The Gangue

GAC - Mineral Deposits Division Newsletter

Issue 34 January 1991

Hemlo Gold District Metamorphic Petrology & Alteration Assemblages

by M.E. Fleet & Y. Pan
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Abstract from Dec. 1990:
Ontario Mines & Minerals Symposium

The Hemlo-Heron Bay greenstone belt is comprised mainly of metamorphosed volcanic and clastic sedimentary rocks and is bordered by two granitoid complexes, the Pukaskwa Gneissic Complex to the south and the Gowan Lake Pluton to the north. The clastic metasedimentary rocks are highly immature (in both texture and geochemistry) and have relatively high contents of LREE. The geochemical uniformity of given rock types throughout the stratigraphic section (*e.g.*, greywackes and mafic metavolcanic rocks from both sides of the Hemlo Fault zone, and from the Playter Harbour Group and Heron Bay Group) indicates that the greenstone belt most likely formed in a single tectonic setting (oceanic island arc) rather than by a juxtaposition of suspect terranes.

Detailed field and petrographic observations (including mineral assemblages and textures, xenoliths of deformed country rocks and a narrow contact aureole) reveal that the granodioritic Cedar Lake Pluton has not been affected by the metamorphism recorded in the supracrustal rocks. Therefore, both the local plutonism and formation of the Hemlo gold deposit postdate the peak thermal metamorphism and peak ductile deformation of the region.

Observations on the C zone of the Williams mine, the North zone of the Golden Sceptre Resources property (GSRp), and the Muir zone (which is fault-related to the South zone, GSRp) confirms the association of gold mineralization with sheared rocks. However, gold deposition was probably related to migration of fluids along dilatant structural failures of regional extent. A late calcsilicate alteration (epidote, prehnite), first recognized on the White River exploration property, has been identified at numerous localities within the greenstone belt in the vicinity of the Hemlo deposit. In the main ore zone, this late calcsilicate alteration is indicated by assemblages of epidote, tremolite, titanite, prehnite, pumpellyite, grossular and armenite.

The Hemlo gold deposit is well known for its enrichment in vanadium and the presence of a large number of vanadium-rich minerals pumpellyite and allanite (with up to 25.7 and 9.1 wt. % V_2O_3, respectively) have been found in green mica schists from the gold deposit. The former represents a new mineral end-member composition for the pumpellyite series: $Ca_8(V,Mg,Fe)_4(V,Al)_8Si_{12}O_{55-n}(OH)_n$, with vanadium as the dominant cation in both X and Y sites. This is the first report of a substantial substitution of vanadium into the allanite structure.

Green mica schists associated with a barite-rich horizon west of Hemlo are characterized by barium-chromium muscovite and barium feldspars of the alkali feldspar-hylophane-celsian series, both different from counterparts in the main ore zone of the Hemlo gold deposit.

PROFESSIONAL ENGINEERS & GEOSCIENTISTS BRITISH COLUMBIA

The new Engineers and Geoscientists Act was proclaimed on August 2, 1990, clearing the way for professional registration of geoscientists in British Columbia. The act is an amendment of the Engineers Act, 1979 and provides a mechanism for professional registration of geoscientists as *Professional Geoscientists* (P. Geo.) and not *Professional Engineers* (P. Eng.), as in the past.

This important achievement is the result of five years of work by the Earth Science Task Group established in October 1985 by the Association of Professional Engineers of the Province of British Columbia at the urging of many members of the geoscience community, and would not have been feasible without the full support and co-operation of the Association.

Under the new Act, geoscientists applying for registration will have their credentials reviewed by a committee of geoscientists in the discipline of geoscience only and not in unrelated engineering fields as before.

The Association of Professional Engineers and Geoscientists of the Province of British Columbia is currently working on the changes to the Bylaws of the Association required to accommodate the geoscientists amendment, and expects to be ready to accept applications for registration by January 1, 1991.

Prohibition on the practice of geoscience by non-members, as defined by the terms of the Act, is expected about July 1st, 1992. This allows sufficient time for individuals engaged in the practice of geoscience to apply for registration.

A two-year grandfathering period will allow present practitioners to apply. This will end 31st December 1992.

Further details may be obtained by contacting the Association directly at 2210 West 12th Ave, Vancouver, BC, V6K 2N6, Tel: (604) 736-9808 or, V.A. Preto, Geological Survey Branch, 756 Fort Street, Victoria, BC, V8V 1X4, Tel (604) 356-2833.

1990 Julian Boldy Award

The Julian Boldy Award for the most significant and creative paper presented to an MDD session at the 1990 Annual General Meeting was won by three senior geologists from Newmont. The presentation was entitled *Current Geologic Research and Deep Gold Deposits of the Carlin Trend, Northeast Nevada* and was presented by **Galen C. Knutsen** and co-authored by **Charles Zimmerman** and **Odin Christensen.** Each of these authors was presented with a certificate and a $75 book prize in recognition of their professionalism. The authors have kindly supplied a text version of their presentation, which is included in this issue of *The Gangue*, and the following response on receipt of the award:

"On behalf of Chuck Zimmerman, Odin Christensen and myself, may we extend a *Thank You* to the Mineral Deposits Division of the GAC for the Julian Boldy Award. It is quite a surprise and certainly an honour to be so awarded.

"J. Alan Coope of Newmont has described to us the many contributions of Mr. Boldy (Alan, by the way, wrote Mr. Boldy's obituary in *Geolog* in 1985) and he surely strikes me as one who would bave been a great mentor in a mature district, such as the Carlin Trend. The word *pragmatic* in describing Mr. Boldy's approach to exploration strikes a chord; we at Newmont pride ourselves in that philosophy to exploration on the Trend.

"It can be difficult in a mature district to avoid becoming dogmatic. To continue to be successful, one must create the atmosphere necessary to integrate the practicality and experience of the production geologists, the optimism and creativity of the explorationists, and the focus of the academics, into a pragmatic philosophy for exploration.

"We in the geologic sciences are sometimes accused of collecting information for information's sake. We are data brokers; increasingly so for non-traditional users of geological data and particularly now for geotechnical, geohydrological and geo-environmental concerns. There is a need for balance in data acquisition because of the costs associated with collection, as well as storage of information.

"Geologists tend to be *future-oriented* and thus must anticipate the needs of clients be they managers, engineers or environmental regulators. Consider, for example, the ramifications of the classification of mine dump material as hazardous waste, or the need to characterize the acid rock drainage potential of waste dumps. Geologists must supply the classification scheme and must characterize the distribution of these potential bad-actors. In addition to anticipating client needs, we must let them know that we have, or can supply, the answers. Further, and perhaps most importantly, information must be delivered to the end user in a suitable form. Geologists tend to be qualifiers, and commonly assign limits or conditions to geological data, much to the frustration of managers and engineers who look for quantifiable answers.

"In addition to the value of a pragmatic approach to our business, it is important to create a sense of urgency. For those of us in production, that urgency is usually provided by the operators. It is critical to impart upon explorationists that they are the future of our companies. Managers too must realize that explorationists are the key to long-range planning in a corporation. It must be made clear to the exploration geologists that they are integral to corporate success, and are being paid to look for economic mineral concentrations, now, not later...

"In accepting the Julian Boldy Award, we must acknowledge the contributions of many geoscientists involved in furthering our understanding of the Carlin Trend; the graduate students, college professors, U.S. Geological Survey geologists, and particularly, the many Carlin Trend geologists - those who really make things happen!"

Sincerely,
Galen C. Knutsen
Manager of Mine Geology

MDD Lapel Pins

The Executive and Directors of the MDD decided at the May 16, 1990 Executive Committee Meeting to have an MDD lapel pin made resembling the current logo. The pin design, illustrated at right and used on the newsletter masthead, is now available to members and other interested individuals.

The bronze pins are available for $3.00 each and may be purchased from Bob Hewton, Director-MDD, in Vancouver, Tel: (604) 687-2557; or, by mail from Michael Gray, Secretary-MDD, c/o Falconbridge Ltd. (Exploration), P.O. Box 40, Falconbridge, Ontario, P0M 1S0. Please make cheques payable directly to Michael Gray.

Special thanks go to Bob Hewton, who was instrumental in having the pins made in Vancouver, and also to Carol Podchashinsky of BP Mining Ltd. who submitted the original design for the MDD logo.

The Gangue No. 34 January 1991

The Gangue is published quarterly by the Mineral Deposits Division, GAC, and is distributed to all members of the MDD as part of their membership fee.

Publication Schedule:

SUBMISSION DEADLINE	PUBLICATION DATE
December 15	January
March 15	April
June 15	July
September 15	October

Information for contributors:

The objective of this newsletter is primarily to provide a forum for members and other professionals to voice new ideas, describe interesting mineral occurrences or expound on deposit models. Articles on ore deposits, deposit models, news events, field trips, book reviews, conferences or other material which may be of interest to the economic geology community are welcomed. Reprints of presentations given to companies, mining groups or conferences are particularly encouraged.

Manuscripts should be submitted on 5¼" or 3½" IBM- formatted diskettes in any major word processor format. A printed version should be included. Illustrations should be in camera-ready format; photos should be of good quality. Short items dealing with news events or meetings may be submitted by FAX or mail.

All contributions may be edited for clarity or brevity.

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Again, we ask everyone to encourage geologists to join the division; more members mean a wider base from which to draw articles and information which will be of interest to all.

CURRENT GEOLOGIC RESEARCH AND DEEP DEPOSITS OF THE CARLIN TREND NORTHEAST NEVADA

By: Galen C. Knutsen,
Newmont Exploration Limited
Charles J. Zimmerman
Newmont Gold Company
Odin D. Christense,
Newmont Exploration Limited

INTRODUCTION

Since the original discovery of the Carlin deposit in 1962, more than 250 tonnes (8 million ounces) of gold have been produced from the Carlin Trend. Exploration, particularly for deeper targets has been very successful, such that at the end of 1989, Carlin Trend resources stood at about 20 000 tonnes (65 million ounces); 1200 tonnes (38 million ounces) of that being within proven and probable reserves.

The Carlin Trend is one of several alignments of epithermal, sedimentary rock-hosted, disseminated gold deposits in the Great Basin geologic province. Five subdistricts comprise the 65-kilometre long, north-northwest elongate Carlin Trend. Each subdistrict exhibits unique or distinctive controls on the distribution of gold. From north to south these are the Bootstrap, Blue Star, Lynn, Maggie Creek, and Rain subdistricts.

GEOLOGY OF THE CARLIN TREND

Three stratigraphic assemblages comprise most bedrock outcrops along the Carlin Trend. Lower Paleozoic eastern or carbonate autochthonous miogeoclinal rocks were deposited on the ancestral North American platform and continental slope. Coeval western or siliceous allochthonous, eugeoclinal assemblage rocks were deposited on the continental slope and ocean-basin floor. Compressional tectonism during the Late Devonian to Early Mississippian Antler orogeny, thrust the western assemblage siliceous rocks over the eastern assemblage carbonates, juxtaposing the units along the Roberts Mountains thrust. Overlap assemblage rocks, eroded from the Antler orogen, were deposited in the foreland basin east of the Antler highland.

In late Mesozoic time, calcalkalic plutonic activity was accompanied by doming and folding of the sedimentary units along north-northwest trending axes. Windows of uplifted miogeoclinal carbonates have eroded through the structurally broken antiforms. Carlin-type gold deposits occur near the margins of these windows along high angle faults (Figure 1). Most of the major gold deposits are hosted in the eastern assemblage Silurian-Devonian Roberts Mountains Formation and Devonian limestone units, in an autochthonous calcareous and siliciclastic package known informally as the Rodeo Creek unit, and in the Mississippian Webb Formation at the base of the overlap assemblage.

Carlin Trend deposits are controlled by: favorable stratigraphy, major through-going high angle faults, zones of structural stockworks, and antiformal traps. Favorable stratigraphy characterized by both primary and secondary porosity and permeability is typified by the calcareous siltstones of the Roberts Mountains Formation in the Carlin mine. Hydrothermal breccias superimposed upon depositional breccias preferentially host the deep mineralization at the Lower Post deposit. Structural traps, such as brecciated portions of the Tuscarora Spur antiform, control oxide mineralization at Genesis and Post in conjunction with favourable stratigraphy. Gold distribution at Gold Quarry is a structural stockwork, wherein the rock is pervasively fractured and gold is fracture controlled and broadly disseminated throughout the rock mass. Structural control by a single major fault segment is exemplified by the Bootstrap fault, where the gold mineralized zone is fairly tightly constrained to the trend of the fault. Elsewhere, such as at the Rain deposit, gold mineralization pervades the sedimentary strata adjacent to the Rain fault.

STACKED DEPOSITS

As exploration for deeper mineralization has progressed on the Carlin Trend, a stacking of gold deposits one atop another has been observed. Various levels within the mineralized system exhibit differing host lithologies and styles of control on gold distribution, as described above.

The Gold Quarry deposit in the Maggie Creek subdistrict is considered as two distinct deposits: the near surface Gold Quarry main orebody and the underlying Deep West deposit. Gold Quarry is one of the largest deposits on the Carlin Trend, having a gold reserve in excess of 315 tonnes (10 million ounces). It is localized at the intersection of the major northeast and northwest trending window-bounding Gold Quarry and Good Hope faults, respectively. The oxidized Gold Quarry main orebody has an average grade of 1.5 grams per tonne and is hosted in highly fractured Devonian siliciclastic rocks. The

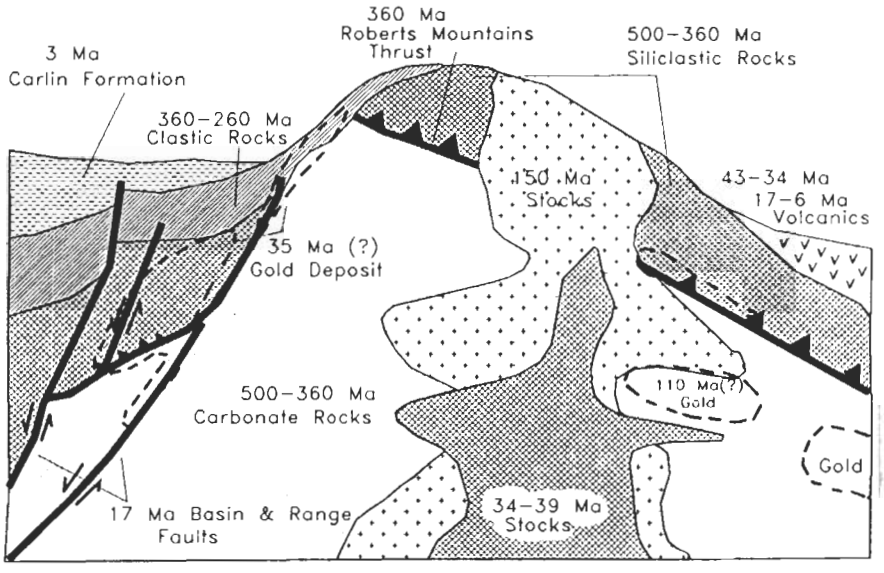
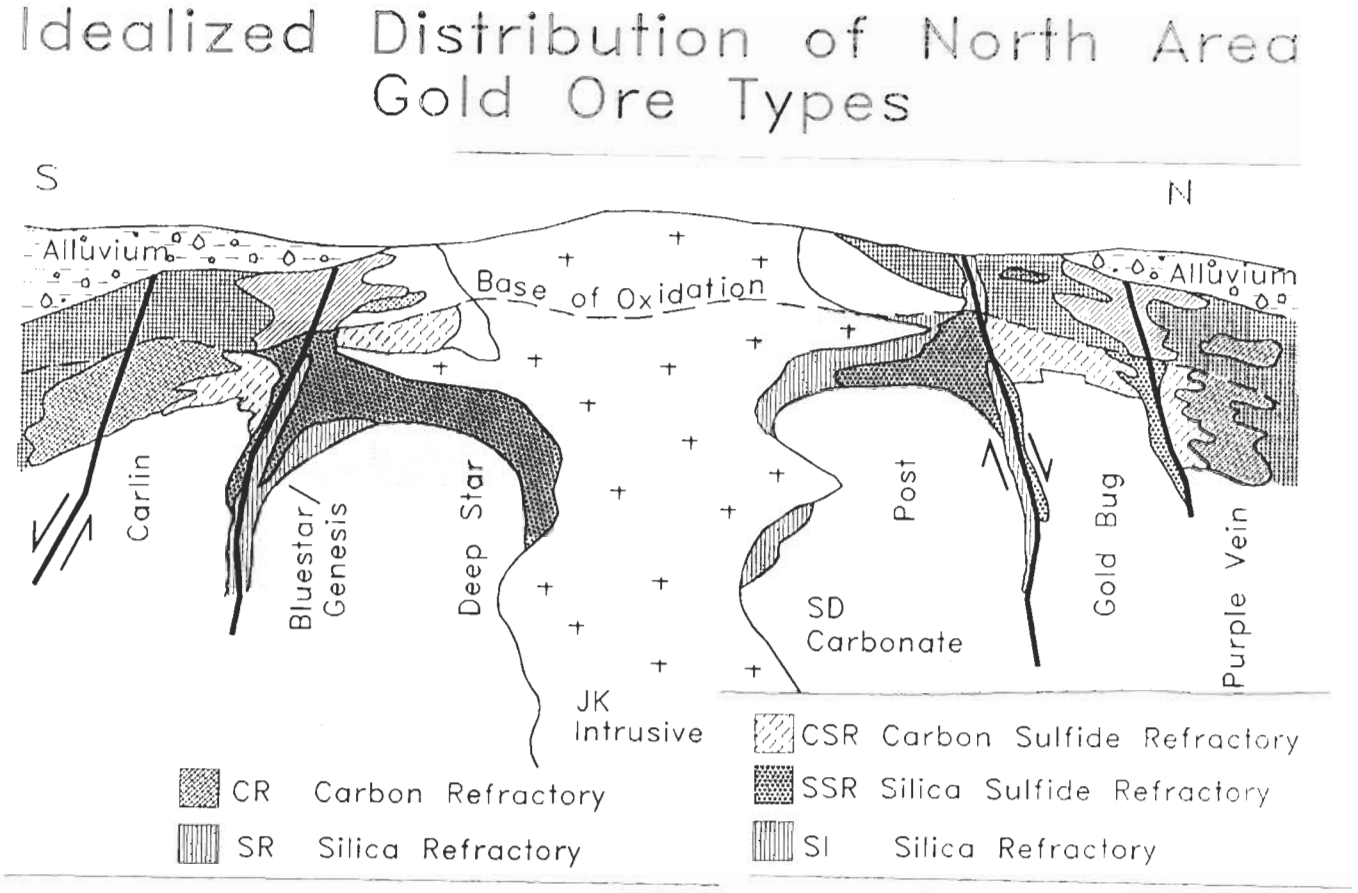


Figure 1



Deep West refractory deposit underlies the Gold Quarry main zone at depths up to 200 metres, and is stratigraphically controlled within decarbonatized and silicified Devonian limestone. Deep West exhibits ore grades two to three times that of Gold Quarry. Four ore types are observed in the Gold Quarry system:

silica-sulphide: pyrite and quartz associated with hydrothermal feeder zones

carbon-sulphide: intermixed refractory carbon and sulfides

silica refractory: silica encapsulated particulate gold

oxide: ores amenable to direct cyanidation treatment

Surface oxidized ores at the Post deposit, grade between two and three grams per tonne and are hosted in siltstones and argillites of the highly fractured Devonian Rodeo Creek unit which has been folded into a broad antiform. The orebody is bounded on the east by the 340°-trending Post fault, which is a major hydrothermal conduit. At a depth of 250 metres, coincident with the base of oxidation, lies the Devonian limestone. Near the base of this miogeoclinal unit, a depositional breccia acts as a preferred host to higher grade (3 to 6 g/t) gold mineralization. Adjacent to the 160 Ma Goldstrike granodiorite stock, at Deep Post, gold grades within a structurally prepared zone range from 10 to 20 grams per tonne.

Margins of the Goldstrike intrusion play a major role in localizing gold deposits in the Blue Star subdistrict. The stock intrudes the Paleozoic sediments of the NNW-trending Tuscarora Spur antiform. Deposits which exhibit a distinct clustering at the periphery of the intrusion include the Blue Star, Post, Betze, Genesis, North Star, Long Lac, Baza, Bobcat, and Deep Star. Cumulatively, the Blue Star subdistrict hosts the greatest concentration of gold on the Carlin Trend, approaching 950 tonnes or 30 million ounces as reserves and geologic resources.

A symmetry of ore types around the Goldstrike intrusion is apparent (Figure 2). Close to the intrusion, ores are characterized by gold-bearing fine-grained pyrite and marcasite. This grades outward into a sulphide-carbon ore, which grades distally to simple carbon-refractory ore. Supergene and/or hypogene oxidation of sulphidic and carbonaceous protores may have locally enriched gold grades along specific structural zones.

Endoskarn, exoskarn, hornfels, and marble lithologies indicate significant metasomatic interaction between the intrusion and the calcareous and siliceous sediments. Skarn mineralogy is characterized by diopside, garnet, wollastonite, actinolite, and idocrase. Gold is most enriched at the outer limits of the metamorphic rocks with the sedimentary units. In general, skarn, marble, and hornfels do not make good hosts, generally a function of limited porosity and permeability. Only at the recently discovered Deep Star deposit, with average grades of 30 grams per tonne, is ore hosted in skarns.

DEPOSIT GENESIS

The primary controls on the localization of economic concentrations of gold on the Carlin Trend are stratigraphy and structure. Penetrative, ore-controlling faults have been repetitively activated, in a variety of stress regimes, over geological time. Favoured host stratigraphy include depositional and hydrothermal breccias as well as siltstone, sandstone, and decarbonatized silty limestone units with inherent enhanced porosity and permeability. Sequenced favorable stratigraphy has led to stacked mineral deposits.

Recent discoveries of deeper, high-grade refractory gold beneath oxidized near-surface orebodies, coupled with ongoing research into the origin and evolution of these deposits, suggests that the conventional wisdom concerning their epithermal character be re-evaluated. Fluid inclusion studies by Kuehn and recent age dating by Newmont Exploration Limited and Arehart indicate that economic gold concentrations were deposited by CO_2 and H_2S-rich fluids at 215°C and 800 bars, corresponding to a depth of about 3 kilometres, sometime between Early Cretaceous and Late Eocene time. Age dates from the Deep Post deposit suggest that main stage gold mineralization occurred at 110 Ma, based on hydrothermal sericites with post-ore monzonite dikes and sills dated at 39 Ma. Alunite, which likely reflects waning

tivity, has been dated at 30 and 12 Ma, respectively, at the Gold Quarry and Rain orebodies. Metal ratios are more constant over 2000 vertical feet of gold mineralization than would be found in boiling epithermal systems.

SUMMARY

Five subdistricts comprise the Carlin Trend, each distinguished by important local stratigraphy and by structural setting: Rain, Maggie Creek, Lynn, Blue Star, and Bootstrap. Despite 25 years of exploration and mining on the Carlin Trend many questions remain concerning the genesis and localization of the deposits within these subdistricts. Although, the probability of discovering near-surface, oxide deposits decreases with time, the possibilities with respect to deep targets is open-ended.

Deep deposit geometries reflect the combined influences of: stratigraphy; paleohydrology; contrasting permeabilities between variably altered Paleozoic sedimentary rocks, Mesozoic and Cenozoic plutonic rocks, and associated metamorphic aureoles; and pre and post-ore structures. Vertically and horizontally oriented structural dilational jogs at a variety of scales may have created low pressure regimes where decompressional boiling and mixing of meteoric waters and metalliferous hydrothermal fluids deposited submicron gold in very fine grained pyrite and marcasite. The Deep Post and Deep Star deposits are spatially focused around calcalkalic plutons of intermediate composition that have intruded favorable stratigraphy along NW, NNW and NE structures. Detailed geologic, geophysical, and geochemical modeling will guide future exploration to the base of the Paleozoic section and, perhaps, into the Precambrian basement.

RANKING COUNTRIES FOR MINERALS EXPLORATION

by Dr. Johnson
Minerals Policy Program
East-West Center
Honolulu, Hawaii.

Reprinted in part from: *Natural Resources Forum,* Vol. 14, No. 3, August 1990.

A recent publication by Dr. Charles J. Johnson presents the results of a survey of multinational mining companies in which they ranked countries for nonfuel minerals exploration in the early 1990s. The following article summarizes the highlights of Dr. Johnson's paper.

The paper ranks countries in order of greatest exploration interest for the early 1990s, and those countries that have geologic potential but unacceptable investment climates. The results of the survey indicate that major mineral-exploration activities are concentrated in a small number of countries. Political and economic reforms around the world should increase the number of countries receiving active private sector exploration in the 1990s.

The research is based on the nonfuel minerals exploration priorities of large multinational mining companies with estimated total minerals exploration expenditures in 1989 of roughly US$900 million. The survey is based on the 32 mining companies listed in the table below that returned questionnaires during the period June-November 1989.

COMPANIES RESPONDING TO THE SURVEY

AUSTRALIA	UNITED STATES
Ashton Mining	AMAX Explor.
BHP-Utah Minerals	ASARCO
Bridge Oil	Battle Mt. Gold
CRA Exploration	Cyprus Minerals
Cnt'l Norseman Gold	Freeport-McMoran
N. Broken Hill Peko	Hecla Mining
Western Mining	MinVen Gold
	Newmont Explor.
	Nord Resources
	Pegasus Gold
	Phelps Dodge
CANADA	**WESTERN EUROPE**
Cominco Resources	BP Minerals
Falconbridge	Billiton Int'l Metals
INCO	Cie Generale des Matieres Nucleaires
Noranda	Metallgesellschaft
Placer Dome	Rio Tinto Minerals
	Ste Generale de Belgique
PHILIPPINES	**SOUTH AFRICA**
Atlas Consolidated	Anglo American
Marcopper Mining	

Companies were assured that individual replies would remain confidential, and 48% of the companies contacted returned completed questionnaires. Most of the survey questionnaires were sent to heads of minerals exploration departments. Therefore, the views in the paper probably do not always reflect the views of the financial or legal executives of these companies. This difference is most significant with respect to the terms that would be acceptable at the exploration stage as compared with those terms that would be necessary at the mine development stage.

Selecting Countries for Exploration

The problems in selecting countries for minerals exploration and major mining developments are well known. There are technical, economic, legal, political, and security risks that must be weighed. In this survey, risks were grouped into two categories: geologic and investment climate risks. The results indicated that geologic potential is the most important criterion in selecting countries for minerals exploration. Most exploration programs begin with an assessment of a country's geologic attractiveness for target mineral commodities and deposit types. There may be a preliminary filter to eliminate countries and regions where the company would not consider minerals exploration because of unacceptable investment climates or other strategic considerations.

The second most important factor is political stability, with mineral policies third. Other factors of less importance include infrastructure and utilities, geographic location, and past experience. Past experience had a low priority in the survey. However, in the author's experience, once companies become established in a country, they will usually continue to explore as long as there are attractive exploration areas and an acceptable investment climate.

From a government policy perspective, providing information on the country's geologic potential is very important in attracting investor interest. However, the governments of most developing countries are quite inefficient in compiling and distributing geologic information to potential investors. It is unusual to find a complete list of up-to-date maps, publications and open-file reports that can be readily obtained or examined by potential investors. A related critical issue is that governments must ensure that attractive exploration areas are open to active exploration.

Discussions with company executives indicated that if one of the key criteria (minerals potential, political risk, or mineral policies) changed from favorable to unfavorable, the country would be dropped from their active exploration list. Thus, the value of modern

Errata

Please note that the last issue of The Gangue carried an error in the financial statement for the MDD. Table 3, page four of Issue #33, for the Newfoundland Guidebook should have indicated a revenue of $4408 during 1989 (not $1176) with a resulting deficit of $8575.11 (not $4437.11).

Our apologies to the Treasurer for any misunderstandings.

country would be dropped from their active exploration list. Thus, the value of modern legislation and consistent policies that reflect the minerals potential and political risks of a country are becoming increasingly important in attracting active private-sector investment.

Priority Countries

Companies in the survey were asked to list in order countries where active exploration was probable during the early 1990s, the per cent of their exploration expenditures in each country, and their overall investment climate ranking for each country. The ranking of countries shown in the table below is based on the number of companies that listed the country and not the total amount to be spent in the country. This is because large expenditures by one or two companies could rank a country high even though other companies in the survey showed little interest in it.

The top three countries are the United States, Canada, and Australia. They also top the total amount to be spent (71% of the total), and the investment climate ratings. Australia, ranked third, is expected to receive greater exploration expenditures by the companies in this survey than Canada, ranked second.

Chile is the top developing country, with Indonesia and Papua New Guinea following in second and third place among developing countries. Papua New Guinea, rated for most of the past decade as one of the most favourable investment climates among developing countries, is still rated as good in this survey, but is in danger of falling in company ratings if the central government is unable to halt terrorist activities against mining projects.

Countries Where Active Minerals Exploration is Probable in the Early 1990s[a]

Rank[b]	Country	Investment Climate[c]
1	United States	VG+
2	Canada	VG+
3	Australia	VG+
4	Chile	VG-
5	Indonesia	G
6	Papua New Guinea	G
7	Mexico	G-
8	Brazil	F+
8	China	F
10	Botswana	G+
10	New Zealand	VG
10	Thailand	G-
13	Malaysia	G-

[a] *Includes countries on the lists of at least four companies in the survey.*

[b] *Rank is based on the number of companies that list the country. The European Economic Community was also on the lists of five of the companies in the survey.*

[c] *Investment climate ratings in the questionnaire were: E=excellent, VG=very good, G=good, and F=fair to poor(a simple average of company ratings was used).*

Botswana is the only African country to make the list with the second best investment climate rating among developing countries. Botswana is one of the few developing countries in the world that has had active minerals exploration for most of the past two decades, continued mine developments and expansions, and consistent policies that allow the private sector to control mining activities. The combination of rich mineral resources and a stable investment climate have allowed the Botswana government to negotiate more favourable terms for the government than is possible in most developing countries.

China shows up on the exploration lists of six companies, but planned expenditures are low. It received the lowest investment climate rating of any country where investment is planned in the early 1990s. The apparent contradiction between investor interest and the investment climate is primarily for two longer-term strategic reasons. First, there is great potential for major mineral discoveries in China. Second, the internal China minerals market is the largest among developing countries, and among the fastest growing in the world.

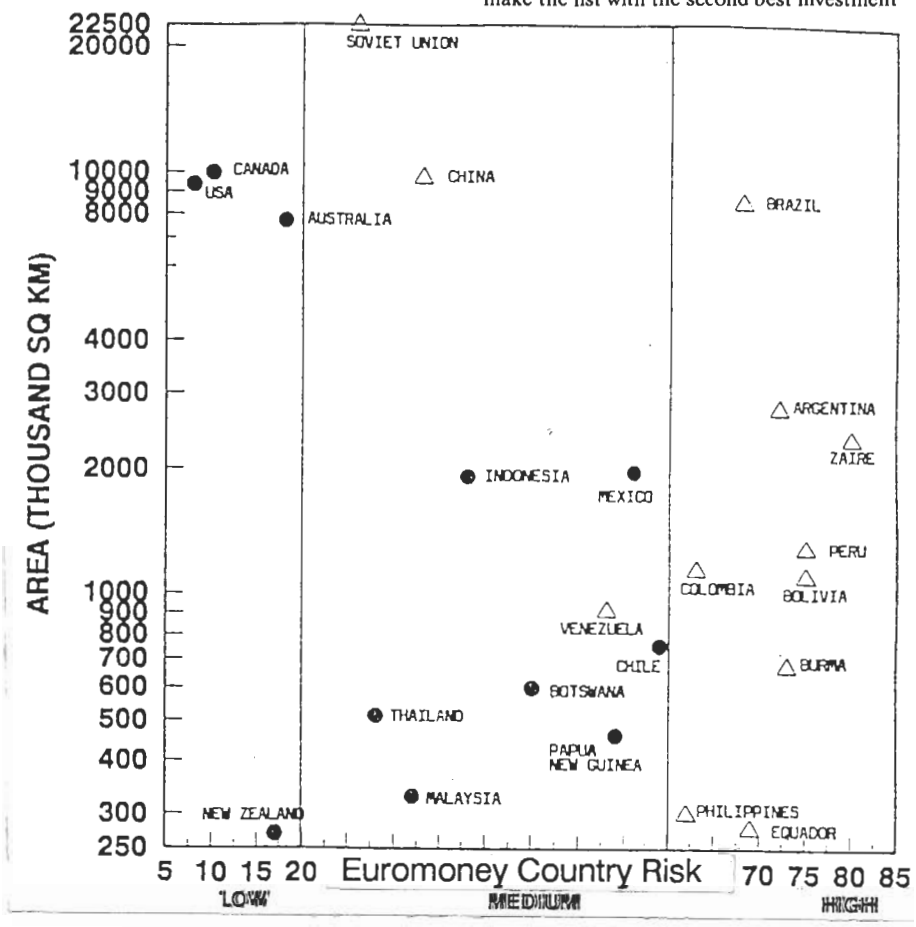
The survey also identified countries, as listed in the following table, which have substantial geologic potential and could expect a particularly strong response in exploration activity if their investment climates improved.

Countries with Favorable Geologic Potential But Needing Improvements in Investment Climate[a]

Rank	Country
1	China
1	Peru
1	Philippines
4	Brazil
5	Argentina
5	Mexico
7	Bolivia
7	Venezuela
9	Burma
9	Indonesia
9	U.S.S.R.
9	Zaire
13	Chile
13	Colombia
13	Thailand
16	Ecuador

[a] *Includes countries on the lists of at least four companies in the survey. Rank is based on the number of companies that listed the country. Countries on the list of two or three companies include: Angola, New Zealand, Papua New Guinea, Zambia, Zimbabwe, Ghana, Panama, South Africa, Turkey, and Vietnam.*

Brazil, Chile, China, Indonesia, Mexico, and Thailand are included in both acceptable and unacceptable lists of countries for exploration. This apparent contradiction is because companies have different assessments of investment climates, and different levels of acceptable risks. Companies most often listed Chile and Indonesia among the acceptable countries. Companies were roughly equally divided on whether Mexico and



predominantly included on the unacceptable list.

Eight of the unacceptable countries are in Central and South America. This can be linked to the fact that the majority of companies in the survey are from North America and have historically dominated exploration activity in South America. The second largest group of countries where companies would like to explore is in Asia and the western Pacific. Only one African country, Zaire, is in the top 16. If the list was extended to 24 countries, it would include Angola, Ghana, South Africa, Zambia, and Zimbabwe. The small number of companies that listed African countries as potential exploration targets is surprising given the large minerals potential of the region. This may partly be due to a general decline in interest in investing in Africa over the past 25 years because of unacceptable investment climates in many African countries. It may also reflect the fact that the survey placed less emphasis on the more traditional investors in Africa the European companies.

South Africa is the second or third largest nonfuel minerals-producing country in the world in terms of value, but does not show up on the exploration list in either the probable or the potential exploration lists. It is known that there is active exploration by South African companies, but limited exploration by non-South African companies because of the government's present apartheid policies. It is surprising that South Africa did not show up for potential exploration, because it is likely that active exploration will occur in South Africa when apartheid policies are dismantled (probably in the next few years), assuming an acceptable investment climate is maintained. A return of investment to South Africa could also stimulate exploration in neighboring countries.

The survey also provided a list of priority commodities for exploration. Gold was the foremost exploration target, with 97 per cent of the companies in the survey including gold on their exploration lists. In every case, gold was placed among the top three mineral commodity targets. The top three exploration targets are gold, copper, and zinc. They probably account for over 80% of nonfuel minerals exploration. Commodities which show up on the exploration lists of less than 15% of the companies included chromite (13%), molybdenum and phosphate (9%), silver and tin (6%), cobalt and sulfur (3%).

Exploration Plans Vs Country Risk & Area

The level of country risk is usually an important factor indetermining whether a geologically attractive country receives active exploration activity (*see* figure). The countries in the preceding tables are plotted on the bases of country area (a rough substitute for minerals potential and should be viewed with caution) and *Euromoney's* country risk ratings for mid-1989. Country risk ratings are published each September by *Euromoney* magazine, and are based on the views of specialists from investment banks and investment insurance institutions. In 1989 Euromoney's country risk ratings for 120 countries (weighted 40% on analytical factors - political risk, economic risk & economic indicators; 40% on market indicators - access to bond markets & other forms of commercial lending; and 20% on credit indicators - repayment record on loans & ease of rescheduling of loans) ranged from the least risk of 5 for Japan and Switzerland to the highest risk of 83 for Lebanon. However, these country risks apply to loans to governments and may be quite different from private sector financing on minerals projects.

Major mining companies were shown by the East-West survey to be most interested in countries with an area larger than 250 000 square kilometres, and 19 of the 23 favourite countries for exploration are among the top 50 countries in the world in terms of area (larger than 450 000 km^2).

The three countries indicated as needing an improvement in investment climates, but having a *Euromoney* country risk rating below 60 were Venezuela, China and the Soviet Union. The restrictions on private sector activities in China and the Soviet Union are an important factor why the investment climate rating by the private sector is poor, while the *Euromoney* country risk rating is good.

Conclusions

The main conclusions drawn from the survey include:

- Companies target 16 countries (9% of countries) as having attractive geologic environments, but unacceptable investment climates.
- Only 14 per cent of the countries of the world are on either the active or potential exploration lists of companies. But these 23 countries account for over 50 per cent of the world's land area and probably a similar proportion of the world's nonfuel mineral resources.
- An estimated 70-85 per cent of the world's private sector nonfuel minerals exploration is probably in 13 countries. Within these 13 countries, about 70 per cent of exploration expenditures are concentrated in 3 developed countries: the United States, Canada, and Australia.
- The apparent concentration of exploration activities in fewer countries during the past decade increases the need for developing countries to improve their investment climates. The geologic advantage appears less today due to the advantages of technological innovations and more efficient operating practices introduced in the 1980s.
- Gold, copper and zinc, in that order, are the three nonfuel commodities expected to receive the most exploration interest in the early 1990s. Gold continues to hold first place on the exploration lists of most companies.
- Over 75 per cent of the companies in the survey indicated that the right to mine discoveries, repatriate profits, and retain management control of mining projects are critical before undertaking a major exploration program in a country.
- Economic and political reforms are sweeping the world, and during the 1990s numerous countries are likely to be added to the list of countries having both attractive minerals potential and acceptable investment climates. Most of the best potential for new mineral deposits exists within developing and centrally planned economies.

In closing, the pattern of exploration revealed in the survey indicated that most developing countries were not on the exploration lists of major mining companies for the early 1990s. However, the number of developing countries meeting acceptable investment climate criteria may increase rapidly over this decade. Those companies that are able to anticipate the regional and country trends in economic and political change have opportunities to gain strategic business advantages in minerals exploration, mine developments, and market positions in the early part of the 21st century.

LAST CALL FOR NOMINATIONS

Nominators of potential recipients of the William Harvey Gross Award and the Duncan R. Derry Medal Award are hereby reminded that the deadlines for this year's nominations are fast approaching.

Those interested in making nominations for either of these annual awards should do so immediately. Details may be found in the previous issue of *The Gangue* (Issue #33) or by contacting Robert Cathro (604) 926-6033 (for William Harvey Gross Award) or Andy Fyon (416) 965-4261 (Duncan Derry Medal).

GOLD IN PORPHYRY

Alteration & Precious Metal Distribution In The Copper Mountain–Ingerbelle District, B.C.

by Huyck, Holly L.O.
Dept. of Geology
Univ. of Cincinnati
Abstract from GAC Vancouver '90

The Copper Mountain - Ingerbelle district includes disseminated and vein-related mineralization. Within the dominantly disseminated areas, this district contains less gold and similar silver relative to other alkaline porphyry systems in British Columbia. Silver-gold ratios vary from 4.5 to 24. The main alteration assemblages are:

- Potassium feldspar - biotite - chalcopyrite±bornite or pyrite (potassic)
  epidote-chlorite-chalcopyrite-pyrite (propylitic)
- Minor phyllic alteration occurs locally. The vein-related mineralization, with silver-gold ratios of less than one, is associated with chlorite-chalcopyrite-hematite-magnetite-pyrite (hematite-magnetite) alteration.

In disseminated zones, silver is highest in the bornite-stable alteration. Gold increases slightly from the bornite-stable to the pyrite-stable (potassic and propylitic) alteration. Silver occurs mainly in solid solution within the sulphides, particularly in bornite. Gold occurs erratically within the sulphides and as electrum associated with pyrite±chalcopyrite. Gold zonation differs from other alkaline porphyry systems, where gold is commonly associated with bornite. Either gold was initially low in this system or gold, initially in bornite, has been redistributed by later fluids related to propylitic or phyllic alteration (as at the Bell deposit).

Gold is highest in the vein-related, hematite-magnetite alteration, which resulted from transport by either thio-gold or chloride-gold complexes.

GEOLOGY IN PRINT

Compiled by Brian Grant

The following are publications which have come to my attention and which may be of some interest to the MDD membership. Information on new publications of economic or general geological interest will be welcomed by the Editor. Please contact the indicated distributor or your favourite technical bookstore to obtain copies.

NEW TECTONIC ASSEMBLAGE MAP FOR ONTARIO

by G.M. Stott & Staff
Precambrian Geology Section
Ontario Geological Survey

The newly designed **Tectonic Assemblage Map of Ontario** illustrates the geology of the province from a new perspective. Its principal function is to display, through compilation and interpretation, the subdivision of lithostratigraphic successions into tectonic assemblages and the grouping of some of the intrusive complexes into plutonic suites. It also displays volcanic centres, structural features, and sample locations of U/Pb isotopic age determinations on zircons from magmatic units.

A **tectonic assemblage** is composed of stratified rock units developed in a common depositional or tectonic setting during a discrete interval of time, and is typically bounded by faults or unconformities. Assemblages may be subdivided into one or more groups or formations. Identifying tectonic assemblages in Precambrian rocks, particularly by employing field geology and geochronology, constitutes the first stage in the process of formal stratigraphic mapping.

A **plutonic suite** comprises a set of plutons of common age, composition and probably common origin that are spatially associated and occur in a common tectonic environment.

A new geochronometric subdivision for the Precambrian and a subdivision of Phanerozoic time into tectonic cycles, adopted for this map, will permit map users to visually identify patterns of ages for assemblages and plutonic suites across the province.

This map is part of a folio of geological and geophysical maps of Ontario being produced at a scale of 1:1 000 000. It is accompanied by charts that summarize the main magmatic, sedimentary, structural and tectonic events recorded in the bedrock of Ontario. The charts complement the map by permitting regional correlation and interpretation of tectonic events. They also illustrate, for example, the episodicity of volcanic and plutonic activity more explicitly than is possible on the map.

This new Tectonic Assemblage Map should prove valuable to researchers and mineral explorationists. We believe this type of map has many metallogenic and exploration applications; it may be used to develop detailed stratigraphic correlations or, to relate the distribution of mineral deposit types to tectonic-assemblage environments and boundaries.

- **A Classification of Igneous Rocks and Glossary of Terms: Recommendations of the International Union of Geological Sciences Subcommission on the Systematics of Igneous Rocks.**

Edited by R.W. Le Maitre; The first chapter in this book, devoted to classification & nomenclature, contains a summary of all previously published recommendations for classification submitted to the Subcommission on the Systematics of Igneous Rocks(IUGS). It contains numerous diagrams useful for identifying igneous rock categories and presents the conditions required for each specific classification.

The second part of the book is comprised of a Glossary and a Bibliography. The Glossary contains a brief description of 1586 igneous rock names including; alternative spellings; a brief petrological description; author(s), year and page number of source reference; origin of the term; and, the location of the term in three standard texts. The Bibliography lists all references used in compiling the information and each reference is followed, in brackets, by the terms it contains.

This 193-page volume is packed with data on igneous rock classifications and nomenclature which would be a valuable asset to any geologist's library. It is accompanied by a large wall chart of classification diagrams. Published by Blackwell Scientific Publications and available from Oxford Univ. Press, 70 Wynford Drive, Don Mills, Ont. M3C 1J9. Tel: (416) 441-2941.

- **Earth Science Investigations**

Edited by Margaret A. Oosterman & Mark T. Schmidt. This is a 232-page geoscience activities manual produced by the American Geological Institute in cooperation with numerous geologists and earth science teachers. Although not designed for the libraries of most economic geologists it is eminently useful for school teachers and those geologists who contribute at least some of their time helping educate our young people. The volume contains 27 independent exercises designed to be completed within a single class period and usually with a limited amount of technical equipment.

Each exercise contains clearly stated objectives, time & materials required, a background-geological explanation and detailed procedures to accomplish the objectives. Questions and an answer key are supplied to reinforce the learning experience

once the exercise is completed. All exercises have been field tested in classroom environments. Activity topics include such items as Beach Profile investigations, geological block-diagram problems, earthquakes, was Mount St. Helens affected by the moon?, modelling crystal growth in magmas and determining ground-water contamination.

This is one publication you or your employer should buy and contribute to the local school library or earth science teacher! Available from the American Geological Institute, 4220 king Street, Alexandria, VA 22302-1507. Tel: (703) 379-2480. US$34.95 plus $8.00 shipping. ISBN 0-922152-07-1. Please tell them *The Gangue* sent you and also ask for a catalog of their technical & educational publications!

■ **Gold in Porphyry Copper Systems**

Edited by R.Shase, R.P. Ashley and L.M.H. Carter. This is a compilation of four articles which describe the occurrence of gold in porphyry copper systems in the Bingham District, Utah *(by E.W. Tooker, USGS)*, the Butte District, Montana *(by E.W. Tooker)* and the Ely *(by L.P. James, BHP-Utah)* and Copper Canyon *(by T.G. Theodore, S.S. Howe, USGS & D.W. Blake, Battle Mt. Gold Exploration)* districts, Nevada . Each article discusses history, production, geologic setting and details of the gold-bearing deposits. Where appropriate, suggestions for possible undiscovered resources are made. Bulletin B1857-E, US$3.25 plus $1 handling, available from US Geological Survey, Books & Open-file Reports, Federal Center, Box 25425, Denver CO 80225. Tel: (303) 236-7476.

TALE FROM THE BUSH!

An old prospector finally decided to marry. Not knowing the form too well he asked a friend for advice and was told he had to buy a trousseau.

"What the hell is that?" he asked.

"Clothes, lingerie and that kind of stuff", he was told.

So, off to the store he went and explained that he wanted a trousseau for his bride, but was uncertain of the details.

"What material did you want, Sir?"

"Let me feel a few, and I'll tell you", he replied.

After feeling linen, silk and nylon with no reaction his face lit up at the chiffon.

"That's it!", he said. "Give me 150 yards of that."

"150 yards, Sir? Why so much?"

"Hell, every old prospector knows that looking for it is much more fun than finding it!

EXECUTIVE & DIRECTORS 1990-1991

Executive

Directors:

MEETINGS, WORKSHOPS & FIELDTRIPS

{Editor's Note: If you are sponsoring or are aware of a meeting or event of potential interest to economic geologists please FAX me a note at (604) 356-7413 so that it may be included in the next issue of The Gangue. Notices must include a contact address or phone number. Thanks!}

JANUARY 1991

Jan 29 - Feb 1 **CORDILLERAN ROUNDUP.** Hotel Vancouver & Hyatt Regency, Vancouver, B.C. Most exciting mining/exploration convention of the year! Talks, core shack, posters & trade show. For details contact: Mr. Jack Patterson, B.C. & Yukon Chamber of Mines. Tel: (604) 681-5328.

FEBRUARY 1991

20 - 23 **STRUCTURAL SHORT COURSE FOR EXPLORATION & MINING GEOLOGISTS.** Holiday Inn, Tucson Airport, 4550 South Palo Verde Boulevard, Tucson, Arizona. $600 fee includes lectures, materials & field trip. Sponsored by the Dept of Geology, University of Idaho. Details: Conference Services (208) 885-6486. Preregistration is required and limited to first 25 applicants.

22 **ORE DEPOSITS, TECTONICS & METALLOGENY IN THE CANADIAN CORDILLERA.** MDRU Short Course #3. Fee $125. Instructional Resource Centre, The University of British Columbia. Presented by the BC Geol. Survey Branch; sponsored by the Mineral Deposit Research Unit, UBC & Cordilleran Sect., GAC. Details: Director, MDRU, UBC, 6339 Stores Road, Vancouver, BC, V6T 2B4. Tel: (604) 228-6136 FAX (604) 228-6088.

11 - 14 **SEVENTH ANNUAL V.E. McKELVEY FORUM ON MINERAL AND ENERGY RESOURCES.** Bakky's Reno Hotel, Reno, Nevada. Forum is sponsored by the USGS and will focus on USGS mineral resource research. Oral & poster sessions. Details: R.K. Kotra, Chairman, 1991 McKelvey Forum Committee, USGS, 923 National Center, Reston, VA 22092. Tel: (703) 648-6271.

24 - 27 **NATIONAL WESTERN MINING CONFERENCE - Colorado Mining Association Annual Meeting & Exhibition.** Denver, Colorado. Details CMA, 1340 Colorado State Bank Building, 1600 Broadway, Denver, Colorado 80202. Tel.(303) 894-0536 FAX (303) 894-8416.

MARCH 1991

18 - 21 **HYDROTHERMAL ALTERATION GUIDES TO MINERALIZATION.** MDRU Short Course # 4. Dept. of Geological Sciences, The University of British Columbia. Fee $750. Presented by Dr. P. Siems, U. of Idaho. Details: Director, MDRU, UBC, 6339 Stores Road, Vancouver, BC, V6T 2B4. Tel: (604) 228-6136 FAX (604) 228-6088.

24 - 27 **PROSPECTORS & DEVELOPERS CONVENTION.** Annual PDAC convention moved to FOURTH WEEK OF MARCH from the traditional second week of March. At Royal York Hotel in Toronto, Ont. Includes **seminar on sampling & ore reserves and a workshop on exploration geochemistry.** Details: Cary McLeod, Convention Manager, Tel: (416) 362-1969, FAX: (416) 362-0101.

APRIL 1991

8 - 9 **FOURTH ANNUAL KAMLOOPS EXPLORATION CONFERENCE.** Stockman's Hotel, Kamloops, BC. Symposium on geology & tectonics of South-central BC, field trip and presentations. Details: R. Meyers, BC Geol. Survey Branch, Kamloops. Tel: (604) 828-4566 FAX (604) 828-4726.

10 - 12 **MINERALS NORTH 1991.** Stewart, B.C. Overview presentations on exploration & mining in northern B.C. Details: District of Stewart, Tel: (604) 636-2251 FAX (604) 636-2417.

13 - 24 **GOLD-SILVER DEPOSITS OF CHILE** Field conference sponsored by the Society of Economic Geologists and the Association of Exploration Geochemists. Seven new-generation Au-Ag deposits in the Andean Cordillera. Cost est. $2400US, limit 35 participants. Deadline for registration Dec.1, 1990. Details: Harold F. Bonham, Jr. or Larry J. Garside Tel: (702) 784-6691, FAX: (702) 784-1709.

22 - 27 **GEOSTATISTICS FOR THE MINING INDUSTRY: NEW CONCEPTS, NEW TOOLS.** MDRU Short Course #5. Dept. of Geological Sciences, The Univ. of BC. Presented by FSS International. Fee $875. Details: Director, MDRU, UBC, 6339 Stores Road, Vancouver, BC, V6T 2B4. Tel: (604) 228-6136 FAX (604) 228-6088.

April 29 - May 1 **15th INTERNATIONAL GEOCHEMICAL EXPLORATION SYMPOSIUM.** Reno, Nevada. Association of Exploration Geochemists. Details: Harold Bonham, Symposium Chairman, 15th IGES, PO Box 9126, Reno, Nevada 89507.

April 29 - May 2 **8th THEMATIC CONFERENCE ON REMOTE SENSING FOR EXPLORATION GEOLOGY.** Denver, Colorado, USA. Contact: Nancy Wallman, ERIM, P.O. Box 8618, Ann Arbor, Michigan 48107-8618, USA.

MAY 1991

5 - 9 **FORUM '91.** 27th forum on the geology of industrial minerals. Banff Springs Hotel, Banff, Alberta, Canada. Sponsored by the Alberta Geological Survey and the British Columbia Geological Survey. Details: Danny Hora, BC Geological Survey, Victoria, BC, V8V 1X4. Tel: (604) 356-2846; or, Wylie Hamilton, Alberta Geological Survey, PO Box 8330, Station F, Edmonton, Alberta, T6H 5X2. Tel: (403) 438-7634.

7 - 22 **BRAZIL GOLD '91.** Meeting and fieldtrips, Belo Horizonte, Brazil. Contact: Brazil Gold '91, Av. Afonso Peno, 3880-3/5 andares, 30130 Belo Horizonte MG, Brazil OR, C.H. Thorman, USGS, Mail Stop 905, 25046 Federal Center, Denver, Colorado 80225, USA.

27 - 29 **GAC/MAC/SEG ANNUAL MEETING.** TORONTO 1991. Joint annual meeting of the Geol. Assoc. of Canada, Mineralogical Assoc. of Canada and the Society of Economic Geologists. Details: Toronto 1991, Dept. of Geology, U of T, Earth Sciences Centre, 22 Russell Street, Rm. 1066B, Toronto, Ont. M5S 3B1, Canada. Tel: (416) 978-6588 FAX: (416) 978-3938.

Aug 30 - Sept 3 **SOURCE, TRANSPORT AND DEPOSITION OF METALS;** 25th Anniversary Meeting, Society for Geology Applied to Mineral Deposits. Nancy, France. Details: CREGU BP 23, 54501 Vandoeuvre-lès-Nancy Cédex, France. FAX 33-83-44-00-29.

SEPTEMBER 1991

9 - 10 **ANNUAL FIELD CONFERENCE ON MINERAL DEPOSITS AND EXPLORATION METHODS.** Sponsored by the Saskatchewan Section of the Geological Society of CIM - First annual field conference. Papers on Canadian and US deposits; will focus on deposits, geological settings and exploration methods for base & precious metals, uranium and industrial minerals. 5 field trips in Canada & US. Details: Len Homeniuk, General Chairman, PO Box 8201, Saskatoon, Sask, Canada, S7K 6G5. Tel: (306) 956-6380.

Sept 29 - Oct 2 **UNDERWATER MINING INSTITUTE.** Hawaii. Ocean Basins Division of the Marine Mineral Technology Center will host the meeting in Hawaii. Technical sessions will feature presentations on deep water mining and activities along the Pacific Rim. Details: Allen H. Miller, UMI Coordinator, Underwater Mining Institute, 1800 University Ave., Madison, WI 53705. Tel (608) 262-0645.

OCTOBER 1991

21 - 24 **SOCIETY OF ECONOMIC GEOLOGISTS/GEOLOGICAL SOCIETY OF AMERICA ANNUAL MEETING.** San Diego, California. Details: Michael A. McKibben, SEG Program & Fieldtrip Chairman, Dept. of Earth Sciences, 2413 Geology Bldg., University of California, Riverside, CA 92521-0423. Tel: (714) 787-3444 FAX (714) 787-4324.

MAY 1992

25 - 27 **GAC/MAC ANNUAL MEETING, WOLFVILLE '92.** Contact: A. Fricker, Atlantic Geoscience Centre, Bedford Institute of Oceanography, P.O. Box 1006, Dartmouth, N.S. Tel: (902) 426-6759.