PRECIOUS METALS IN THE NORTHERN CORDILLERA

GOLD "81"
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PRECIOUS METALS IN THE NORTHERN CORDILLERA

A Symposium organized by
The Association of Exploration Geochemists
AND
The Cordilleran Section, GAC
APRIL 13-15, 1981 - HYATT REGENCY
Vancouver, British Columbia, Canada

PROGRAMME AND ABSTRACT

"For many people today the entire story of the Klondike gold rush is evoked by a single scene. It shows a solid line of men, forming a human chain, hanging acoss the white face of a mountain rampart. Caught in the instant of a lens opening, each man, bent almost double under the weight of his burden, yet still straining upwards towards the skies, seems to be frozen in an attitude of supplication. It is a spectacle that at one glance mirrors all the terror, all the hardships, and all the yearning of '98. The Chilkoot Pass has come to be a symbol of the stampede."
Pierre Berton, Klondike - The Last Great Gold Rush, 1896-1899.

PROGRAMME

Sunday, April 12

PRE-REGISTRATION REGENCY FOYER

7:00 pm-11:00 pm	Delegates may pick up registration kits and have one free drink. There will be a No Host Bar.

Monday, April 13 — Regency Centre

8:00 am-4:00 pm	Registration, in foyer.

MORNING SESSION

Chairman	P. Bradshaw, Placer Development
9:00 am-9:15 am	Introduction — P. Bradshaw, R. Hewton
9:15 am-10:00 am	**Boyle, R.W.**: Gold, silver and platinum metal deposits in the Canadian Cordillera — their geological and geochemical setting.
10:00 am-10:25 am	**Van Loon, J.C.**: Accurate determination of the noble metals — an overview.
10:25 am-10:50 am	COFFEE
10:50 am-11:15 am	**Hoffman, E.L., Brooker, E.J.H., and White, M.V.**: The determination of gold by Neutron Activation Analysis.
11:15 am-11:40 am	**Robbins, J.C., Radziuk, B. and Kinrade, J.D.**: Trace gold analysis with a newly-developed field-portable Atomic Absorption Spectrometer.
11:40 am-12:05 pm	**Turner, L.D., and Ikramuddin, M.**: Electrothermal Atomic Absorption determination of gold, silver and arsenic in stream waters and their relationship to gold-silver occurrences in the Republic Graben, Washington.
12:05 pm-2:00 pm	LUNCH — Regency East Speaker: Lew Green Title: Pack-horse days on the Survey. Door Prizes: 1 - 1 oz. Au bar 2 - 5 oz. Ag bars

AFTERNOON SESSION

Chairman	K. Fletcher, U.B.C.
2:00 pm-2:25 pm	**Ingamells, C.O.**: Sampling theories — an overview.
2:25 pm-2:50 pm	**Harris, J.F.**: Analysis of gold in soils and stream sediments: a useful exploration technique?
2:50 pm-3:15 pm	**Barakso, J.J., and Tegart, P.**: Stream sediment geochemistry of gold.
3:15 pm-3:40 pm	COFFEE
3:40 pm-4:05 pm	**Garman, M.R.W. and Gilfillan, J.F.**: A case history of geochemical exploration for gold in central N.S.W., Australia.
4:05 pm-4:30 pm	**Radtke, A.S.**: Relationship between geochemical dispersions and geologic settings of select types of disseminated gold deposits.
7:00 pm-11:00 pm	**Wine and Cheese** — Complimentary — Regency East

POSTER SESSION

Daikow, L.J. and Panteleyev, A.: Geological setting of Cassiar gold deposits of northwest B.C.

Smith, F.M.: Hallsted property, Quincy, Calif.: volcaniclastic mineralization.

Babcock, R.S. and Seward, T.M.: Deposition of precious metals in hot springs.

Robbins, J.C. and Radziuk, B.: Gold analysis with a portable atomic absorption spectrometer.

Church, B.N. and Barakso, J.: Computer processing of lithogeochemical data from the Buck Creek area, central B.C.

Asarco: Geology of the Waterloo Silver Deposit in southern California.

Vangeochem Lab: An analytical method for gold trace analyses in geochemical samples.

Bondar-Clegg: Sampling and analytical problems.

Gresens, R.L., Nisbet, P.C. and Cool, C.A.: Alkali enrichment haloes and nickel depletion haloes around gold-bearing silica-carbonate veins in serpentinite, Washington State.

Tuesday, April 14 — Regency Centre

8:00 am-4:00 pm	Registration in foyer

MORNING SESSION

Chairman	D. Barr, Du Pont
9:00 am-9:25 am	**Hodgson, C.J.**: Application of exploration criteria for gold deposits in the Superior Province of the Canadian Shield to gold exploration in the Cordillera.
9:25 am-9:50 am	**Antweiler, J.C. and Campbell, W.L.**: Gold in exploration geochemistry.
9:50 am-10:15 am	**Warren, H.V.**: The significance of a discovery of gold crystals in overburden.
10:15 am-10:45 am	COFFEE
10:45 am-11:10 am	**Baker, W.E.**: A biogeochemical approach to gold prospecting in N.E. Tasmania, Australia.
11:10 am-11:35 am	**Sinclair, A.J., Dawson, K.M., Drummond, A.D., and Carter, N.C.**: Interpretation of gold-silver content of selected property copper-molybdenum deposits of the Canadian Cordillera.
11:35 am-12:00 pm	**Peatfield, G.R.**: Gold geochemistry in the search for porphyry copper-gold deposits, Eddontenajon Lake Area, northwestern B.C.
12:00 pm-2:00 pm	LUNCH — Regency East Speaker: John Wheeler Title: It feels so good when you stop. Door Prizes: 1 — 1oz. Au bar 2 — 5oz. Ag bars

AFTERNOON SESSION

Chairman	J. Monger, G.S.C.
2:00 pm-2:25 pm	**Middleton, R.S., Durham, R.B., Harron, G., Philipp, A. and Markov, R.A.**: Geophysical and geochemical techniques for gold exploration.
2:25 pm-2:50 pm	**Brown, R.F. and Grove, E.**: Geology and alteration with emphasis on whole rock geochemistry and auriferous mineralization at Poison Mountain, B.C.

2:50 pm-3:15 pm	**Berger, B.R., Tingley, J.V., Filipek, L. and Neighbor, J.**: Origin of pathfinder trace-element patterns associated with gold-silver mineralization in late Oligocene volcanic rocks, Round Mountain, Nevada.
3:15 pm-3:40 pm	**Cuddy, A.S. and Kesler, S.E.**: Gold in the Granisle and Belle porphyry copper deposits, B.C.
3:40 pm-4:05 pm	COFFEE
4:05 pm —	A.E.G. Annual General Meeting

Wednesday, April 15 — Regency Centre

MORNING SESSION

Chairman	V. Hollister, Consultant
9:00 am-9:25 am	**Carne, J. and Gower, S.**: The discovery of the Toodoggone Gold Camp.
9:25 am-9:50 am	**Champigny, N. and Sinclair, A.J.**: Cinola gold deposit, Queen Charlotte Islands, B.C. — a geochemical case history.
9:50 am-10:15 am	**Nauman, C.**: Volcanogenic massive sulphides with apparently elevated precious metal levels, east central Alaska Range, Alaska.
10:15 am-10:40 am	COFFEE
10:40 am-11:15 am	**Schroeter, T.**: Selected precious metal deposits of northern B.C.
11:15 am-11:40 am	**Morin, J.A.**: Element distribution in Yukon gold-silver deposits.
11:40 am-12:05 pm	**Cabri, L.J.**: Classification of platinum — group element deposits with reference to the Cordillera.
12:05 pm-2:00 pm	LUNCH —Regency East
	Beer and Sandwich
	Door Prizes: 1 — 1oz. Au bar 2 — 5oz. Ag Bars

AFTERNOON SESSION

Chairman	A. Archer, Archer Cathro
2:00 pm-2:25 pm	**Watson, B.N.**: Geologic setting and characteristics of bulk-tonnage, low-grade silver deposits in the southern Cordillera.
2:25 pm-2:50 pm	**Hopkins, D.M., Domenico, J.A. and Leach, D.L.**: Multi-element analysis techniques for partially extractable and total metal determinations in stream sediment reconnaissance for silver occurrences.
2:50 pm-3:15 pm	**Leach, D.L., Dawson, H.E., Domenico, J.A. and Hopkins, D.M.**: A regional geochemical reconnaissance for silver in stratabound and vein deposits in Proterozoic Y rocks of the Belt Supergroup, Idaho and Montana.
3:15 pm-3:40 pm	COFFEE
3:40 pm-4:15 pm	**Franzen, J.P. and Van Tassell, R.E.**: Grid rotary percussion-drilling: a bedrock geochemical approach to silver vein exploration at United Keno Hill Mines Ltd.
4:15 pm-4:40 pm	**Kowalchuk, J.M., Church, B.N., Barakso, J.J. and Bradshaw, P.M.D.**: Primary dispersion of gold, silver and related elements at Equity Silver Mines near Houston, B.C.
4:40 pm —	**Kesler, S.E.**: Summary Talk.

Gold in Exploration Geochemistry

Antweiler, J.C., and Campbell W.L.; United States Department of the Interior, Geological Survey, Denver, Colorado

The presence of visible alluvial gold in panned concentrates has led to the discovery of a vast number of the world's great mining areas. The development and use, in recent years, of rapid, sensitive, analytical methods for the detection of gold in panned concentrates, when it is not visible, is also of value in locating mineralized areas. For example, gold in panned concentrates was found to be the most reliable indicator of mineralized areas in the Absaroka Mountains of Wyoming and Montana. Experimental surveys in drainages below three known mineralized areas (Gold Reef, Eagle Creek, and Sunlight) showed that the technique of analyzing panned concentrates for gold was more definitive than various kinds of analyses of other sampling media (stream sediment, soil, water, vegetation). In subsequent work, gold was found to be associated with 15 mineralized areas in the Absaroka Mountains — many of them previously undescribed.

Certain characteristics of gold have a unique value in exploration. Native gold is associated with a great variety of ore deposits and has a characteristic signature for each type of deposit indicated by alloy proportions of Au, Ag, and Cu, together with certain quantities of associated trace elements.

When the gold signature is determined, the type of related deposits can be identified. The search for mineralization can then be focussed on that type of deposit or deposits. Examples discussed are porphyry copper deposits in the Absaroka Mountains, undiscovered bedrock gold deposits, tungsten-bearing skarn deposits, and disseminated molybdenum deposits.

A Biogeochemical Approach to Gold Prospecting in N.E. Tasmania, Australia

Baker, W.E.; Department of Mines, Hobart, Tasmania, Australia

Literature on the Au content of plants is not extensive and conflicting data are presented. Babicka (1943) gives a range of 10,000 ppb in the ash of Tilia parvifolia (linden) to an incredible 610,000 ppb for Equisetum palustre (horsetail rush) for plants from Czechoslovakian localities. Warren and Delavault (1950) found a maximum of 340 ppb for Equisetum spp. from a Canadian Au bearing area and values of this magnitude were also found by Cannon et al. (1968) for various localities in U.S.A. Boyle (1979) records values up to 8500 ppb for the same genus from a Canadian location.

Studies of Au mobilization at the Department of Mines, Tasmania (Baker, 1978) suggested that this metal could be highly mobile in natural biochemical systems. As an applied extention of these studies it was decided to investigate the Au content of local plant species from a known Au-bearing area. The Lisle Valley, which is situated 20 km south west of Scottsdale in north east Tasmania, was selected since around 1889 this alluvial field produced 250,000 ozs Au. The valley is a wide alluvium and soil covered basin underlain by Devonian granodiorite intruding Silurian sedimentary rocks which stand as steep walls 300 m above the floor. The source of the Au has not been located although it is likely that the deep scree covered contact zone carries stringers of auriferous vein quartz.

The analytical method developed involves:

1. grinding of plant materials to minus 0.25 mm
2. wet oxidation with HNO_3, H_2SO_4 and $HClO_4$
3. treatment with aqua regia to produce $AuCl_4$ —
4. extraction of $AuCl_4$ from 2N HCl with heptan-2-one
5. determination of Au by use of atomic absorption carbon furnace techniques.

Since a Forestry Department plantation of Pinus radiata covers much of the Lisle Valley, second year twigs of this species were used in the initial study. Samples from just outside the valley averaged 50 ppb Au in the ash whilst near old workings values up to 4800 ppb were found. These results encouraged sampling along roads in the area at 100 m intervals and subsequent analyses revealed several anomalous locations. To date, one of these has been sampled at 10 m intervals along traverses set 100 m apart. This has resulted in the recognition of an auriferous streak 15 m in width and which persists for at least 500 m.

A study is continuing of the gold content of a range of plant species in the Lisle Valley and maximum values exceeding 10,000 ppb Au have been recorded. The methods in use at the Dept. of Mines, Tasmania, are still very much on trial but appear to have potential in gold prospecting.

At this stage it seems possible that biogeochemical studies of gold in an alluvial situation can define target areas very precisely and thus reduce the amount of mechanical testing generally found necessary. Evidence of anomalous Au in plants has been found well above the floor of the Lisle Valley and it is hoped that future studies may suggest whether this is due to the presence of auriferous veinlets or some channel along which groundwater is migrating.

References

Babicka, J. (1943). Gold in lebewesen. Mikrochim.Acta 31, 201-253.

Baker, W.E. (1978). The role of humic acid in the transport of gold. Geochim.Cosmochim.Acta 42, 645-649.

Boyle, R.W. (1979). The geochemistry of gold and its deposits. Geol.Surv.Canada Bull. 280, 79-88.

Cannon, H.L., Shacklette, H.T. and Bastron, H. (1968). Metal absorption by Equisetum (horsetail). U.S. Geol.Surv.Bull. 1278-A, 1-21.

Warren, H.V. and Delavault, R.E. (1950). Gold and silver content of some trees and horsetails in British Columbia, Geol.Soc.Amer.Bull. 61, 123-128.

Stream Sediment Geochemistry of Gold

Barakso, J.J.; Min-En Laboratories, North Vancouver, B.C. and Tegart, P.; Serem Ltd., Vancouver, B.C.

In spite of the many prospects which have been discovered by conventional stream geochemistry, dispersion studies of various existing prospects and orebodies indicated that a revision of stream geochemistry was inevitable.

In this work, emphasis was concentrated on those areas where conventional stream geochemistry failed to produce anomalies at a reasonable sampling density.

For further improvement of stream geochemical techniques, a routine low cost Heavy Mineral sampling and processing procedure was worked out and implemented at various areas.

Details of sampling and analytical data along with dispersion processes will be discussed for Chappelle Creek (Baker Mine), Lawyers Creek, Sam Goosley (Equity Silver Mines), Carolin Mines, and Consolidated Cinola Mines.

Also, along with the environmental aspects of gold and silver dispersion, the applicable pathfinder elements will be discussed briefly.

Origin of Pathfinder Trace-Element Patterns Associated With Gold-Silver Mineralization in Late Oligocene Volcanic Rocks, Round Mountain, Nye County, Nevada

Berger, B.R., Tingley, J.V., Filipek, * L. and Neighbor, J.; U.S. Geological Survey, Federal Center, Denver CO; * Nevada Bureau of Mines and Geology, Reno, NV.

Gold was discovered at Round Mountain, Nye County, Nevada, in 1906, and lode and/or placer deposits have been mined intermittently to the present. The lode deposits occur as stockwork veins and disseminations in the intracaldera part of the Oligocene rhyolite ash-flow tuff (26.1 $\pm$ 0.8 m.y. old). A K/Ar age on adularia indicates that mineralization took place about 25.2 $\pm$ 0.8 m.y. ago.

The deposit is interpreted to be the result of convective hydrothermal fluids above an intrusive rhyolitic (?) body. The fluids probably vented as hot springs and ascended along swarms of high-angle joints to form a disseminated, blanket-like deposit in the lower, nonwelded portion of the tuff, vein deposits in the welded, central portion of the tuff, and silicification in the upper nonwelded portion of the tuff and overlying water-laid tuffs and epiclastic volcanic rocks. Intermittent boiling brecciated the welded tuff in pipe-like zones and along flat dilated joints that consequently dip into the pipe-like breccias.

Alteration zoning from the top to the base of the ash-flow sheet is silicification, quartz-mixed layer phyllosilicate-pyrite, and quartz-muscovite-pyrite. Alteration due to acid-leaching is superimposed on the above alteration zones in the areas of pipe-like brecciation, resulting in alunite veins, massive seams of kaolinite, and argillic alteration of feldspars in the rock matrix. K/Ar ages on the alunite average 10 m.y. old, suggesting that the acid-leaching may be supergene; and may have resulted from the oxidation of abundant pyrite in the breccias.

Gold and silver are associated with arsenic, antimony, thallium, mercury, and fluorine in the primary system. The altered area as a whole is anomalous in molybdenum, tungsten, tellurium, and tin. The concentration of gold shows a positive correlation with the concentration of silver, arsenic, and iron in the quartz-adularia veins and pipe-like breccias. Thallium, antimony, and fluorine are enriched in the breccias but do not correlate well with gold. Manganese was mobile during the boiling, and is highly enriched around the breccias where it is associated with anomalous silver, thallium, zinc, beryllium, and molybdenum. Acid-leaching depleted or enriched areas in certain elements, changing the geochemical associations. Gold still correlates with silver, but the gold/silver ratio increases from about 1.2 - 2.3 to about 1.9 - 9.0. Arsenic and antimony are pervasive and present in higher average concentrations than before the leaching. Arsenic shows no linear relationship with gold. Iron, manganese, and calcium are depleted.

Data from composited, rotary drill-hole samples reflect the broad alteration patterns and sequences in contrast to the vein samples, which reflect details of the ore-forming processes along the veins. Associations discerned from vein samples may not be readily applied to the interpretation of associations found in composited drill samples.

Gold, Silver and Platinum-Metal Deposits in the Canadian Cordillera — Their geological and Geochemical Setting

Boyle, R.W.; Geological Survey of Canada, Ottawa

The geology and geochemistry of the principal types of gold, silver and platinum-metal deposits that occur or can be expected to occur in the Canadian Cordillera are described.

The gold and silver deposits include various skarn, vein, lode, disseminated, and tabular types in which quartz, carbonates, pyrite, pyrrhotite, arsenopyrite, and the base-metal sulphides and sulphosalts are the principal constituents. Auriferous quartz-pebble conglomerate deposits are unknown in the Canadian Cordillera but should be sought in the Precambrian (Proterozoic) terranes of this geological province. Gold placers are widespread in the Cordillera and have been exploited for more than a century.

Only one platinum-metal placer (Tulameen) has been worked in the Canadian Cordillera, but platinoid minerals have a widespread occurrence in many auriferous placer districts. Bedrock platinum-metal deposits are not presently known in the Cordillera. However, numerous occurrences of platinum metals in Ni-Cu sulphide ores, in Cu ores, and in segregations and impregnations in basic and ultra-basic rocks suggest that terranes containing such rocks should be explored carefully for these primary deposits.

Most geochemical methods of prospecting are applicable in the search for argentiferous, auriferous and platinum-metal deposits, including those based on rocks (lithochemical), soils and glacial materials (pedochemical), waters and drainage sediments (hydrochemical), vegetation (biogeochemical), and gases (atmochemical). Particularly effective, especially for locating gold and platinum metal deposits, are those methods based on the sampling of drainage sediments, glacial materials, and soils, analyzing these materials directly or analyzing heavy mineral separates obtained from them.

Geology and Alteration with Emphasis on Whole Rock Geochemistry and Auriferous Mineralization at Poison Mountain, B.C.

Brown, R.F. and Grove, E.; Long Lac Mineral Exploration Limited, Vancouver, B.C.

An effort will be made to outline the geology of a 10 x 10 km area around Poison Mountain and give a more detailed look at the immediate deposit geology and structure. The potassic and propylitic alteration will then be superimposed on the above structure and the stratigraphy along with the possible relationship it has (shown through whole rock geochemistry) on the auriferous mineralization. It is early speculation, but it is possible that potassic alteration (K-spar, bio-tization, quartz) and auriferous mineralization are linked.

Classification of Platinum-Group Element Deposits with Reference to the Canadian Cordillera

Cabri, L.J.; CANMET, Department of Energy, Mines & Resources, Ottawa, Ontario

Recent mineralogical and geochemical studies provide data for a classification of platinum-group element (PGE) deposits on the basis of commodities and petro-tectonic features. A primary division is made between (a) PGE-dominant deposits and (b) PGE co- and by-product deposits. The PGE-dominant deposits may be divided into three types: Merensky, layered chromitite, and Alaskan (including derived placers). The PGE co- and by-product deposits may also be divided into three types: Alpine, (Cr), Ni-Cu and Ni magmatic sulfides, and miscellaneous deposits ranging from those in mafic rocks to carbonatites to black shales.

The Republic of South Africa and the U.S.S.R. produced 91% and possessed an estimated 97% of world reserves in 1977. However, significant undeveloped resources are known to occur in North America. While the most important North American examples occur outside the Canadian Cordillera, the geological belts of the Cordillera are reviewed in terms of the proposed classification of PGE deposits.

The Discovery of the Toodoggone Gold Camp

Carne, J., and Gower, J.; Serem Ltd., Vancouver, B.C.

The Toodoggone district is becoming a well recognized major precious metal camp. Although the area has a limited history of small placer and lode operations, the majority of the discoveries have come about utilizing modern techniques of geochemistry in the last fifteen years. At present there are twelve operators exploring the camp which include the Chappelle-Baker Mine of Du Pont and the Lawyers property currently being explored by Serem under joint venture with Agnico Eagle, Sudbury Contact and Kennco.

The district is located in a belt of Upper Triassic to Middle Jurassic volcanic rocks which include the Takla and Hazleton Groups and the Toodoggone volcanics as well as related intrusive rocks. Precious metal mineralization is hosted in a variety of settings including silicified zones and quartz veins. The recently discovered deposits and occurrences which form the Toodoggone gold-silver camp are classed in the "No-See-Em" gold type and are indicative of the exploration possibilities still available in the Western Cordillera.

Cinola Gold Deposit, Queen Charlotte Islands, B.C. — A Geochemical Case History

Champigny, N., and Sinclair A.J.; The University of British Columbia, Department of Geological Sciences, Vancouver, B.C.

Shortly after the prospecting discovery of the Cinola deposit in 1970, a soil geochemical survey was undertaken on the property. Mainly B horizon samples were collected and analyzed for numerous elements, including Au, Ag, Hg, Cu, Zn and Pb. The deposit is covered by glacial overburden ranging from 0 to 35 m in thickness with an average of 3 m. Au, Ag and Hg anomalies outline the areal extent of a mineralized zone about 1.3 km^2 in area. Mercury and gold anomalies are roughly coincident and centred on the locus of the mineralized system. Major faults and intensely silicified rock containing micron size gold particles are the two obvious causes for the observed geochemical patterns.

A rigorous statistical evaluation of these data form the basis of evaluating the potential for soil geochemistry in exploration for similar large-tonnage, low-grade Carlin-type gold deposits.

Gold in the Granisle and Bell Porphyry Copper Deposits, British Columbia

Cuddy, A.S., Serewin, Reno, NV., Kesler, S.E.; University of Michigan, Ann Arbour MI.

Gold in the form of electrum is a very important by-product of the Granisle and Bell porphyry copper deposits in central British Columbia. At Granisle, electrum occurs as small grains (10-60 microns) deposited on the surface of the bornite. Rare small inclusions (less than 1 micron) are found in the bornite. At Bell, gold occurs as small inclusions (10-55 microns) within chalcopyrite or attached to pyrite. The composition of electrum from both deposits ranges from 81.5 to 88.5 weight percent gold, the remainder being silver. Gold zoning coincides with copper zoning at both deposits.

Fluid inclusions and instrumental neutron activation analyses of various alteration assemblages suggest that the gold was derived from a crystallizing magma, rather than leached from surrounding country rock. Both Granisle and Bell can be classified as copper-gold types of porphyry copper deposits as opposed to copper-molybdenum types despite their differences in alteration and other mineralogy. This suggests that the class of deposit is established before the actual deposit is formed by such things as the composition of the mineralizing intrusion, its level of emplacement, or the timing of the mineralization with respect to the evolution of the intrusion.

Poorer recoveries of gold at Bell (50%) compared to Granisle (70%) may be due to the loss of some gold with pyrite, the use of only one collector rather than a combination of collectors, the abundant use of lime, and the possibility of refractory coated gold from the supergene zone at Bell.

Grid Rotary Percussion-Drilling: A Bedrock Geochemical Approach to Ag Vein Exploration at United Keno Hill Mines Limited

Franzen, J.P., and Van Tassell, R.E.; United Keno Hill Mines Limited, Elsa, Yukon

The Keno Hill District has been a prolific silver producer for nearly 70 years. Valleys and lower slopes in the district are covered by 9 to 30 metres of residual soil and felsenmeer. Early silver vein discoveries were made where streams had dissected this overburden cover and by isolated float occurrences. As these deposits approached exhaustion in the early 1960's, it became apparent that an effective exploration tool was required to maintain and expand ore reserves. The deep drift-covered vein structures did not respond to traditional geochemical and geophysical exploration methods. To this end, a rotary-percussion drill was developed to penetrate and sample overburden and underlying bedrock. Over the past 17 years, United Keno Hill air-flushing rotary-percussion drills have completed 15,000 holes at an average depth of 35 metres/hole. This ongoing drilling programme, in conjunction with limited follow-up diamond drilling, has been instrumental in maintaining mining operations at United Keno Hill Mines Limited.

The operation, economics and limitations of the United Keno Hill rotary-percussion drilling programme are outlined; several silver deposit case histories are described.

Pathfinders for Precious Metal Deposits, A Case History of Geochemical Exploration for Gold in Central N.S.W., Australia

Garman, M.R.W., and Gilfillan, J.R.; John F. Gilfillan and Associates Pty. Limited, Lane Cove, N.S.W., Australia

Exploration for gold in the Parkes Forbes Goldfield, 300 km west of Sydney, necessitated the development of techniques suitable for an area of modest to low relief, poor outcrop and extensive farm and pastoral development.

Base maps available are adequate for regional purposes but offer little help in the identification of specific targets for drilling.

Extensive geochemical orientation has been carried out based on lode-rock analyses and closely spaced soil sampling to develop suitable geochemical exploration techniques and to identify suitable pathfinder elements. Rock samples were analysed by 32 element Emission Spectroscopy scans. Soil samples were the subject of size-fraction analyses and scans for 7 elements by A.A.S. plus Hg determinations with a Jerome gold film mercury analyser.

Lode-rock analyses indicated that the elements most likely to be useful as pathfinders for gold are copper, lead, zinc?, silver, vanadium, molybdenum and possibly barium.

Orientation soil surveys demonstrated little variation in response for the various size fractions. Samples are now sieved to give a -20# fraction only to preserve the influence of mineralization associated with coarser particulate matter close to lode zones.

Assays of -20 mesh fraction soil samples from two traverses showed that lead gave the best correlation with the known mineralization. However, weak anomalies coincident with the mineralization were also noted with copper, zinc, vanadium, arsenic (?) and molybdenum.

Mercury analyses of the -80 mesh fraction soil samples showed good correlation with known mineralization.

Based on the above orientation studies, routine soil surveys are being undertaken with 10m sample intervals on traverses 50 m apart on the London-Victoria Mine area. It was recognized that the lode zone was non-specifically outlined by lead analyses from sample sites up to 40 m apart and the closer sample spacing allowed a more precise determination of drilling targets from the Hg anomalies.

Drilling results to date in this area tend to confirm the specific nature of the Hg anomalies related to gold-bearing lode zones. Although a general relationship exists between the base-metal elements and Hg, the non-specific nature of the former was demonstrated in drilling near the Victoria mine. Base metals remain a useful additional source of data for subsurface geological interpretation.

The specific nature of Hg as a regional pathfinder has yet to be demonstrated by the drilling of anomalies located in virgin areas. Some encouragement has been gained from the identification of favourable lode rock minerals in ploughed-up fragments in wheat fields of these areas.

Some evidence demonstrates the usefulness of Hg in following lode structures under alluvial cover but has yet to be proven by drilling. No estimate of "depth penetration" of this method through alluvial cover can yet be made but valid anomalies have been found in surface sampled with over 2 m of alluvium to bedrock.

Data presented in this paper has been acquired for Mineral Management & Securities Pty Ltd. of Sydney and their approval and encouragement to publish this paper is gratefully acknowledged.

Analysis of Gold in Soils and Stream Sediments: A Useful Exploration Technique?

Harris, J.F.; Cominco Ltd., Vancouver, B.C.

Geochemical exploration programmes based on the analysis of Au in soils and stream sediments frequently show a dearth of anomalous (i.e., detectable) values, coupled with a low level of reproducibility. This casts doubt on the effecitveness of such surveys, both at the regional and property scales.

By comparison, the high reproducibility obtained for Au in rock samples, even at concentrations near the limit of detection, suggests that the problem is not inherent in the analytical method (in Cominco's case, the widely-used aqua regia digestion/solvent extraction/atomic absorption procedure).

Data are presented on the repeatability of Au analyses from surveys in different terrains and geological environments using different sampling media. In addition, results are given of test work designed to investigate the sources of variance in geochemical exploration for gold via surficial materials, and suggestions made as to modifications in field sampling and lab preparation techniques which may yield improved detectability of anomalies and reliability of results.

Application of Exploration Criteria for Gold Deposits in the Superior Province of the Canadian Shield to Gold Exploration in the Cordillera

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In a review of the geological characteristics of the 135 "gold-only" deposits in the Superior Province which have produced 1 million ounces or more, it was concluded that the deposits are of two main types: *Lamaque-Kirkland type* (33% of deposits, 29% of production) which are vein ores associated with small epizonal felsic intrusives genetically related to volcanic rocks, but emplaced into the stratiform rock sequence after its initial stages of deformation, the deformation being caused by the rise of source magmas into their own volcanic piles; and, *Dome-Beattie type* (67% of deposits, 71% of production), which are syngenetic volcanic exhalative and epigenetic volcanic "vent" ores formed in a submarine volcanic environment. Much of the ore in the volcanic deposits, later epizonal intrusive-related orebodies, is superimposed on the earlier volcanic ores. The study indicates that the most important exploration criteria at the mining camp scale for gold in the Superior Province is the contact areas of mafic volcanic successions with a significant ultramafic (komatiitic) component, and clastic sedimentary successions, commonly with a significant exhalative component. A less important criteria is major fault zones or "breaks". At the mine or property scale, the most important exploration criteria is albite-rich felsic intrusive or extrusive bodies, and in decreasing order of importance, major sediment-volcanic contacts, sulfide $\pm$ carbonate $\pm$ oxide $\pm$ graphite cherty tuffaceous or argillaceous exhalites, presence of indicator minerals (Mg-Fe carbonates, arsenopyrite, tourmaline, scheelite, fuchsite, and Sb and Hg minerals), major stratiform zones of carbonization, and lithogeochemical anomalies defined by depletion in alkalies (especially Na) and enhancement in Au, As, and Sb. At the scale of an individual ore zone, the most important single exploration criteria is structure, i.e. faults, fractures, and various linear features.

A brief review of Cordilleran gold-rich deposits indicates that most (but not all) can be grouped in the same two classes as Superior Province deposits, i.e. epizonal intrusive-related veins (Zeballos and Rossland), and veining and disseminated ores associated with volcanic rocks, and formed just below the lithosphere surface (Cinola). Additional Cordilleran Deposit types are surface deposits formed in non-volcanic geothermal systems (Carolin), and deposits of uncertain origin (possibly also epizonal intrusive-related?) hosted by clastic sedimentary sequences without a volcanic component (Barkerville).

Despite the wide range of rock types associated with Cordilleran deposits, many of the geological criteria for exploration in the Superior Province appear to be applicable to the Cordillera as well. Major clastic sedimentary successions are in contact with major volcanic successions in most camps, with the "Cache Creek-type" volcanic-sediment assemblage being particularly favourable. In many camps there are major fault zones, but in many there are not. At the mining property scale, felsic intrusions or extrusions are common, but in contrast to the Superior Province, the felsic intrusions are much younger than the rocks they intrude, generally, and are not genetically related to them. Also in contrast to the Superior Province, stratiform and cross-cutting zones of intense carbonatization do not appear to be widespread in Cordilleran deposits, and chemical sediments, while present in many of the major camps, are not in most of those of obvious exhalative origin. Finally, the indicator minerals and elements are the same in both areas.

Many of the differences between volcanic-related deposits of the Cordillera and of the Superior Province may be due to Superior Province deposits having formed in submarine environments, whereas most similar Cordilleran deposits appear to have formed in subareal geothermal systems.

The Determination of Gold by Neutron Activation Analysis

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The determination of gold in geological materials presents a challenge to the analytical geochemist. Difficulties are encountered at every stage from sampling through preparation to the final analytical determination.

Most gold analytical work has centered around the fire assay technique. The first detailed recorded use of fire assay was that of Lazarus Ercker — Assayer to the Holy Roman Empire in his book, Treatise on Ores and Assaying, published in 1574.

The reasons for the widespread use of the classical lead fire-assay are simple. Gold is often present in geological materials at the low ppb level. In addition, the distribution of the metal can be very inhomogeneous. Fire assaying allows a relatively large sample size (usually at least 10 grams) to be analyzed as well as concentrating the gold from a complex matrix into a small bead of a relatively simple metal alloy matrix. Until recently, the common procedure was to dissolve (or part) the fire assay bead in acid and to weigh the gold flake remaining (assay method detection limit determined by smallest size of gold flake which can be weighed) or dissolve the gold flake further and run the solution by the atomic absorption spectrophotometric method (geochemical method-detection limit determined by the sensitivity of atomic absorption).

An alternate method has been developed at N.A.S. This involves the irradiation of the fire assay beads and then determining their gold content by instrumental neutron activation analysis. The detection limit of about 1 ppb is determined by the analytical blanks which reflect the gold content in the fire assay reagents. In addition to gold, palladium and platinum can be determined simultaneously.

In recent years, Robert et al. have developed a nickel-sulphide fire assay procedure for all the platinum group elements and gold. This type of fire assay was adapted to instrumental neutron activation analysis by Hoffman et al. This method is the only one commercially available in North America for all the platinum group elements and gold.

In recent years, biogeochemical surveys are gaining tremendous importance in major geochemical exploration programmes for gold. Advances in analytical technology, particularly neutron activation analysis, are directly responsible for the increase in use of this technique.

Geochemical exploration in the Cordillera frequently involves stream sediment sampling with heavy liquid separation of various size fractions for analysis. Sample size commonly available for analysis is extremely small. We have developed analytical procedures for determining Au non-destructively by instrumental neutron activation analysis as well as providing a low cost analytical package for certain "pathfinder" elements.

Multielement Analysis Techniques for Partial Extractable and Total Metal Determination in Stream-Sediment Reconnaissance for Silver Occurrences

Hopkins, D.M., Domenico, J.A., and Leach, D.L.; United States Department of the Interior, Denver, Colorado

Multielement determinations offer the potential of incorporating several pathfinder elements to help delineate precious metal occurrences. Methodology is here described whereby total metal concentrations are determined in stream sediments by semiquantitative optical emission spectrometry for 31 elements and atomic absorption spectrometry for 8 elements. Seven elements are partially extracted from the stream sediments by a weak HCL solution and determined by atomic absorption spectrometry. Analytical uncertainties associated with the analysis methods used are also compared.

The samples are air-dried and sieved to minus 80-mesh (less than 180 microns) before being pulverized in a vertical grinder with ceramic plates. Semiquantitative spectographic values are reported in parts per million or in percent at the approximate geometric midpoints: 1, 0.7 0.5, 0.3, 0.2, 0.15 (or appropriate multiples of 10) of ranges whose respective boundaries are: 1.2, 0.83, 0.56, 0.38, 0.22, 0.18, 0.12 (or appropriate multiples). In general, the precision is within one adjoining interval on each side of the reported value approximately 85 percent of the time.

Samples for total metal determination by atomic absorption spectrometry are dissolved and evaported to dryness in a mixture of hydrofluoric acid and nitric acid, maintained at or below 90 degrees C to prevent volatization of arsenic and antimony. Silver, bismuth, antimony, arsenic , copper, lead, cadmium, and zinc are then selectively extracted from the dissolved residue with a hydrochloric acid solution containing ascorbic acid and potassium iodide, into an Aliquat 336 MIBK reagent organic phase. A portion of this organic phase is stripped with water to remove the As for determination by a flameless atomic absorption technique. The seven remaining elements are determined on the organic phase using flame atomic absorption methods. The partial extractable metal determinations are made by a similar procedure but modified in that a weak solution of hydrochloric acid containing ascorbic acid and potassium iodide is used to leach the sample at room temperature. Then the solubilized metals are extracted by Aliquat 336 MIBK and determined by atomic absorption spectrometry. The total digestion and the leach solution methods allow determination of Ag and Cd to the 0.05 ppm level, and of Cu, Pb, Zn, Sb and Bi to the 1.0 ppm level. Arsenic is determined to the 1.0 ppm level. Investigations involved with stripping the organic extract phase prior to the As determination suggest that similar procedures might be used for lower level determination of Sb and Bi.

The leach solution used for the partial extractable metal determinations dissolves loosely bound metals associated with clays and surface coatings of Fe-Mn oxides. This solution also dissolves most of the secondary minerals such as sulfates, carbonates, and oxides, which are stable under oxidizing conditions, but will not significantly dissolve most sulfide minerals. The total metal digestion solution will solubilize the same materials as will the weak acid leach and also effectively decompose silicates and sulfide minerals. The difference in completeness for the two metal digests makes it possible to compare total metal determinations of optical emission and atomic absorption spectroscopy to partial extractable determinations. In addition, comparisons of the partially extractable metal concentrations to total metal concentrations can be used to aid in delineating known occurrences of stratabound and vein silver deposits.

Sampling Theories — An Overview

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Mining exporation usually involves collection and assay of a large number of samples, each of which must be suitably reduced to an analytical sub-sample and analyzed for constituents of interest. Data are evaluated, and a decision to proceed past the exploration stage may follow.

In these days of diminishing mineral reserves, increasingly marginal deposits must be investigated. As the difference between an economic and an uneconomic grade narrows, it becomes increasingly important to control sampling and subsampling errors. If sampling or subsampling procedures are deficient, the resulting bias in the data may lead to abandonment of a viable property or to exploitation of one which contains too little of the element of interest to be profitable.

Geostatistics is commonly applied in the evaluation of exploration data. The geostatistician must assume 1) that each exploration sample represents, within tolerable limits, the composition of the ore surrounding the sample location, 2) that reduction error is small, and 3) that the analytical procedure is accurately calibrated. If these assumptions are not met, the geostatistical process must fail to give an accurate evaluation.

Knowledgeable application of the sampling theories of Pierre Gy, J. Visman and others will help avoid expensive errors in geostatistical evaluations. If sampling theory is ignored, not only are the chances of a bad evaluation increased, but the exploration may be unnecessarily expensive — sometimes by an order of magnitude.

Primary Dispersion of Gold, Silver and Related Elements at Equity Silver Mines Near Houston, B.C.

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A primary dispersion study was carried out in a 12 x 14 km area around the Equity orebody. Approximately 200 rock samples were collected and analyzed for 17 elements. Plots of these data show a strong multielement anomaly around the orebody and display good zoning characteristics. The lithogeochemical anomaly is up to 4 km across, very much larger than visible alteration, and provides a good ore guide. The geochemical halo cuts all rock types indicating a late stage origin for the mineralization. The implications of the trace element patterns on the origin of the mineralization will be discussed in some detail.

A Regional Geochemical Reconnaissance for Silver in Stratabound and Vein Deposits in Proterozoic Y Rocks of the Belt Supergroup, Idaho and Montana

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There are similar significant occurrences of silver in stratabound and vein deposits in Proterozoic Y rocks of the Belt Supergroup in the Wallace 1 degree x 2 degree quadrangle, Idaho and Montana. To assist in evaluating the potential for undiscovered silver and other mineral resources in this area, a regional geochemical study was conducted as part of the U.S. Geological Survey's CUSMAP program (Conterminous United States Mineral Resource Appraisal Program). Samples of stream sediment and heavy-mineral concentrate were collected at an average density of 1 site per 13 km^2 (5 mi^2). The stream sediments were analyzed by semiquantitative emission spectrometry for 31 elements and by atomic absorption spectrometry for 8 elements. In addition, a weak-acid, partial-extraction of 7 elements in stream sediments was determined. The heavy-mineral concentrates

were analyzed by semi-quantitative emission spectrometry for 31 elements. These data were subjected to a variety of multielement analysis techniques to identify promising areas for more detailed studies. This paper describes the geochemical patterns observed for the silver occurrences in the stratabound and vein deposits and identifies some anomalous areas that may be related to undiscovered silver deposits.

The silver-lead-zinc replacement veins of the Coeur d'Alene district at the western edge of the Wallace 1 degree x 2 degree quadrangle have produced more silver than any other mining district in the world. From 1884 to 1978, approximately 910 million ounces of silver have been produced, together with significant amounts of lead, copper, zinc, and gold. The most important ore minerals are galena, tetrahedrite, and sphalerite. Detailed geochemical studies in the district show that antimony, silver, lead, manganese, and copper form dispersion patterns that are associated with known ore deposits and mineral belts. Our reconnaissance geochemical data show that silver, antimony, lead (and possibly zinc, bismuth, copper and arsenic) and partially extractable antimony, silver, lead, and zinc define anomalous areas that may be related to possible extensions of the Coeur d'Alene district. Possibly the most significant geochemical signature of what we believe to represent Coeur d'Alene mineralization is the partially extractable suite of elements in stream sediments — silver, antimony, lead, and zinc. This geochemical signature may be the result of secondary redistribution of the ore-forming elements by weathering processes.

Anomalous concentrations of copper (at least 100 ppm) have been reported in all formations of the Belt basin except the Prichard and Bonner Formations and their equivalents. These stratabound copper occurrences characteristically contain anomalous concentrations of silver. The most important occurrences in the northwestern part of the Wallace quadrangle are within the Revett Formation. An economic stratabound copper-silver deposit in the Revett Formation is located at Spar Lake, Montana, a few kilometers north of the Wallace quadrangle.

Detailed studies at a stratabound copper-silver deposit in the Revett Formation show that the geochemical anomaly decreases rapidly to background values within 1-2 kilometers of the deposit. The geochemical dispersion away from the deposit is largely the result of the mechanical transport of ore minerals within rock fragments and as fine-grained (less than 30 microns) sulfides. Partial-extractable metal content of the stream sediments is low, suggesting that significant hydromorphic dispersion patterns have not developed away from the deposit. Only copper, silver, and lead make up the geochemical signature observed in this study. The restricted geochemical signature of the stratabound copper-silver deposit, both in size and number of anoma lous elements, may explain the lack of well defined regional trends in the reconnaissance geochemical data that could be related to areas of stratabound copper-silver deposits.

The reconnaissance geochemical data in the Wallace 1 degree x 2 degree quadrangle have proved very useful in defining promising areas for more detailed studies, particularly for Coeur d'Alene vein-type deposits and other mineral resources. However, only limited success has been achieved with the data to date in delineating areas of stratabound copper-silver occurrences. The stratabound copper-silver occurrences may be better delineated when other aspects of the Wallace CUSMAP project are integrated with the geochemical studies.

Geophysical and Geochemical Techniques for Gold Exploration

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Geophysical-geochemical surveys have been carried out over the past three years in the Timmins area by Rosario — Du Pont with the purpose of outlining structures, stratigraphy and carbonate alteration as guides to gold mineralization. Methods employed included major element rock analysis for area selection; induced polarization-resistivity for the detection of carbonate alteration and pyritization; magnetics for mapping both structural trends and magnetic low gradient regions corresponding to carbonatization and ferro-magnetic minerals destruction; and electromagnetics for outlining graphitic stratigraphy, boundaries of carbonate alteration, fold structures, faults, and angular unconformities.

Geophysical data correlated with known geology provided the basis for optimum cost effective overburden-drill till sampling along the trend of, and "down ice" from favourable geological-geophysical areas. Nevertheless, more than one phase of overburden drilling was required to define an anomalous source. Heavy liquid mineral separates from the till samples were analyzed for gold and pathfinder elements, i.e., zinc and arsenic. The application of these methods in Hoyle Township, Ontario, resulted in the discovery of three gold-bearing zones. These zones are currently being further explored by diamond drilling.

These techniques can be directly applied to gold exploration in other regions of Canada.

Element Distribution in Yukon Gold-Silver Deposits

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Selected samples from gold-silver deposits in Yukon representing epithermal, mesothermal, and replacement manto types were analyzed for Au, Ag, B, Mn, Cu, Zn, As, Se, Tl, Pb, Bi, Sb, Te, W, Hg, Mo, and Cd.

Epithermal veins characterized by open space fillings, central quartz-rich metal-poor zones, argillized and propylitized country rock, cockscomb texture and chalcedony are found in, or close to, hypabyssal and subaeraial volcanic rocks of the Late Cretaceous to Early Tertiary Mt. Nansen group in western Yukon. The Vensus mine, a gently dipping fissure filled with quartz, arsenopyrite, pyrite, sphalerite, galena and gold exhibits element zoning that is typical of volcanic-hosted epithermal deposits. Sample sections across the vein from the 2600 to 2850 foot mining levels show that Sb, As, Tl and Au are high in the upper level and Pb, Zn, Cd, Ag are high in the lower level.

From the 2600 foot to 2850 foot levels the following variations are present: Sb—116 ppm to 336 ppm, As—49, 500 ppm to 123,400 ppm, Au—0.24oz/ton to 0.92oz/ton, Pb—1.25% to 0.12%, Zn—1562 ppm to 421 ppm, Cd—37 ppm to 10 ppm and Ag—3.13 oz/ton to 1.30 oz/ton. Tl content is constant in the vein at 20 ppm, but the altered wall rock varies from 40 ppm at the 2600 ft. level to 70 ppm at the 2850 ft. level. In the Mt. Freegold—Mt. Nansen area, quartz vein systems are peripheral to Early Tertiary rhyolite plugs within argillized country rock. Au/Ag ratios are bimodal in the range of 2 to 4 and 0.0X to 0.00X with one quartz vein system on Emmons Hill enriched in Sb, Ba and Hg in addition to gold and silver. The nearby Mt. Pitts area hosts three deposits of chalcedony cemented breccia within argillized granitic country rocks. Both creccia country rock are barren in silver and base metals, but locally argillized quartz monzonite contains up to 0.16 oz/ton gold.

Mesothermal veins are characterized by phyllic wallrock alteration, homogeneous composition, massive interlocking gangue and ore minerals and relatively high Au/Ag ratios with minor base metals. The AJ vein is in hornfels and quartzite near the contact with the Cretaceous Antimony Mountain granodiorite stock. High gold and low silver characterize the As, B, Sb-rich, base metal-poor veins. The Cabin vein south of Dublin Gulch contains high Au, As, and Sb values with a Au/Ag ratio ranging from 0.5 to more than 3.0.

The Woodcock or Ketza River deposit is a manto of massive pyrrhotite and arsenopyrite in Lower Cambrian limestone. Reserves are estimated at 75,000 tons of 0.35 oz/ton Au, and Au varies sympathetically with Cu, As and Sb. Ag is absent. Analyses along a vertical drillhole indicate that the upper portion of the manto is enriched in Cu and Zn and the lower portion is enriched in Au, Cu, As and Sb.

Volcanogenic Massive Sulphides with Apparently Elevated Precious Metal Levels, East Central Alaska Range, Alaska

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A brief discussion of the geological and geochemical aspects of discovery and geological setting of the Delta Massive Sulphide District will be given. Base and precious metal zoning within individual massive sulphide occurrences and similar zoning on a regional basis will be discussed in context with some thoughts on the depositional environment of the massive sulphide bodies.

Gold Geochemistry in the Search for Porphyry Copper-Gold Deposits, Eddontenajon Lake Area, Northwestern British Columbia

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Since 1973, Texasgulf has performed exploration work on several copper-gold porphyry prospects in the Eddontenajon Lake area of northwestern British Columbia. The deposits and showings comprise quartz vein stockworks in highly altered, sub-alkalic monzonitic plutons of mid-Mesozoic age. These generally elongate sub-volcanic intrusive bodies were emplaced into volcanic and volcaniclastic rocks of the Upper Triassic Takla Group. Sulphide mineralization consists of pyrite, chalcopyrite and rare bornite, either disseminated or in sulphide and quartz veinlets. Gold values are low, reaching about 3 ppm in the highest grade sections. The best delineated deposit, RED-CHRIS, contains about 41 million tonnes grading 0.56% copper and of the order of 0.3 ppm gold overall. Other showings in the area have broadly similar gold contents relative to copper values, although within a single drill hole the copper:gold ratio can vary, usually systematically, by a factor of three or exceptionally four. Usually, the lowest copper:gold ratios correlate with the highest copper grades.

Early geochemical work on the properties consisted of copper, zinc and molybdenum analyses in various sample media (stream sediments, soils, basal till), and it was determined that basal till or bedrock surface sampling with a hand-held gasoline-powered sampling drill yielded very good results. Such surveys outlined coherent, well defined and distinct anomalies in copper which closely correspond with the known sub-outcrop distribution of mineralized stockwork zones. In cases where till is absent or very thin, soil samples yielded similarly useful copper anomalies, though there tended to be some downslope dispersion. Stream sediment sampling was found to be of dubious merit.

Subsequently, in view of the distinctive gold content of the mineralization, a selected number of samples of all types from several different properties in the region were analyzed for gold, silver and lead. While neither silver nor lead yielded meaningful patterns, gold analyses generally defined anomalies which were coincident with those for copper, and which showed similar marked contrast between background and anomalous values. There is some suggestion that the gold anomalies are less extensive or dispersed, and show less tendency to migration, especially downslope in the case of soil samples taken in an alpine environment. Gold analyses were performed using a combined fire assay— atomic absorption technique; some problems were encountered with small samples.

It appears that gold geochemistry would be at least as efficient as copper in the search for hidden deposits of this type in this region. Since copper geochemistry is viable, and incidentally considerably less expensive than gold, it is probably not justifiable to use gold analyses, except as a screening check to discriminate between copper anomalies from different types of mineral occurrences. If gold analyses are to be used, there seems to be no need to search for subtle anomalies; in the cases studied values ranged from background at 10 ppb or less, to anomalies at 100 ppb and often as high as 1000 ppb.

Relationship Between Geochemical Dispersions and Geologic Settings of Select Types of Disseminated Gold Deposits

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Important types of disseminated gold deposits include: (1) deposits with gold dispersed through sedimentary carbonate rocks (Carlin type); (2) quartz stockworks in sedimentary carbonate rocks with gold in both the veins and in the carbonate rocks (Cortez type); (3) auriferous quartz veins or stockworks spatially associated with copper mineralizations in siliceous sedimentary rocks; (4) gold or gold-silver bearing jasperoid in either sedimentary or volcanic rocks; and (5) quartz stockworks with gold or gold-silver in volcanic and intrusive igneous rocks.

Hydrothermal fluids responsible for the formation of these deposits contained a variety of elements, and quartz veins and host rocks into which gold was introducted show enrichments in numerous elements. Arsenic, antimony and mercury are generally closely associated with gold and show strong positive correlation coefficients within the gold-arsenic-antimony-mercury suite and generally are the preferred pathfinder elements.

In Carlin-and Cortez-type deposits, primary dispersion halos of most elements away from mineralized areas are very restricted in size. Solution leakage usually occurs upward and outward along fractures and faults, and surface exposures of these features are very good sites for sampling.

Primary geochemical anomalies in arsenic, antimony and mercury occur along surface exposed structures and jasperoids, and can be in positions as much as 150-300 metres horizontally away from underlying ore bodies. Drilling programs for these types of deposits must take into account spatial relations among geologic features and not simply positions of geochemical anomalies.

Sparse low-grade copper mineralization often expressed as veinlets of copper oxides, or malachite, chrysocolla, and/or turquoise coatings on fractures, may have low levels of gold in the veinlets or in fracture walls. Anomalous levels of arsenic, antimony, and/or mercury associated with the copper mineralization may indicate nearby spatially associated quartz stockwork, vein gold mineralization in large volumes, or rock with relatively low base-metal content.

Gold- or gold-silver-bearing jasperoids with ore-grade levels of these elements form along faults or at lithologic contacts where hydrothermal fluids were confined to select zones and were unable to penetrate far into wallrocks. This confinement is due to unfavourable attitudes between wallrock bedding and fault zones. The jasperoid, which is the ore, commonly contains high levels of arsenic, antimony and mercury, together with large amounts of iron oxide after oxidized pyrite. Surface geochemical anomalies represent secondary dispersion of mechanically weathered jasperoid outcrops. Any dispersed mineralization in volcanic rocks away from faults and contacts tends to be in heavily silicified zones. Typical Carlin-type mineralization can occur in nearby sedimentary carbonate rocks in areas where orientations or attitudes between structures and wallrock permit fluid movement along bedding.

Gold or gold-silver stockwork deposits in volcanic and intrusive igneous rocks vary in physical and chemical properties, including varieties and levels of gold-associated elements and in types of wallrock alteration. High levels of arsenic, antimony, and mercury, plus other elements, occur in relatively large primary dispersion halos up to 150+ metres beyond zones of gold mineralization. Selenium is a useful pathfinder element for deposits containing high silver: gold ratios in volcanic rocks.

In prospecting for any of the types of disseminated gold deposits discussed here, it is important to recognize that the pathfinder elements or geochemical anomalies sought are simply used as a guide to find another geochemical anomaly containing as little as a few parts per million gold, which is the ore body.

Trace Gold Analysis with a Newly-Developed Field-Portable Atomic Absorption Spectrometer

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A compact low-power atomic absorption spectrometer for field camp use has been developed. The sequential steps of sample drying, ashing, and atomization of 10 microlitre liquid samples are provided by a miniature tungsten furnace, operating in an argon atmosphere. Background correction is supplied by Zeeman modulation, a technique in which the effect of a strong magnetic field on the atomic absorption line profile is used to correct for the presence of absorbers other than the analyte element.

The instrument has been used for determination of trace Pb, Zn, Cu, Ni and Ag. The bulk of recent work has, however, been the development of methods for trace Au determinations in various geological materials including rocks, ores, gossans and soils.

Compared to many base metals, the dissolution of Au is difficult, particularly if an in-field method is required. The present method utilizing a hydrobromic acid-bromine digestion followed by extraction into methyl isobutyl ketone is not ideal but has proved to be relatively quick and reliable. Concentrations as low as 1 ng.g x.1 can be detected in 10 g samples. Results for samples containing Au in concentrations ranging from a few ppb to 10's of ppm compare favourably with those obtained using established methods (e.g. NAA, fire assay - AA) once the problems of sample inhomogeneity are recognized.

Selected Precious Metals Deposits of Northern British Columbia

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Several old and new precious metal deposits are currently being explored for and some have become recent producing mines. Five areas are described briefly: Toodoggone, Capoose, Equity Silver, Big Missouri-Premier and Torbrit-Dolly Varden. Some common characteristics of epithermal type deposits include:

1. Fissure-related.

2. Associated with volcanic environment.

3. Porosity and/or permeability allow for travel and entrapment of ore-forming solutions.

4. Epithermal mineralization includes argentite, polybasite, pyrargyrite, electrum native gold, native silver with minor galena, chalcopyrite and sphalerite in a gangue of silica, carbonate, fluorite, barite and brecciated country rock.

5. Large gossans adjacent to epithermal ores reflecting weathering of widespread pyrite in the country rock.

6. A possible vertical zoning or telescoping of sulphides and gangue minerals.

7. Genetic relationship of granitoid bodies and co-eval or non-coeval volcanic equivalents.

8. "Low pH cap" if preserved.

Interpretation of Gold-Silver Content of Selected Porphyry Copper-Molybdenum Deposits of the Canadian Cordillera.

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The impact of precious metal prices on the porphyry copper-molybdenum deposits of the Canadian cordillera have caused a renewed examination of the distribution and tenor of gold and silver. This paper examines the available gold-silver values statistically for a number of deposits.

Certain geological parameters are compared to the gold-silver values from the deposits reviewed in an effort to further define the usual generalization that has been presented previously in a global context.

Electrothermal Atomic Absorption Determination of Gold, Silver and Arsenic in Stream Waters and Their Relationship to Gold-Silver Occurrences in the Republic Graben, N.E. Washington

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Fifty-two water samples collected from about one thousand square km of the eastern half of the Republic Graben, NE Washington, were analyzed for Au, Ag, and As by electrothermal atomic absorption spectrometry. The sensitivity and precision of the analytial methods used proved adequate for defining the anomaly/background thresholds for each of the three elements.

Sample density was one sample per 10-20 square km of drainage. The one liter samples collected in the field were refrigerated in the laboratory until bicarbonate analyses were made. After filtration through a 0.45 micrometer membrane, each sample was acidified to

pH 2. Silver and arsenic were analyzed by directly aspiriting 20 microliter of sample into the graphite tube with the automatic sampler. Because of low concentration of gold it was necessary to concentrate by evaporation an aliquot of each sample by a factor of 50.

Gold values averaged 0.049 ppb. Silver concentrations had a mean of 0.11 ppb and arsenic averaged 5 ppb.

Good correlations were found to exist between anomalies in one or more of the three pathfinder elements and 18 of the 20 known gold-silver mining areas present in the study area.

For example, the California Mine is a quartz vein gold-silver deposit in Permian greenstone and argillite located within the drainage feeding the Middle Fork of O'Brien Creek. A sample site 1 km downstream of the California Mine yielded an anomalous value in gold. Similarly, a water sample anomalous in silver from West Deer Creek in the Curlew District detected the silver-bearing copper-lead mineralization of the Lancaster Mine.

Correlation analysis of the log-normalized silver, gold and arsenic data against log-normalized silica showed significant positive correlation between gold and silica, silver and silica, and arsenic and silica. Scatter plots of the above pairs were used to help define the gold, silver and arsenic anomalies. The silica content of the waters appears to reflect the chemical weathering intensity of the sample drainage cells.

Accurate Determination of the Noble Metals — An Overview

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A review of the analytical chemistry of the noble metals is given. Particular emphasis is placed on fire assay, the technique most favoured by noble metal analytical chemists both past and present. Wet extractions done directly on ores are also effective in selected conditions. These will be detailed. In the last decade atomic absorption spectroscopy has become the pre-eminent determinative method and attention is given to strengths and problems of this approach. Other separational and determinative methods are discussed, pointing out the important applications of each. Mention is made of standard reference materials and the indispensible role of these samples.

The Significance of a Discovery of Gold Crystals in Overburden

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In 1978, phacelia (Phacelia sericea) was found with up to fifty times what is considered to be its normal quota of gold. Phacelia generates cyanide and when ashed at a dull red heat about ninety percent of its gold is lost. Thus, it seems reasonable to assume that the gold in this plant is present as a gold cyanide.

During 1979 and 1980, fragments of gold crystals were found in overburden on the hillside below where the phacelia was growing in abundance. In the twenties and thirties of this century, several thousand ounces of placer gold were recovered from the creek in this vicinity, now known as "Stirrup Creek".

These facts suggest that gold may be more mobile than is generally assumed. This, in turn, suggests that biogeochemistry may well play a role not only in the formation of some placer deposits but also in the origin of such occurrences as those of the Rand in South Africa.

Geological Setting and Characteristics of Bulk-Tonnage, Low-Grade Silver Deposits in the Southern Cordillera.

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The bulk-tonnage, low-grade silver deposits are considered herein to be a *specific deposit type* in the same sense as are, for example, the "porphyry coppers". Thus, it seems desirable to exclude from this category mineralization belonging to other deposit types (i.e., the Sam Goosly "volcanogenic massive sulphide" or the Spar Lake "Belt-type stratabound silver-copper") which are now silver deposits in large part because of the high price of silver relative to other metal prices.

A number of bulk-tonnage, low-grade silver deposits in the southern Cordillera are discussed and are found to fall generally into two classes 1) the disseminated type, and 2) the stockwork type. The truly disseminated silver deposits are found in clastic host rocks within Cenozoic or Mesozoic volcanic terrains, are usually associated with silicification, and often present severe metallurgical problems. The stockwork-type silver deposits can, at times, be spatially and genetically related.

Several large silver lodes are also now known which fall into a "replacement" or "manto" category. They are hosted by Paleozoic carbonates or shale-limestone contacts. Similarities to certain bulk-tonnage gold deposits are evident. For that matter, grade and tonnage figures on several new operations and recent drilling projects suggest that an entire spectrum might well exist between bulk-tonnage silver deposits with little gold, and bulk-tonnage gold deposits with little silver.

The application of exploration geochemistry to finding bulk-tonnage, low-grade silver deposits is not yet well-documented. Nearly all of the disseminated and stockwork deposits noted herein were delineated by drilling clusters of old workings which evinced good surface mineralization.

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