 190-197.

Menzie, W.D., and Singer, D.A. (1993): Grade and Tonnage Model for Porphyry Cu Deposits in British Columbia, Canada, and Alaska, United States; *U.S. Geological Survey,* Open-File Report 93-275, 8 pages.

Table 20. Grade and Tonnage Data for Porphyry Mo (Low F-type) - L05[1]

Deposit Name	MINFILE # or Country	Status		Tonnes	Mo %
Stewart 2	082FSW229	DEPR -	R	204000	0.22
Roundy Creek	103P 113	DEPR -	R	8385000	0.09
Tidewater	103P 111	PAPR -	RP	9000347	0.06
Boss Mountain	093A 001	PAPR -	RP	11000000	0.18
Joem	104P 059	DEPR -	R	12000000	0.09
Lucky Ship	093L 053	DEPR -	R	18000000	0.1
Gem	092HNW001	DEPR -	R	23000000	0.1
Carmi Moly	082ENW036	DEPR -	R	20700000	0.064
Mount Thomlinson	093M 080	DEPR -	R	41000000	0.07
Serb Creek	093L 083	DEPR -	R	41000000	0.05
Trout Lake	082KNW087	DEPR -	R	50000000	0.14
Redbird	093E 026	DEPR -	R	64000000	0.1
Glacier Gulch	093L 110	DEPR -	R	90000000	0.17
Bell Moly	103P 234	DEPR -	R	96000000	0.05
Kliyul	094D 113	DEPR -	R	100000000	0.06
Storie	104P 069	DEPR -	R	101000000	0.08
Kitsault	103P 120	PAPR -	RP	113000000	0.1
Adanac	104N 052	DEPR -	R	152000000	0.06
Ajax	103P 223	DEPR -	R	179000000	0.07
Red Mountain	Yukon	DEPR -		187000000	0.1
Mt. Ogden	104K 013	DEPR -	R	217704000	0.17
Endako	093K 006	PROD -	RP	513000000	0.07
Quartz Hill	Alaska, USA	DEPR -	R	1600000000	0.08

The Red Mountain data is from Brown and Kahlert (1995) and the Quartz Hill figures are from Wolfe (1995). Some grade and tonnage data has been converted from MoS_2% to Mo% by multiplying by 0.5995.

Brown. P. and Kahlert, B. (1995): Geology and Mineralization of the Red Mountain Porphyry Molybdenum Deposit, south-central Yukon, *in* Schroeter, T.G., Editor, Porphyry Deposits of the Northwestern Cordillera of North America, *Canadian Institute of Mining, Metallurgy and Petroleum*, Special Volume 46, pages 747-756.

Menzie, W.D., and Theodore, T.G. (1986): Grade and Tonnage Model of Porphyry Mo, Low-F; *in* Cox, D.P. and Singer, D.A., Editors, Mineral Deposit Models, *U.S. Geological Survey*, Bulletin 1693, pages 120-122.

Wolfe, W.J. (1995): Exploration and Geology of the Quartz Hill Molybdenum Deposit, southeast Alaska, *in* Schroeter, T.G., Editor, Porphyry Deposits of the Northwestern Cordillera of North America, *Canadian Institute of Mining, Metallurgy and Petroleum*, Special Volume 46, pages 764-770.

[1] *For complete and current data for the British Columbia deposits listed in this table please refer to the provincial MINFILE database.*

Table 21. Grade and Tonnage Data for Broken Hill-type Pb-Zn-Ag+/-Cu - S01

Deposit Name	MINFILE # or Country	Status		Tonnes	Zn %	Pb %	Ag g/t	Au g/t	Cu %
Garpenberg	Sweden	PAPR		220000	5.0	4.0	130	0	0.4
Cottonbelt	082M 086	DEPR -	R	726000	2	6	50.0	0	0
Pinnacles	Australia	DEPR -	R	800000	2.5	10.0	420	0	0.00
CK	082M 224	DEPR -	R	1500000	0	8.6	8.6	0	1.4
Kingfisher	082LNE007	DEPR -	RP	1632616	2.6	0.58	0	0	0
River Jordan	082M 001	DEPR -	R	2600000	0	5.6	37.7	0	5.1
Saxberget	Sweden			4500000	6.8	2.1	42	0	0.9
Ruddock Creek	082M 084	DEPR -	R	5000000	7.5	2.5	0	0	0
Sala	Sweden			5000000	2.0	4.2	350	0	0.7
Big Ledge	082LSE012	DEPR -	R	6500000	4	0	0	0	0
Zinkgruvan	Sweden	PROD?		40000000	10.0	5.5	100	0	0.0
Broken Hill	South Africa	PROD		85000000	1.8	3.6	48	0	0.34
Black Mountain	South Africa	DEPR?		82000000	0.6	2.7	30	0	0.75
Big Syncline	South Africa	DEPR?		101000000	2.5	1.0	13	0	0.09
Gamsberg	South Africa	DEPR?		150000000	7.1	0.6	6	0	0.02
Broken Hill	Australia	PROD -	PR	280000000	8.5	10.0	148	0	0.14

Information for foreign deposits is derived from Parr and Plimer (1993).

Parr, J.M. and Plimer, I.R. (1993): Models for Broken Hill-type Lead-zinc-silver Deposits; in Kirkham, R.V., Sinclair, W.D., Thorpe, R.I. and Duke, J.M., Editors, Mineral Deposit Modeling, Geological Association of Canada, Special Paper 40, pages 253-288.

APPENDIX I

LISTING OF DEPOSIT PROFILES BY DEPOSIT GROUP AND COMMODITY

Table 22. Listing of British Columbia Deposit Profiles by Deposit Group

BC PROFILE #	DEPOSIT TYPE	APPROXIMATE SYNONYMS	U.S.G.S. MODEL #
A - ORGANIC			
A01	Peat		--
A02	Lignite	"Brown coal"	--
A03	Sub-bituminous coal	Thermal coal, Black lignite	--
A04	Bituminous coal	Coking coal, Thermal coal	--
A05	Anthracite	Stone coal	--
B - RESIDUAL/SURFICIAL			
B01*	Laterite Fe	Gossan Fe	--
B02*	Laterite Ni		38a
B03*	Laterite-Saprolite Au	Eluvial placers	38g
B04*	Bauxite Al	Lateritic bauxite	38b
B05	Residual kaolin	Primary kaolin	38h*
B07*	Bog Fe, Mn, U, Cu, Au		--
B08	Surficial U	"Calcrete U"	--
B09*	Karst-hosted Fe, Al, Pb-Zn		--
B10	Gossan Au-Ag	Residual Au; Precious metal gossans	--
B11*	Marl		
B12*	Sand and Gravel		
C - PLACER			
C01	Surficial placers	Placer Au-PGE-Sn-diamond-mag-gar-gems	39a to e
C02	Buried-channel placers	Paleochannel placers	39a to e
C03	Marine placers	Off-shore heavy mineral sediments	39f*?
C04*	Paleoplacer U-Au-PGE-Sn-Ti-diam-mag-gar-zir	Quartz pebble conglomerate Au-U	29a
D- CONTINENTAL SEDIMENTS AND VOLCANICS			
D01	Open-system zeolites		25oa
D02	Closed-basin zeolites		25ob
D03	Volcanic redbed Cu	Basaltic Cu	23
D04	Basal U		--
D05*	Sandstone U	Roll front U, Tabular U	30c
D06	Volcanic-hosted U	"Epithermal" U, Volcanogenic U	25f
D07	Iron oxide breccias & veins ±P±Cu±Au±Ag±U	Olympic Dam type, Kiruna type	29b,25i

BC PROFILE #	GLOBAL EXAMPLES Deposit (Province, State or Country)	B.C. EXAMPLES
	A- ORGANIC	**Version 2.1**
A01	Ireland, Ontario, New Brunswick	Fraser Delta, North Coast
A02	Estevan (Saskatchewan)	Skonun Point (Graham Island)
A03	Highvale (Alberta), Powder River Basin (Wyoming)	Hat Creek, Princeton
A04	Gregg River (Alberta), Sydney Coalfield (Nova Scotia)	Quintette, Bullmoose, Greenhills, Fording
A05	Pennsylvannia Coalfields, Canmore (Alberta)	Mt Klappan
	B - RESIDUAL/SURFICIAL	
B01*	Glenravel (Ireland)	
B02*	Riddle (Oregon), Mt. Vernon (Washington)	
B03*	Mt. Gibson (Australia), Akaiwang (Guyana)	
B04*	Queensland, Pocos de Caldas (Brazil), Salem Hills (Oregon)	Florence (Sooke)
B05	Germany, North Carolina, Idaho	Lang Bay, Sumas Mountain
B07*	Trois Riviéres (Québec)	Whipsaw Creek, Limonite Creek, Iron King
B08	Flodelle Creek (Washington)	Prairie Flats
B09*	Transvaal (Pb-Zn, South Africa), Sardinia (Pb-Zn), Jamaica (Al)	Villalta (Fe)
B10	Rio Tinto (Spain)	Villalta
B11*		Cheam Lake (Chiliwack)
B12*		
	C- PLACER	
C01	North Saskatchewan River (Saskatchewan), Nome (Alaska)	Fraser River, Quesnel River, Graham Island
C02	Livingstone Creek (Yukon), Valdez Creek (Alaska)	Williams Creek, Otter Creek, Bullion mine
C03	New South Wales & Queensland (Australia)	Middlebank (off north end of Vancouver Island)
C04*	Elliot Lake & Blind River (Ontario), Witwatersrand (S. Africa)	Mulvehill
	D - CONTINENTAL SEDIMENTS AND VOLCANICS	
D01	Ash Meadows (California), John Day Formation (Oregon)	Princeton Basin, Cache Creek area
D02	Bowie (Arizona), Lake Magadi (Kenya)	
D03	Keewenaw (Michigan), Coppermine (Northwest Territories)	Sustut Copper, Shamrock, NH
D04	Sherwood (Washington)	Blizzard, Tyee
D05*	Colorado Plateau, Grants (New Mexico)	
D06	Marysvale (Utah), Aurora (Oregon)	Rexspar, Bullion (Birch Island)
D07	El Romeral (Chile), Sue-Dianne (Northwest Territories)	Iron Range

Table 22. Listing of British Columbia Deposit Profiles by Deposit Group

BC PROFILE #	DEPOSIT TYPE	APPROXIMATE SYNONYMS	U.S.G.S. MODEL #
	E - SEDIMENT-HOSTED		
E01*	Almaden Hg	Carbonate-hosted Au-Ag	27b
E02*	Kipushi Cu-Pb-Zn	Carbonate-hosted Cu-Pb-Zn	32c
E03	Carbonate-hosted disseminated Au-Ag	Carlin-type Au, Sediment-hosted micron Au	26a,19c
E04	Sediment-hosted Cu	Sediment-hosted stratiform Cu	30b
E05	Sandstone Pb		30a
E06	Bentonite	Volcanic clay, Soap clay	28e?*
E07*	Sedimentary kaolin	"Secondary" kaolin	31k*
E08	Carbonate-hosted talc	Dolomite-hosted talc	18?i*
E09	Sparry magnesite	Veitsch-type, carbonate-hosted magnesite	18i*
E10	Carbonate-hosted barite	Mississippi Valley-type barite	- -
E11	Carbonate-hosted fluorspar	Mississippi Valley-type fluorite	32d*
E12	Mississippi Valley-type Pb-Zn	Carbonate-hosted Pb-Zn, Appalachian Zn	32a/32b
E13	Irish-type carbonate-hosted Zn-Pb	Kootenay Arc-type Zn-Pb, Remac-type	- -
E14	Sedimentary exhalative Zn-Pb-Ag	Sedex, Sediment-hosted massive sulphide	31a
E15	Blackbird sediment-hosted Cu-Co	Sediment-hosted Cu-Co massive sulphide	24d
E16	Shale-hosted Ni-Zn-Mo-PGE	Sediment-hosted Ni	- -
E17	Sediment-hosted barite	Bedded barite	31b
	F - CHEMICAL SEDIMENT		
F01	Sedimentary Mn		34b
F02	Bedded gypsum	Marine evaporite gypsum	35ae
F03	Gypsum-hosted sulphur	Frasch sulphur	- -
F04*	Bedded celestite		35aa*
F05*	Palygorskite	Attapulgite	34e*
F06	Lacustrine diatomite	Diatomaceous earth, Kieselguhr	31s
F07	Upwelling-type phosphate		34c
F08	Warm current-type phosphate		34d
F09*	Playa and Alkaline Lake Evaporites	Hydromagnesite, Na carbonate lake brines	35ba,bm(T)
F10*	Lake Superior & Rapitan types iron-formation		34a
F11*	Ironstone	Minette ores	34f
	G - MARINE VOLCANIC ASSOCIATION		
G01	Algoma-type iron-formation		28b
G02	Volcanogenic Mn		24c
G03*	Volcanogenic anhydrite / gypsum		- -
G04	Besshi massive sulphide Cu-Zn	Kieslager	24b
G05	Cyprus massive sulphide Cu (Zn)		24a
G06	Noranda / Kuroko massive sulphide Cu-Pb-Zn		28a
G07	Subaqueous hot spring Ag-Au		- -

BC PROFILE #	GLOBAL EXAMPLES Deposit (Province, State or Country)	B.C. EXAMPLES
	E - SEDIMENT-HOSTED	**Version 2.1**
E01*	Almaden (Spain), Santa Barbara (Peru)	
E02*	Tsumeb (Namibia), Kipushi (Zaire), Ruby Creek (Alaska)	
E03	Brewery Creek? (Alaska), Carlin, Getchell & Cortez (Nevada)	Golden Bear ?
E04	Kupferschiefer (Germany & Poland), White Pine (Michigan)	Roo, Commerce, Chal 4
E05	Laisvall (Sweden), George Lake (Saskatchewan)	
E06	Black Hills (Wyoming), Rodalquilar (Spain)	Parton River, Princeton, Quilchena
E07*	Cordova District (Alabama), Ozark Region (Missouri)	Sumas Mountain, Quinsam
E08	Treasure Mtn (Montana), Trimouns (France)	Red Mountain, Silver Dollar
E09	Eugui (Spain), Veitsch (Austria)	Mt. Brussilof, Driftwood Creek
E10	Illinois - Kentucky, Italian Alps	Muncho Lake
E11	Illinois - Kentucky, Italian Alps	Liard Fluorite
E12	Viburnum Trend (Missouri), Pine Point (Northwest Territories)	Robb Lake, Monarch
E13	Navin, Lisheen & Tynagh (Ireland), Troya (Spain)	Reeves MacDonald, HB, Jersey, Duncan
E14	Mount Isa (Australia), Faro & Grum (Yukon)	Sullivan, Cirque, Driftpile
E15	Blackbird & Sheep Creek (Montana), Boleo (Mexico)	
E16	Nick (Yukon), Tianeshan & Zunyi (China)	
E17	Tea (Yukon), Magcobar (Ireland)	Kwadacha
	F - CHEMICAL SEDIMENT	
F01	Molongo (Mexico), Atasu (Kazakhstan), Kalahari (South Arica)	
F02	Paris Basin (France), Appalachian Basins (New York)	Lussier River, Windermere
F03	Texas, Louisiana, Poland, Coronation (Alberta)	Trutch area
F04*	Lake Enon (Nova Scotia), Mexico, Germany	Kitsault Lake
F05*	Metalline Falls (Washington)	
F06	Juntura and Trout Ck Formations (Oregon), Lake Myvatn (Iceland)	Crownite Formation (Quesnel)
F07	Phosphoria Formation (Idaho), Meskala (Morocco)	Fernie synclinorium
F08	Athabaska Basin (Saskatchewan), Florida	
F09*		Milk River
F10*	Mesabi Ranges (Minnesota), Mackenzie Mountains (Yukon)	
F11*	Clinton Formation (Alabama), France, Germany	Peace River region
	G - MARINE VOLCANIC ASSOCIATION	
G01	Vermillion iron formation (Minnesota), Helen mine (Ontario)	Falcon, Lady A
G02	Olympic Mountains (Washington), Nicoya (Costa Rica)	
G03*		Britannia, Falkland
G04	Besshi (Japan), Greens Creek (Alaska)	Goldstream, Windy Craggy, Standard
G05	Mavrovouni (Cyprus), Lasail (Oman)	Anyox camp, Chu Chua, Lang Creek?
G06	Horne & Millenbach (Québec), Kuroko District (Japan)	Britannia, Kutcho Creek, Myra Falls
G07	Osorezan (Japan)	Eskay Creek

Table 22. Listing of British Columbia Deposit Profiles by Deposit Group

BC PROFILE #	DEPOSIT TYPE	APPROXIMATE SYNONYMS	U.S.G.S. MODEL #
	H - EPITHERMAL		
H01	Travertine	Tufa	35d*
H02	Hot spring Hg		27a
H03	Hot spring Au-Ag		25a
H04	Epithermal Au-Ag-Cu; high sulphidation	Acid-sulphate, qtz-alunite Au, Nansatsu-type	25d
H05	Epithermal Au-Ag; low sulphidation	Adularia-sericite epithermal	25c
H06*	Epithermal Mn		25g
H07	Sn-Ag veins	Polymetallic Sn veins	25h, 20b
H08	Alkalic intrusion-associated Au	Alkalic intrusion-related Au, Au-Ag-Te veins	22b
H09*	Hydrothermal alteration clays-Al-Si	Kaolin, Alunite, Siliceous cap, Pyrophyllite	25lb*
	I - VEIN, BRECCIA AND STOCKWORK		
I01	Au-quartz veins	Mesothermal, Motherlode, saddle reefs	36a
I02	Intrusion-related Au pyrrhotite veins	Subvolcanic shear-hosted gold	- -
I03	Turbidite-hosted Au veins	Meguma type	36a
I04	Iron formation-hosted Au	Iron formation-hosted gold	36b
I05	Polymetallic veins Ag-Pb-Zn±Au	Felsic intrusionassociated Ag-Pb-Zb veins	22c, 25b
I06	Cu±Ag quartz veins	Churchill-type vein Cu	?
I07*	Silica veins		- -
I08	Silica-Hg carbonate		27c
I09	Stibnite veins and disseminations	Simple and disseminated Sb deposits	27d,27e
I10	Vein barite		IM27e
I11	Barite-fluorite veins		26c*
I12*	W veins	Quartz-wolframite veins	15a
I13*	Sn veins and greisens		15b, 15c
I14	Five-element veins Ni-Co-As-Ag±(Bi, U)	Ni-Co-native Ag veins, cobalt-type veins	- -
I15	"Classical" U veins	Pitchblende veins, vein uranium	
I16	Unconformity-associated U	Unconformity-veins, Unconformity U	37a
I17	Cryptocrystalline magnesite veins	Bone magnesite, Kraubath-type magnesite	- -
	J - MANTO		
J01	Polymetallic manto Ag-Pb-Zn	Polymetallic replacement deposits	19a
J02	Manto and stockwork Sn	"Replacement Sn", Renison-type	14c
J03*	Mn veins and replacements	covered by I05 and J01	19b
J04	Sulphide manto Au	Au-Ag sulphide mantos	- -

BC PROFILE #	GLOBAL EXAMPLES Deposit (Province, State or Country)	B.C. EXAMPLES
	H - EPITHERMAL	**Version 2.1**
H01	Gardiner (Montana), Salida (Colorado), Lazio (Italy)	Clinton, Slocan, Deep River
H02	Sulphur Bank (California), Steamboat Springs (Nevada)	Ucluelet
H03	McLaughlin (California), Round Mountain (Nevada)	Cinola, Clisbako, Wolf?, Trout?
H04	El Indio (Chile), Nansatsu (Japan)	Westpine, Taylor-Windfall, Mt. McIntosh
H05	Comstock (Nevada), Sado (Japan)	Lawyers, Blackdome, Silbak Premier
H06*	Talamantes (Mexico), Gloryana (New Mexico)	
H07	Black Range (New Mexico), Potosi (Bolivia), Ashio (Japan)	D Zone and Lang Creek (Cassiar)
H08	Emperor (Fiji), Cripple Creek (Colorado), Zortman (Montana)	Flathead, Howell, Howe
H09*	Cornwall (England)	Monteith Bay, Pemberton Hills
	I - VEIN, BRECCIA AND STOCKWORK	
I01	Alaska-Juneau (Alaska), Campbell, Dome(Ontario)	Bralorne, Erickson, Polaris-Taku
I02		Scottie, Snip, Johnny Mountain, Iron Colt
I03	Ballarat (Australia), Meguma (Nova Scotia)	Frasergold, Reno, Queen, Island Mountain
I04	Homestake (South Dakota)	
I05	Elsa (Yukon), Coeur d'Alene (Idaho), Creede (Colorado)	Silver Queen, Beaverdell, Silvana, Lucky Jim
I06	Nikolai (Alaska), Bruce Mines (Ontario), Butte (Montana)	Davis-Keays, Churchill Copper, Bull River
I07*		Granby Point
I08	Red Devil? (Alaska), New Almaden, New Idria (California)	Pinchi, Bralorne Takla, Silverquick
I09	Becker-Cochran (Yukon), Lake George (New Brunswick)	Minto, Congress, Snowbird
I10	Matchewan (Ontario), Jbel Ighoud (Morocco)	Parson. Brisco, Fireside
I11	St. Lawrence (Newfoundland), Mongolian fluorite belt	Rock Candy, Eaglet
I12*	Pasto Bueno (Peru), Carrock Fell (England)	
I13*	Cornwall (England), Lost River (Alaska)	Duncan Lake
I14	Cobalt camp (Ontario), Erzgebirge district (Germany)	
I15	Beaverlodge area (Saskatchewan), Schwartzwalder (Colorado)	Purple Rose, Fisher, Dixie
I16	Rabbit Lake, Key Lake (Saskatchewan), Jabiluka (Australia)	
I17	Chalkidiky area (Greece), Kraubath (Austria)	Sunny, Pinchi Lake
	J - MANTO	
J01	East Tintic district (Utah), Naica (Mexico), Sa Dena Hess (Yukon)	Bluebell, Midway
J02	Renison Bell & Cleveland (Australia), Dachang district (China)	
J03*	Lake Valley (New Mexico), Phillipsburg (Montana)	
J04	Ketza River (Yukon)	Mosquito Creek , Island Mountain

Table 22. Listing of British Columbia Deposit Profiles by Deposit Group

BC PROFILE #	DEPOSIT TYPE	APPROXIMATE SYNONYMS	U.S.G.S. MODEL #
	K - SKARN		
K01	Cu skarns		18a,b
K02	Pb-Zn skarns		18c
K03	Fe skarns		18d
K04	Au skarns		18f*
K05	W skarns		14a
K06	Sn skarns		14b
K07	Mo skarns		- -
K08	Garnet skarns		- -
K09	Wollastonite skarns		18g
	L - PORPHYRY		
L01	Subvolcanic Cu-Ag-Au (As-Sb)	Enargite Au, Transitional Au-Ag	22a/25e
L02*	Porphyry-related Au	Granitoid Au, Porphyry Au	20d
L03	Alkalic porphyry Cu-Au	Diorite porphyry copper	- -
L04	Porphyry Cu ± Mo ± Au	Calcalkaline porphyry	17,20,21a1
L05	Porphyry Mo (Low F- type)	Calcalkaline Mo stockwork	21b
L06	Porphyry Sn	"Subvolcanic tin"	20a
L07	Porphyry W	Stockwork W-Mo	21c*
L08	Porphyry Mo (Climax-type)	Granite molybdenite	16
	M - ULTRAMAFIC / MAFIC		
M01*	Flood Basalt-Associated Ni-Cu	Basaltic subvolcanic Cu-Ni-PGE	5a/5b
M02	Tholeiitic intrusion-hosted Ni-Cu	Gabbroid-associated Ni-Cu	7a
M03	Podiform chromite		8a/8b
M04	Magmatic Fe-Ti±V oxide deposits	Mafic intrusion-hosted Ti-Fe deposits	7b
M05	Alaskan-type Pt±Os±Rh±Ir	Zoned ultramafic, Uralian-type	9
M06	Ultramafic-hosted asbestos	Serpentinite-hosted asbestos	8d
M07	Ultramafic-hosted talc-magnesite		8f*
M08	Vermiculite deposits		- -
	N - CARBONATITES		
N01	Carbonatite-hosted deposits		10
N02*	Kimberlite-hosted diamonds	Diamond pipes	12
N03*	Lamproite-hosted diamonds		12
	O - PEGMATITE		
O01	Rare element pegmatite - LCT family	Zoned pegmatite (Lithium-Cesium-Tantalum)	13a*,b*
O02	Rare element pegmatite - NYF family	Niobium-Yttrium-Fluorine pegmatite	- -
O03	Muscovite pegmatite	Mica-bearing pegmatite	13f*
O04*	Feldspar-quartz pegmatite	Barren pegmatite	IM13g*,e*

BC PROFILE #	GLOBAL EXAMPLES Deposit (Province, State or Country)	B.C. EXAMPLES
	K - SKARN	**Version 2.1**
K01	Mines Gaspé (Québec), Carr Fork (Yukon)	Craigmont, Phoenix
K02	San Antonio (Mexico), Ban Ban (Australia)	Piedmont, Contact
K03	Shinyama (Japan), Cornwall (Pennsylvannia)	Tasu, Jessie, Merry Widow, HPH
K04	Fortitude (Nevada), Buckhorn Mountain (Washington)	Nickel Plate
K05	Cantung & Mactung (Yukon), Pine Creek (California)	Emerald Tungsten, Dimac
K06	Lost River (Alaska), JC (Yukon)	Daybreak
K07	Little Boulder Creek (Idaho), Mt. Tennyson (Australia)	Coxey, Novelty
K08		Crystal Peak
K09	Fox Knoll & Lewis (New York)	Mineral Hill, Rossland
	L - PORPHYRY	
L01	Lepanto (Philippines), Resck (Hungary), Kori Kollo (Bolivia)	Equity Silver, Thorn
L02*	Marte & Lobo (Chile), Lihir (Papua New Guinea)	Snowfields
L03	Tai Parit (Philippines)	Afton, Copper Mountain, Galore Creek
L04	Chuquicamata & La Escondida (Chile)	Highland Valley, Gibraltar
L05	Quartz Hill (Alaska)	Endako, Kitsault, Glacier Gulch
L06	Llallagua (Bolivia), Potato Hills (Yukon)	
L07	Logtung (Yukon), Xingluokeng (China)	Boya
L08	Climax & Henderson (Colorado)	
	M - ULTRAMAFIC / MAFIC	
M01*	Noril'sk (Russia), Duluth (Minnesota)	
M02	Lynn Lake (Manitoba), Kluane (Yukon)	Giant Mascot, Nickel Mountain
M03	Josephine ophiolite (Oregon), Coto (Philippines),	Castle Mountain, Scottie Creek
M04	Lac Tio & Magpie (Quebec), Tellnes (Norway)	Lodestone Mountain?, Tanglewood Hill?
M05	Red Mountain (Alaska), Tin Cup Peak (Oregon)	Tulameen Complex
M06	Thetford (Québec)	Cassiar, Kutcho
M07	Thetford & Magog (Québec), Deloro (Ontario)	
M08	Enoree (USA)	Fort Fraser area
	N - CARBONATITES	
N01	Palabora (South Africa), Mountain Pass (California)	Aley, Mount Grace tuff
N02*	Kimberley & Premier (South Africa)	Cross
N03*	Argyle (Australia)	
	O - PEGMATITE	
O01	Bikita Field (Zimbabwe), Blackhills (South Dakota)	
O02	South Platte district (Colorado), Bancroft (Ontario)	
O03	Rajahstan (India), Appalachian Province (USA)	
O04*	Buckingham (Québec)	

Table 22. Listing of British Columbia Deposit Profiles by Deposit Group

BC PROFILE #	DEPOSIT TYPE	APPROXIMATE SYNONYMS	U.S.G.S. MODEL #
P - METAMORPHIC-HOSTED			
P01	Andalusite hornfels		--
P02	Kyanite-sillimanite schists		--
P03	Microcrystalline graphite	"Amorphous" graphite	18k
P04	Crystalline flake graphite		37f
P05	Vein graphite	"Lump and chip" graphite	37g
P06	Corundum in aluminous metasediments		--
Q - GEMS AND SEMI-PRECIOUS STONES (diamonds under N)			
Q01	Jade		--
Q02	Rhodonite		--
Q03*	Agate		--
Q04*	Amethyst		--
Q05*	Jasper		--
Q06	Columbia-type emerald		31c
Q07	Schist-hosted emerald	Exometamorphic emerald deposit	--
Q08	Sediment-hosted opal	Australian-type opal	--
Q09	Gem corundum in contact zones		--
Q10	Gem corundum hosted by alkalic rocks		--
Q11	Volcanic-hosted opal		--
R - INDUSTRIAL ROCKS			
R01	Cement shale		--
R02	Expanding shale		--
R03	Dimension stone - granite		--
R04	Dimension stone - marble		--
R05	Dimension stone - andesite		--
R06*	Dimension stone - sandstone		30d*
R07	Silica sandstone	High-silica quartzite	30e*
R08*	Flagstone		--
R09	Limestone		--
R10*	Dolomite		--
R11*	Volcanic ash - pumice		--
R12*	Volcanic glass - perlite		IM25ka*
R13*	Nepheline syenite		--
R14*	Alaskite		--
R15*	Crushed rock	Road metal, Riprap, Railroad ballast	--
S - OTHER			
S01	Broken Hill type Pb-Zn-Ag±Cu	Shuswap-type, Ammeburg-type Pb-Zn	--

BC PROFILE #	GLOBAL EXAMPLES Deposit (Province, State or Country)	B.C. EXAMPLES
	P - METAMORPHIC-HOSTED	**Version 2.1**
P01	Bushveld (South Africa), Brittany (France)	Leech River
P02	Willis Mountain (Virginia), NARCO (Québec)	
P03	Keiserberg (Austria)	
P04	Lac Knife (Québec)	AA
P05	Calumet & Clot (Québec), Bogala (Sri Lanka)	
P06	Gallatin & Madison Counties (Montana)	
	Q - GEMS AND SEMI-RPECIOUS STONES (diamonds under N)	
Q01		Cry Lake, Ogden Mountain
Q02		Hill 60, Arthur Point, Cassiar
Q03*		
Q04*	Thunder Bay (Ontario), Artigas (Uruguay), Maraba (Brazil)	
Q05*		
Q06	Chivor and Muzo districts (Columbia)	
Q07	Habachtal (Austria), Leysdorp (South Africa), Socoto (Brazil)	
Q08	Coober Pedy (Australia)	
Q09	Umba (Tanzania), Kinyki Hill (Kenya)	
Q10	Yogo Gulch (Montana)	
Q11		
	R - INDUSTRIAL ROCKS	
R01		Dunsmuir shale, Sumas Mountain
R02	Wabamun shales (Alberta)	Nanaimo shale, Saturna Island
R03	Riviére á Pierre (Québec), Black Hills (South Dakota)	Nelson Island
R04	Vermont, Alabama, Georgia	Marblehead, Anderson Bay (Texada Island)
R05		Haddington Island
R06*		Saturna Island, Newcastle Island
R07		Moberley, Nicholson
R08*	Southowram (England)	Salmo, Revelstoke
R09		Texada Island, Quatsino Belt
R10*		Crawford Bay, Rock Creek
R11*		Meagher Mountain, Buse Lake
R12*		Frenier, Francois Lake
R13*	Blue Mountain (Ontario)	Trident Mountain
R14*	Spruce Pine alaskite (North Carolina)	
R15*		McAbbee, Gissome
	S- OTHER	
S01	Broken Hill (Australia), Aggeneys district (South Africa)	Cottonbelt, River Jordan, Ruddock Creek

Table 23. Listing of British Columbia Deposit Profiles by Commodity

Commodities	Deposit Type	BC Profile #
Ag	Gossan Au-Ag	B10
Ag	Carbonate-hosted disseminated Au-Ag	E03
Ag	Sediment-hosted Cu	E04
Ag	Mississippi Valley-type Pb-Zn	E12
Ag	Irish-type carbonate-hosted Zn-Pb	E13
Ag	Sedimentary Exhalative Zn-Pb-Ag	E14
Ag	Besshi massive sulphide Cu-Zn	G04
Ag	Noranda / Kuroko massive sulphide Cu-Pb-Zn	G06
Ag	Subaqueous hot spring Au-Ag	G07
Ag	Epithermal Au-Ag-Cu; high sulphidation	H04
Ag	Epithermal Au-Ag; low sulphidation	H05
Ag	Sn-Ag veins	H07
Ag	Alkalic intrusion-associated Au-Ag	H08
Ag	Intrusion-related Au pyrrhotite veins	I02
Ag	Polymetallic veins Ag-Pb-Zn±Au	I05
Ag	Five-element veins Ni-Co-As-Ag±(Bi,U)	I14
Ag	Polymetallic mantos Ag-Pb-Zn	J01
Ag	Sulphide manto Au	J04
Ag	Pb-Zn skarns	K02
Ag	Subvolcanic Cu-Au-Ag (As-Sb)	L01
Ag	Broken Hill-type Pb-Zn-Ag±Cu	S01
Ag*	Laterite-Saprolite Au	B03*
Ag*	Buried-channel placers	C02
Ag*	Marine placers	C03
Ag*	Volcanic redbed Cu	D03
Ag*	Iron oxide breccias and veins ±P±Cu±Au±Ag±U	D07
Ag*	Kipushi Cu-Pb-Zn	E02*
Ag*	Sandstone Pb	E05
Ag*	Carbonate-hosted barite	E10
Ag*	Carbonate-hosted fluorspar	E11
Ag*	Blackbird sediment-hosted Cu-Co	E15
Ag*	Cyprus massive sulphide Cu (Zn)	G05
Ag*	Hot spring Au-Ag	H03
Ag*	Au-quartz veins	I01
Ag*	Turbidite-hosted Au veins	I03
Ag*	Iron formation-hosted Au	I04
Ag*	Cu±Ag quartz veins	I06
Ag*	Silica-carbonate Hg	I08
Ag*	Vein barite	I10
Ag*	"Classical" U veins	I15
Ag*	Manto and stockwork Sn	J02
Ag*	Mn veins and replacements	J03*
Ag*	Cu skarns	K01
Ag*	Fe skarns	K03

Table 23. Listing of British Columbia Deposit Profiles by Commodity

Commodities	Deposit Type	BC Profile #
Ag*	Au skarns	K04
Ag*	Porphyry Cu-Au: alkalic	L03
Ag*	Porphyry Cu G486 Mo ± Au	L04
Ag*	Porphyry Sn	L06
Ag*	Porphyry W	L07
agate	Agate	Q03*
agate*	Opal deposits in volcanic sequences	Q11
aggregate	Sand and Gravel	B12*
aggregate	Expanding shale	R02
aggregate*	Dimension stone - granite	R03
aggregate*	Dimension stone - marble	R04
aggregate*	Dimension stone - andesite	R05
aggregate*	Dimension stone - sandstone	R06*
aggregate*	Limestone	R09
Al	Bauxite Al	B04*
Al	Karst-hosted Fe, Al, Pb-Zn	B09*
Al*	Playa and Alkaline Lake Evaporites	F09*
alunite	Hydrothermal alteration clays-Al-Si	H09*
amethyst	Amethyst	Q04*
analcime	Closed-basin zeolites	D02
andalusite	Andalusite schist and hornfels	P01
andalusite	Kyanite family minerals	P02
andesite	Dimension stone - andesite	R05
anhydrite	Volcanogenic anhydrite / gypsum	G03*
anhydrite*	Bedded gypsum	F02
apatite*	Magmatic Fe-Ti±V oxide deposits	M04
apatite*	Vermiculite deposits	M08
aquamarine*	Schist-hosted emerald deposits	Q07
As*	Volcanic-hosted U	D06
As*	Subaqueous hot spring Au-Ag	G07
As*	Epithermal Au-Ag-Cu; high sulphidation	H04
As*	"Classical" U veins	I15
As*	Subvolcanic Cu-Au-Ag (As-Sb)	L01
asbestos	Ultramafic-hosted asbestos	M06
Au	Laterite-Saprolite Au	B03*
Au	Gossan Au-Ag	B10
Au	Surficial placers	C01
Au	Buried-channel placers	C02
Au	Marine placers	C03
Au	Paleoplacer U-Au-PGE-Sn-Ti-diam-mag-gar-zir	C04*
Au	Iron oxide breccias and veins ±P±Cu±Au±Ag±U	D07
Au	Carbonate-hosted disseminated Au-Ag	E03
Au	Noranda / Kuroko massive sulphide Cu-Pb-Zn	G06
Au	Subaqueous hot spring Au-Ag	G07
Au	Hot spring Au-Ag	H03

Table 23. Listing of British Columbia Deposit Profiles by Commodity

Commodities	Deposit Type	BC Profile #
Au	Epithermal Au-Ag-Cu; high sulphidation	H04
Au	Epithermal Au-Ag; low sulphidation	H05
Au	Alkalic intrusion-associated Au-Ag	H08
Au	Au-quartz veins	I01
Au	Intrusion-related Au pyrrhotite veins	I02
Au	Turbidite-hosted Au veins	I03
Au	Iron formation-hosted Au	I04
Au	Sulphide manto Au	J04
Au	Au skarns	K04
Au	Subvolcanic Cu-Au-Ag (As-Sb)	L01
Au	Porphyry-related Au	L02*
Au	Porphyry Cu-Au: alkalic	L03
Au	Porphyry Cu ± Mo ± Au	L04
Au*	Bog Fe, Mn, U, Cu, Au	B07*
Au*	Volcanic-hosted U	D06
Au*	Sediment-hosted Cu	E04
Au*	Blackbird sediment-hosted Cu-Co	E15
Au*	Shale-hosted Ni-Zn-Mo-PGE	E16
Au*	Besshi massive sulphide Cu-Zn	G04
Au*	Cyprus massive sulphide Cu (Zn)	G05
Au*	Hot-spring Hg	H02
Au*	Sn-Ag veins	H07
Au*	Polymetallic veins Ag-Pb-Zn±Au	I05
Au*	Cu±Ag quartz veins	I06
Au*	Silica veins	I07*
Au*	Silica-carbonate Hg	I08
Au*	Stibnite veins and disseminations	I09
Au*	Unconformity-associated U	I16
Au*	Polymetallic mantos Ag-Pb-Zn	J01
Au*	Cu skarns	K01
Au*	Pb-Zn skarns	K02
Au*	Fe skarns	K03
Au*	Mo skarns	K07
Au*	Gabbroid Ni-Cu-PGE	M02
Au*	Broken Hill-type Pb-Zn-Ag±Cu	S01
barite	Carbonate-hosted barite	E10
barite	Mississippi Valley-type Pb-Zn	E12
barite	Sedimentary-hosted stratiform barite	E17
barite	Vein barite	I10
barite	Vein fluorite-barite	I11
barite*	Surficial placers	C01
barite*	Buried-channel placers	C02
barite*	Volcanic-hosted U	D06
barite*	Iron oxide breccias and veins ±P±Cu±Au±Ag±U	D07
barite*	Carbonate-hosted fluorspar	E11

Table 23. Listing of British Columbia Deposit Profiles by Commodity

Commodities	Deposit Type	BC Profile #
barite*	Irish-type carbonate-hosted Zn-Pb	E13
barite*	Sedimentary Exhalative Zn-Pb-Ag	E14
barite*	Noranda / Kuroko massive sulphide Cu-Pb-Zn	G06
barite*	Five-element veins Ni-Co-As-Ag±(Bi,U)	I14
barite*	Carbonatite-hosted deposits	N01
barite*	Broken Hill-type Pb-Zn-Ag±Cu	S01
Be	Rare element pegmatite - LCT family	O01
Be*	Rare element pegmatite - NYF family	O02
Bentonite	Bentonite	E06
bertrandite*	Vein fluorite-barite	I11
beryl	Columbia-type emerald deposits	Q06
beryl*	Surficial placers	C01
beryl*	Buried-channel placers	C02
beryl*	Schist-hosted emerald deposits	Q07
Bi	Five-element veins Ni-Co-As-Ag±(Bi,U)	I14
Bi*	Blackbird sediment-hosted Cu-Co	E15
Bi*	Sn-Ag veins	H07
Bi*	"Classical" U veins	I15
Bi*	Polymetallic mantos Ag-Pb-Zn	J01
Bi*	Manto and stockwork Sn	J02
Bi*	Mo skarns	K07
borate minerals*	Fe skarns	K03
calcite*	Carbonatite-hosted deposits	N01
carbon	Anthracite	A05
carbon dioxide*	Playa and Alkaline Lake Evaporites	F09*
Cd*	Mississippi Valley-type Pb-Zn	E12
Cd*	Irish-type carbonate-hosted Zn-Pb	E13
Cd*	Besshi massive sulphide Cu-Zn	G04
Cd*	Cyprus massive sulphide Cu (Zn)	G05
Cd*	Noranda / Kuroko massive sulphide Cu-Pb-Zn	G06
Cd*	Sn-Ag veins	H07
Cd*	Manto and stockwork Sn	J02
Cd*	Pb-Zn skarns	K02
celestite	Bedded celestite	F04*
cement feedstock	Cement shale	R01
cement feedstock*	Sedimentary kaolin	E07
ceramic clay*	Sedimentary kaolin	E07
chabazite	Open-system Zeolites	D01
chabazite	Closed-basin zeolites	D02
chalcedony*	Opal deposits in volcanic sequences	Q11
chromite	Podiform chromite	M03
chromite*	Surficial placers	C01
chromite*	Buried-channel placers	C02
chrysoberyl*	Schist-hosted emerald deposits	Q07
cinnabar*	Surficial placers	C01

Table 23. Listing of British Columbia Deposit Profiles by Commodity

Commodities	Deposit Type	BC Profile #
cinnabar*	Buried-channel placers	C02
clay (fireclay)	Sedimentary kaolin	E07
clinoptilolite	Open-system Zeolites	D01
clinoptilolite	Closed-basin zeolites	D02
Co	Blackbird sediment-hosted Cu-Co	E15
Co	Blackbird sediment-hosted Cu-Co	E15
Co	Five-element veins Ni-Co-As-Ag±(Bi,U)	I14
Co*	Kipushi Cu-Pb-Zn	E02*
Co*	Sediment-hosted Cu	E04
Co*	Besshi massive sulphide Cu-Zn	G04
Co*	Cyprus massive sulphide Cu (Zn)	G05
Co*	"Classical" U veins	I15
Co*	Fe skarns	K03
Co*	Gabbroid Ni-Cu-PGE	M02
Co*	Magmatic Fe-Ti±V oxide deposits	M04
coal	Lignite	A02
coal	Sub-bituminous coal	A03
coal	Bituminous coal	A04
coal	Anthracite	A05
coal liquids	Lignite	A02
coal liquids	Sub-bituminous coal	A03
coal liquids*	Bituminous coal	A04
coke	Bituminous coal	A04
construction aggregate*	Residual kaolin	B05
corundum	Alkalic-hosted gem corundums	Q09
corundum	Gem corundums in basalts and lamprophyres	Q10
corundum*	Surficial placers	C01
corundum*	Buried-channel placers	C02
corundum*	Kyanite family minerals	P02
corundum*	Corundum in aluminous metasedimentary rocks	P06
Cu	Volcanic redbed Cu	D03
Cu	Iron oxide breccias and veins ±P±Cu±Au±Ag±U	D07
Cu	Kipushi Cu-Pb-Zn	E02*
Cu	Sediment-hosted Cu	E04
Cu	Blackbird sediment-hosted Cu-Co	E15
Cu	Blackbird sediment-hosted Cu-Co	E15
Cu	Besshi massive sulphide Cu-Zn	G04
Cu	Cyprus massive sulphide Cu (Zn)	G05
Cu	Noranda / Kuroko massive sulphide Cu-Pb-Zn	G06
Cu	Epithermal Au-Ag-Cu; high sulphidation	H04
Cu	Cu±Ag quartz veins	I06
Cu	Cu skarns	K01
Cu	Subvolcanic Cu-Au-Ag (As-Sb)	L01
Cu	Porphyry Cu-Au: alkalic	L03
Cu	Porphyry Cu ± Mo ± Au	L04

Table 23. Listing of British Columbia Deposit Profiles by Commodity

Commodities	Deposit Type	BC Profile #
Cu	Basaltic subvolcanic Cu-Ni-PGE	M01*
Cu	Gabbroid Ni-Cu-PGE	M02
Cu*	Bog Fe, Mn, U, Cu, Au	B07*
Cu*	Surficial placers	C01
Cu*	Buried-channel placers	C02
Cu*	Sandstone U	D05*
Cu*	Irish-type carbonate-hosted Zn-Pb	E13
Cu*	Sedimentary Exhalative Zn-Pb-Ag	E14
Cu*	Subaqueous hot spring Au-Ag	G07
Cu*	Epithermal Au-Ag; low sulphidation	H05
Cu*	Sn-Ag veins	H07
Cu*	Au-quartz veins	I01
Cu*	Intrusion-related Au pyrrhotite veins	I02
Cu*	Iron formation-hosted Au	I04
Cu*	Polymetallic veins Ag-Pb-Zn±Au	I05
Cu*	Vein barite	I10
Cu*	Vein fluorite-barite	I11
Cu*	"Classical" U veins	I15
Cu*	Polymetallic mantos Ag-Pb-Zn	J01
Cu*	Manto and stockwork Sn	J02
Cu*	Pb-Zn skarns	K02
Cu*	Fe skarns	K03
Cu*	Au skarns	K04
Cu*	W skarns	K05
Cu*	Mo skarns	K07
Cu*	Porphyry-related Au	L02*
Cu*	Porphyry Mo (Low F- type)	L05
Cu*	Magmatic Fe-Ti±V oxide deposits	M04
Cu*	Carbonatite-hosted deposits	N01
Cu*	Broken Hill-type Pb-Zn-Ag±Cu	S01
dawsonite*	Playa and Alkaline Lake Evaporites	F09*
diamond	Kimberlite-hosted diamonds	N02*
diamond	Lamproite-hosted diamonds	N03*
diamond*	Surficial placers	C01
diamond*	Buried-channel placers	C02
diamond*	Marine placers	C03
diamond*	Paleoplacer U-Au-PGE-Sn-Ti-diam-mag-gar-zir	C04*
diatomite	Lacustrine diatomite	F06
dolomite	Dolomite	R10*
emerald	Columbia-type emerald deposits	Q06
emerald	Schist-hosted emerald deposits	Q07
emerald*	Surficial placers	C01
emerald*	Buried-channel placers	C02
emery*	Corundum in aluminous metasedimentary rocks	P06
erionite	Closed-basin zeolites	D02

Table 23. Listing of British Columbia Deposit Profiles by Commodity

Commodities	Deposit Type	BC Profile #
Fe	Laterite Fe	B01*
Fe	Bog Fe, Mn, U, Cu, Au	B07*
Fe	Karst-hosted Fe, Al, Pb-Zn	B09*
Fe	Iron oxide breccias and veins ±P±Cu±Au±Ag±U	D07
Fe	Lake Superior & Rapitan types iron-formation	F10*
Fe	Ironstones	F11*
Fe	Algoma-type iron-formation	G01
Fe	Fe skarns	K03
Fe	Magmatic Fe-Ti±V oxide deposits	M04
feldspar	Nepheline syenite	R13*
feldspar*	Rare element pegmatite - NYF family	O02
feldspar*	Muscovite pegmatite class	O03
filler (white)*	Dimension stone - marble	R04
filler (white)*	Limestone	R09
fluorite	Vein fluorite-barite	I11
fluorite	Carbonatite-hosted deposits	N01
fluorite	Carbonate-hosted fluorspar	E11
flourite*	Volcanic-hosted U	D06
fluorite*	Carbonate-hosted barite	E10
flourite	Mississippi Valley-type Pb-Zn	E12
garnet	Garnet skarns	K08
garnet*	Surficial placers	C01
garnet*	Buried-channel placers	C02
garnet*	Marine placers	C03
garnet*	Paleoplacer U-Au-PGE-Sn-Ti-diam-mag-gar-zir	C04*
garnet*	Andalusite schist and hornfels	P01
garnet*	Kyanite family minerals	P02
gas*	Lignite	A02
gas*	Sub-bituminous coal	A03
gas*	Bituminous coal	A04
gemstones*	Rare element pegmatite - NYF family	O02
granite	Dimension stone - granite	R03
graphite	Microcrystalline graphite	P03
graphite	Crystalline flake graphite	P04
graphite	Vein graphite	P05
gravel	Sand and Gravel	B12*
gypsum	Bedded gypsum	F02
gypsum	Volcanogenic anhydrite / gypsum	G03*
gypsum*	Noranda / Kuroko massive sulphide Cu-Pb-Zn	G06
hematite*	Carbonatite-hosted deposits	N01
Hg	Almaden Hg	E01*
Hg	Hot-spring Hg	H02
Hg	Silica-carbonate Hg	I08
Hg*	Subaqueous hot spring Au-Ag	G07
Hg*	Hot spring Au-Ag	H03

Table 23. Listing of British Columbia Deposit Profiles by Commodity

Commodities	Deposit Type	BC Profile #
hydromagnesite	Playa and Alkaline Lake Evaporites	F09*
illmenite	Marine placers	C03
ilmenite*	Surficial placers	C01
ilmenite*	Buried-channel placers	C02
In*	Sn-Ag veins	H07
In*	Manto and stockwork Sn	J02
Ir*	Podiform chromite	M03
Ir*	Alaskan-type PGE	M05
jade	Jade	Q01
jade*	Ultramafic-hosted asbestos	M06
jasper	Jasper	Q05*
jasper*	Opal deposits in volcanic sequences	Q11
kaolin	Residual kaolin	B05
kaolin	Hydrothermal alteration clays-Al-Si	H09*
kaolin*	Muscovite pegmatite class	O03
kyanite	Kyanite family minerals	P02
kyanite*	Surficial placers	C01
kyanite*	Buried-channel placers	C02
leonardite*	Lignite	A02
Li	Rare element pegmatite - LCT family	O01
lime (agricultural)	Travertine	H01
lime	Marl	B11*
lime	Limestone	R09
lime*	Dimension stone - marble	R04
magnesite	Sparry magnesite	E09
magnesite	Cryptocrystalline ultramafic-hosted magnesite veins	I17
magnesite	Ultramafic-hosted talc-carbonate	M07
magnesite*	Marine placers	C03
magnetite	Cu skarns	K01
magnetite	Fe skarns	K03
magnetite	Garnet skarns	K08
magnetite	Ultramafic-hosted asbestos	M06
magnetite*	Surficial placers	C01
magnetite*	Buried-channel placers	C02
magnetite*	Paleoplacer U-Au-PGE-Sn-Ti-diam-mag-gar-zir	C04*
magnetite*	Sn skarns	K06
magnetite*	Alaskan-type PGE	M05
magnetite*	Carbonatite-hosted deposits	N01
mica	Muscovite pegmatite class	O03
mica*	Andalusite schist and hornfels	P01
Mn	Sedimentary Manganese	F01
Mn	Volcanogenic Mn	G02
Mn	Epithermal Mn	H06*
Mn	Mn veins and replacements	J03*
Mn*	Bog Fe, Mn, U, Cu, Au	B07*

Table 23. Listing of British Columbia Deposit Profiles by Commodity

Commodities	Deposit Type	BC Profile #
Mn*	Algoma-type iron-formation	G01
Mn*	Polymetallic veins Ag-Pb-Zn±Au	I05
Mo	Shale-hosted Ni-Zn-Mo-PGE	E16
Mo	Mo skarns	K07
Mo	Porphyry Cu ± Mo ± Au	L04
Mo	Porphyry Mo (Low F- type)	L05
Mo	Porphyry Mo (Climax-type)	L08
Mo*	Volcanic-hosted U	D06
Mo*	Besshi massive sulphide Cu-Zn	G04
Mo*	W veins	I12*
Mo*	"Classical" U veins	I15
Mo*	Cu skarns	K01
Mo*	W skarns	K05
Mo*	Porphyry W	L07
monazite*	Marine placers	C03
mordenite	Open-system Zeolites	D01
mordenite	Closed-basin zeolites	D02
muscovite*	Kyanite family minerals	P02
Nb	Carbonatite-hosted deposits	N01
Nb	Rare element pegmatite - LCT family	O01
Nb*	Rare element pegmatite - NYF family	O02
nepheline	Nepheline syenite	R13*
Ni	Laterite Ni	B02*
Ni	Shale-hosted Ni-Zn-Mo-PGE	E16
Ni	Five-element veins Ni-Co-As-Ag±(Bi,U)	I14
Ni	Basaltic subvolcanic Cu-Ni-PGE	M01*
Ni	Gabbroid Ni-Cu-PGE	M02
Ni*	Blackbird sediment-hosted Cu-Co	E15
Ni*	"Classical" U veins	I15
Ni*	Magmatic Fe-Ti±V oxide deposits	M04
onyx*	Travertine	H01
opal	Sedimentary-hosted opal deposits	Q08
opal	Opal deposits in volcanic sequences	Q11
Os*	Podiform chromite	M03
Os*	Alaskan-type PGE	M05
palygorskite	Palygorskite	F05*
Pb	Karst-hosted Fe, Al, Pb-Zn	B09*
Pb	Kipushi Cu-Pb-Zn	E02*
Pb	Sandstone Pb	E05
Pb	Mississippi Valley-type Pb-Zn	E12
Pb	Irish-type carbonate-hosted Zn-Pb	E13
Pb	Sedimentary Exhalative Zn-Pb-Ag	E14
Pb	Besshi massive sulphide Cu-Zn	G04
Pb	Noranda / Kuroko massive sulphide Cu-Pb-Zn	G06

Table 23. Listing of British Columbia Deposit Profiles by Commodity

Commodities	Deposit Type	BC Profile #
Pb	Polymetallic veins Ag-Pb-Zn±Au	I05
Pb	Polymetallic mantos Ag-Pb-Zn	J01
Pb	Pb-Zn skarns	K02
Pb	Broken Hill-type Pb-Zn-Ag±Cu	S01
Pb*	Sediment-hosted Cu	E04
Pb*	Carbonate-hosted barite	E10
Pb*	Carbonate-hosted fluorspar	E11
Pb*	Blackbird sediment-hosted Cu-Co	E15
Pb*	Sedimentary-hosted stratiform barite	E17
Pb*	Subaqueous hot spring Au-Ag	G07
Pb*	Epithermal Au-Ag; low sulphidation	H05
Pb*	Sn-Ag veins	H07
Pb*	Alkalic intrusion-associated Au-Ag	H08
Pb*	Vein barite	I10
Pb*	Vein fluorite-barite	I11
Pb*	Manto and stockwork Sn	J02
Pb*	Mn veins and replacements	J03*
Pb*	Mo skarns	K07
Pd*	Shale-hosted Ni-Zn-Mo-PGE	E16
peat	Peat	A01
perlite	Volcanic glass - perlite	R12*
PGE	Surficial placers	C01
PGE	Buried-channel placers	C02
PGE	Marine placers	C03
PGE	Basaltic subvolcanic Cu-Ni-PGE	M01*
PGE*	Paleoplacer U-Au-PGE-Sn-Ti-diam-mag-gar-zir	C04*
PGE*	Sediment-hosted Cu	E04
PGE*	Gabbroid Ni-Cu-PGE	M02
phenacite*	Vein fluorite-barite	I11
phillipsite	Open-system Zeolites	D01
phillipsite	Closed-basin zeolites	D02
phlogopite*	Fe skarns	K03
phosphate	Upwelling-type phosphate	F07
phosphate	Warm current-type phosphate	F08
phosphate	Carbonatite-hosted deposits	N01
phosphate*	Sedimentary Manganese	F01
pozzolan*	Expanding shale	R02
Pt	Alaskan-type PGE	M05
Pt*	Shale-hosted Ni-Zn-Mo-PGE	E16
pumice	Volcanic ash - pumice	R11*
pyrophyllite	Hydrothermal alteration clays-Al-Si	H09*
quartz	Alaskite	R14*
Ra	Rare element pegmatite - LCT family	O01
Rb	Rare element pegmatite - LCT family	O01
red ochre*	Gossan Au-Ag	B10

Table 23. Listing of British Columbia Deposit Profiles by Commodity

Commodities	Deposit Type	BC Profile #
REE	Volcanic-hosted U	D06
REE	Carbonatite-hosted deposits	N01
REE	Rare element pegmatite - NYF family	O02
REE*	Marine placers	C03
REE*	Iron oxide breccias and veins ±P±Cu±Au±Ag±U	D07
refractory claystone	Sedimentary kaolin	E07
Rh*	Alaskan-type PGE	M05
rhodonite	Rhodonite	Q02
rhodonite*	Volcanogenic Mn	G02
rip-rap	Crushed rock	R15*
rip-rap*	Dimension stone - granite	R03
rip-rap*	Dimension stone - marble	R04
rip-rap*	Dimension stone - andesite	R05
rip-rap*	Dimension stone - sandstone	R06*
Ru*	Podiform chromite	M03
ruby	Corundum in aluminous metasedimentary rocks	P06
ruby	Alkalic-hosted gem corundums	Q09
ruby	Gem corundums in basalts and lamprophyres	Q10
ruby*	Surficial placers	C01
ruby*	Buried-channel placers	C02
rutile	Marine placers	C03
rutile*	Surficial placers	C01
rutile*	Buried-channel placers	C02
S	Gypsum-hosted sulphur	F03
S*	Noranda / Kuroko massive sulphide Cu-Pb-Zn	G06
sand	Sand and Gravel	B12*
sapphire	Corundum in aluminous metasedimentary rocks	P06
sapphire	Alkalic-hosted gem corundums	Q09
sapphire	Gem corundums in basalts and lamprophyres	Q10
sapphire*	Surficial placers	C01
sapphire*	Buried-channel placers	C02
Sb	Stibnite veins and disseminations	I09
Sb*	Volcanic-hosted U	D06
Sb*	Subaqueous hot spring Au-Ag	G07
Sb*	Epithermal Au-Ag-Cu; high sulphidation	H04
Sb*	Au-quartz veins	I01
Sb*	Turbidite-hosted Au veins	I03
Sb*	Silica-carbonate Hg	I08
Sb*	Manto and stockwork Sn	J02
Sb*	Subvolcanic Cu-Au-Ag (As-Sb)	L01
Se*	Noranda / Kuroko massive sulphide Cu-Pb-Zn	G06
silica	Silica veins	I07*
silica	Hydrothermal alteration clays-Al-Si	H09*
silica	Quartz pegmatite	O04*
silica	Silica sandstone	R07

Table 23. Listing of British Columbia Deposit Profiles by Commodity

Commodities	Deposit Type	BC Profile #
silica sand*	Residual kaolin	B05
silica*	Muscovite pegmatite class	O03
sillimanite	Kyanite family minerals	P02
Sn	Surficial placers	C01
Sn	Marine placers	C03
Sn	Sn-Ag veins	H07
Sn	Sn veins and greisens	I13*
Sn	Manto and stockwork Sn	J02
Sn	Sn skarns	K06
Sn	Porphyry Sn	L06
Sn*	Surficial placers	C01
Sn*	Buried-channel placers	C02
Sn*	Paleoplacer U-Au-PGE-Sn-Ti-diam-mag-gar-zir	C04*
Sn*	Besshi massive sulphide Cu-Zn	G04
Sn*	Noranda / Kuroko massive sulphide Cu-Pb-Zn	G06
Sn*	Polymetallic mantos Ag-Pb-Zn	J01
Sn*	W skarns	K05
Sn*	Mo skarns	K07
Sn*	Porphyry W	L07
Sn*	Porphyry Mo (Climax-type)	L08
Sn*	Rare element pegmatite - LCT family	O01
soda ash	Playa and Alkaline Lake Evaporites	F09*
soil conditioner	Travertine	H01
sphene*	Surficial placers	C01
spinel*	Buried-channel placers	C02
spodumene	Rare element pegmatite - LCT family	O01
Sr*	Carbonatite-hosted deposits	N01
staurolite*	Surficial placers	C01
staurolite*	Buried-channel placers	C02
staurolite*	Andalusite schist and hornfels	P01
staurolite	Kyanite family minerals	P02
stone (building)	Travertine	H01
stone (building)	Dimension stone - marble	R04
stone (building)	Dimension stone - sandstone	R06*
stone (flagstone)	Flagstone	R08*
stone (limestone)	Limestone	R09
Ta*	Carbonatite-hosted deposits	N01
Ta*	Rare element pegmatite - NYF family	O02
talc	Carbonate-hosted talc	E08
talc	Ultramafic-hosted talc-carbonate	M07
tar*	Lignite	A02
tar*	Sub-bituminous coal	A03
tar*	Bituminous coal	A04
Th*	Marine placers	C03
Th*	Carbonatite-hosted deposits	N01

Table 23. Listing of British Columbia Deposit Profiles by Commodity

Commodities	Deposit Type	BC Profile #
Th*	Volcanic-hosted U	D06
Ti	Marine placers	C03
Ti	Magmatic Fe-Ti±V oxide deposits	M04
Ti*	Paleoplacer U-Au-PGE-Sn-Ti-diam-mag-gar-zir	C04*
Ti*	Carbonatite-hosted deposits	N01
topaz*	Surficial placers	C01
topaz*	Buried-channel placers	C02
topaz*	Schist-hosted emerald deposits	Q07
tourmaline*	Surficial placers	C01
tourmaline*	Buried-channel placers	C02
tourmaline*	Schist-hosted emerald deposits	Q07
U	Surficial U	B08
U	Paleoplacer U-Au-PGE-Sn-Ti-diam-mag-gar-zir	C04*
U	Basal U	D04
U	Sandstone U	D05*
U	Volcanic-hosted U	D06
U	Five-element veins Ni-Co-As-Ag±(Bi,U)	I14
U	"Classical" U veins	I15
U	Unconformity-associated U	I16
U	Rare element pegmatite - NYF family	O02
U*	Bog Fe, Mn, U, Cu, Au	B07*
U*	Iron oxide breccias and veins ±P±Cu±Au±Ag±U	D07
U*	Sediment-hosted Cu	E04
U*	Mo skarns	K07
U*	Carbonatite-hosted deposits	N01
V	Sandstone U	D05*
V*	Sediment-hosted Cu	E04
V*	Magmatic Fe-Ti±V oxide deposits	M04
V*	Carbonatite-hosted deposits	N01
vermiculite	Vermiculite deposits	M08
vermiculite	Carbonatite-hosted deposits	N01
W	W veins	I12*
W	W skarns	K05
W	Porphyry W	L07
W*	Sn-Ag veins	H07
W*	Turbidite-hosted Au veins	I03
W*	Sn veins and greisens	I13*
W*	Cu skarns	K01
W*	Pb-Zn skarns	K02
W*	Sn skarns	K06
W*	Mo skarns	K07
W*	Porphyry Mo (Low F- type)	L05
W*	Porphyry Sn	L06
W*	Porphyry Mo (Climax-type)	L08
wolframite*	Surficial placers	C01

Table 23. Listing of British Columbia Deposit Profiles by Commodity

Commodities	Deposit Type	BC Profile #
wollastonite	Wollastonite skarns	K09
wollastonite*	Garnet skarns	K08
Y	Rare element pegmatite - NYF family	O02
Y*	Marine placers	C03
zircon	Marine placers	C03
zircon*	Surficial placers	C01
zircon*	Buried-channel placers	C02
zircon*	Paleoplacer U-Au-PGE-Sn-Ti-diam-mag-gar-zir	C04*
Zn	Karst-hosted Fe, Al, Pb-Zn	B09*
Zn	Kipushi Cu-Pb-Zn	E02*
Zn	Mississippi Valley-type Pb-Zn	E12
Zn	Irish-type carbonate-hosted Zn-Pb	E13
Zn	Sedimentary Exhalative Zn-Pb-Ag	E14
Zn	Besshi massive sulphide Cu-Zn	G04
Zn	Noranda / Kuroko massive sulphide Cu-Pb-Zn	G06
Zn	Polymetallic veins Ag-Pb-Zn+G155Au	I05
Zn	Polymetallic mantos Ag-Pb-Zn	J01
Zn	Pb-Zn skarns	K02
Zn	Broken Hill-type Pb-Zn-Ag±Cu	S01
Zn*	Sediment-hosted Cu	E04
Zn*	Sandstone Pb	E05
Zn*	Carbonate-hosted barite	E10
Zn*	Carbonate-hosted fluorspar	E11
Zn*	Blackbird sediment-hosted Cu-Co	E15
Zn*	Shale-hosted Ni-Zn-Mo-PGE	E16
Zn*	Sedimentary-hosted stratiform barite	E17
Zn*	Cyprus massive sulphide Cu (Zn)	G05
Zn*	Subaqueous hot spring Au-Ag	G07
Zn*	Epithermal Au-Ag; low sulphidation	H05
Zn*	Sn-Ag veins	H07
Zn*	Alkalic intrusion-associated Au-Ag	H08
Zn*	Vein barite	I10
Zn*	Vein fluorite-barite	I11
Zn*	Manto and stockwork Sn	J02
Zn*	Mn veins and replacements	J03*
Zn*	W skarns	K05
Zn*	Sn skarns	K06
Zn*	Mo skarns	K07
Zr*	Carbonatite-hosted deposits	N01