THE FARALLÓN NEGRO GROUP, NORTHWEST ARGENTINA: Magmatic, Hydrothermal and Tectonic Evolution and Implications for Cu-Au Metallogeny in the Andean Back-arc

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Argentina has rapidly emerged as a major focus of international exploration activity. With the confirmation of the giant status (sensu Clark, 1993) of the Bajo de la Alumbrera porphyry Cu-Au deposit (Guilbert, 1995), few areas have generated greater interest than the Farallón Negro region of Catamarca Province (Fig. 1). Bajo de la Alumbrera (MM/ North/Rio Algom), the largest Au-rich (0.4 g/t) porphyry copper deposit recognized in the Central Andean orogen, with delineated reserves of 780 M tonnes containing 0.52% Cu and 0.67 g/t Au at a 0.226 Cu cut-off (Mining Journal Ltd., 1997), is expected to yield 100,000 t Cu and 670,000 oz Au annually beginning in late 1997. Thirty-two kilometers to the east, the Agua Rica Cu-Au-Mo-Ag prospect (RHP/Northern Orion) has 802 M tonnes of ore containing 0.61% Cu, 0.035% Mo, 0.24 g/t Au and 3.17 g/t Ag at a cut-off grade of 0.4% Cu (Northern Orion Explorations Ltd., 1997). The district also hosts the Farallón Negro-Alto de la Blenda low-sulfidation epithermal Au-Ag vein system, which has yielded an average of 490 kg Au and 4,200 kg Ag.

![FIGURE 1. Location of the Farallón Negro District in relation to the Perí-Chile Trench, Cordillera Principal, Puna, Sierras Pampeanas and selected Chilean and Argentinian mineral deposits. The dip of the subducting slab is indicated by the depth contours on the Wadati-Benioff zone (after Isacks, 1988). Farallón Negro is located in the transition zone between steep subduction to the north and shallow subduction to the south. The metallogenic domains are from Sasso (1997): the "Cu & Au" designation does not imply the absence of Au mineralization but rather the isolated nature of the gold occurrences. In contrast to the clustering that is observed in the transverse shaded area between about 27° and 30° S. The potential significance of the Paramillos and San Luis districts is noted in the text.](image-url)
The Society of Economic Geologists is seeking a qualified candidate or candidates, to fill the position of SEG Newsletter Editor. The position offers extensive interaction with SEG members worldwide, the economic geology community, and issues related to economic geology. This volunteer position is vital to continued communication among SEG members. Candidates should have an established and successful record of writing and editing. Schedules should be flexible enough to permit significant time commitments around four quarterly deadlines for the Newsletter. The new editor(s) should be available to assist with the October, 1998 issue, and would assume full duties after that issue is published. If you are interested in the position, or wish to recommend a qualified person, contact John A. Thomas, SEG Executive Director, at Tel. +1.303.797.0332, or Fax +1.303.797.0417. Email <seconegeol@csn.net> for more information.

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FOR CONTRIBUTORS —

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SEG Newsletter #35: Aug. 24, 1998
Preparing for the New Century

More than 75 years of volunteerism and an illustrious history have brought the Society to the threshold of the 21st century and the beginning of a potentially dynamic era. Building on a well-established, solid foundation, the 1989 "Blue Ribbon" Committee and the 1997 Strategic Planning Panel designed a future course for the Society. Many of the recommendations given in their reports have been, or are being, implemented and, as a result, the Society now has an exceptional opportunity to significantly increase its programs and professional-scientific commitments for the greater benefit of its members and the economic geology profession at large. This is an exciting and challenging time for all of us.

The Society and its sister organizations, the Economic Geology Publishing Company (PUBCO) and the SEG Foundation (SEFG) have never been stronger financially. As pointed out in Tom Loucks' column in the April issue of the Newsletter, the Society, with the ever-increasing support of the Foundation, funded programs and activities at an unprecedented level in 1997. This is really good news, but it is only a start in terms of the potential programs and services that could be provided to our members and to the profession. The Society is expanding dramatically in terms of its geographic diversity, and must be prepared to meet the needs of a more widely dispersed membership. SEG wants to make its lecturers, conferences, field trips, short courses, and workshops accessible to all of its members, wherever they are in the world. Proposals have been made and initiatives are being implemented, particularly in the area of continuing education, to increase the delivery of these programs and services on a worldwide basis. To achieve this goal, funding for programs must be increased significantly.

During the past six years, the Society and PUBCO have consolidated and centralized both administrative and publications functions under one roof at the SEG office in Littleton, Colorado. In the process, significant cost savings have been effected, thus making additional funds available for programs, activities and publications. As of all you know, there has been no increase in SEG annual dues, nor in the subscription rate for the journal, for the past four years—and we want to keep it that way! (As an aside, most Society activities usually net a modest surplus—they are not designed to be major sources of income, but to provide programs, conferences, publications, etc., at very reasonable prices. The modest surpluses provide the seed money for the "next" event.)

The cornerstone of SEG's expansion into the next century will be the new Headquarters building, the design and construction of which are funded completely by the unparalleled generosity of our Anonymous Donor, including an amount to be set aside in a board-restricted fund, the income from which will be used to cover ongoing maintenance and operating costs for the building. This building will not only provide superb housing for the administrative functions of SEG, SEFG, and PUBCO, but because its maintenance will be paid for by "off-budget" funding, it will also make available for programs those funds currently being utilized for office rent and other operating expenses. This will give a further boost to Society-sponsored programs and products. However, for the anticipated worldwide expansion of the Society's outreach programs, the amount currently being expended for programs, etc., should at least be doubled. As always, the Society will look to its Foundation for increased support to make these programs possible. Over the next six to nine months, the SEG Executive Committee and the Council, with appropriate input from all concerned, will be developing a plan of action that will lead us into the new century, and that will be reported in the Newsletter as it unfolds. Exciting times indeed!

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Getting the Message Out (or In)

Communication is one of the buzzwords today and it applies in spades to SEG. In the last Newsletter I noted that we need to tell the general public more about the importance of minerals to society and the role of research in making minerals available to them. In addition to controlling our livelihood, our response to this challenge could affect the vulnerability of minerals for the next generation. At the same time, we need to tell our own members about technical developments, and help students get started in the business. All these efforts involve communication, and several recent developments relate to them.

The first development deals with SEG’s efforts to get the “mineral message” out to the general public. We have a real problem here. There simply are not many ore deposit geologists in the world, and to make matters worse, most of them are concentrating in a few areas where mining is common, the population is relatively small, and most folks already “belong to our church.” It is harder for us to reach the majority of the population, which lives in urban and suburban areas with (what might be called) limited mineral activity. These are the people whose opinions influence legislation, funding, regulations, and all the other government actions that govern our lives. We need to find a constituency in these areas to help us get our message across. Andrew Sice recently suggested that we try the rockhound and mineral clubs that are widespread in populous areas. Many SEG members are mineral collectors and could give very interesting talks to a club of this type, perhaps including information on the role of geologists in making minerals available to society.

Many SEG members are mineral collectors and could give very interesting talks to a club of this type, perhaps including information on the role of geologists in making minerals available to society.

We recommend that SEG make 50-minute (class-length) videos of talks by our Distinguished, Thayer-Lindsley, and International Lecturers, and offer these for sale.

Society. Andrew has agreed to chair an ad hoc Amateur-Professional Outreach Committee including Bruce Bouley, Bob Cook, Peter Megaw and Peter Modreski, that will look into ways that SEG might increase communication with these groups.

The second development relates to the ad hoc Multimedia Opportunities Committee, which I chaired for Past-President Bethke. This committee, which included Phil Brown, Doug Crowe, Shane Ebert, Nori Foley, John Guilbert, Tommy Thompson, and Steve Waters, was asked to evaluate media products that might be produced for Society members. In its deliberations, the committee considered possibilities ranging from production of videos on specific mining districts to compilation of database-type CDs on specific deposits, commodities or areas. In deciding what to do, the committee agreed that it was best to start with efforts that were relatively simple in terms of time and energy needed from our many volunteers and that would not be too costly. We also agreed that media products from SEG should not be in direct conflict with possible profit-making efforts of its members. This second point is of particular importance in view of the growing number of commercially available media-type products.

With these guidelines in mind, we recommended that SEG make 50-minute (class-length) videos of talks by our Distinguished, Thayer-Lindsley, and International Lecturers, and offer these for sale.
As reported in the April 1998 SEG Newsletter, the SEG Foundation Trustees increased the level of anticipated funding for Student Grants to $50,000 for 1998. It is a pleasure to report that these funds were fully awarded by the various Foundation grant sub-committees (BHPI, Hickok-Radford, McKinstry, and General Research Fund). As detailed on this and the next page by R.L. (Dick) Nielsen, SEG Foundation Committee Chairman, a total of $50,000 was awarded to 40 graduate students. The SEG Trustees are pleased with the success of this expanding program and thank SEG Members and others for their continued support.

The Trustees would like to take this opportunity to inform the Society that E.L. (Ernie) Ohle is withdrawing from active participation on the McKinstry Grant Sub-Committee. Ernie was instrumental in setting up this sub-committee in accordance with the desires of the McKinstry's, served as its chairman for a time, and has been active in the ongoing functioning of the group. Additionally, as most of you know, Ernie has been heavily involved in the Society over the years, serving as Vice President in 1976, and as President in 1974. The Trustees heartily thank Ernie for these years of service to the Society and Foundation. Robin P. Breit will replace Ernie on the McKinstry Grant Committee, currently chaired by Don Everhart.

At the recent Orlando meeting, the Membership Subsidy Program funding was increased to $8,600 in response to the request of 26 Zambian geologists for financial support of their membership for three years, in accordance with the program guidelines. A Membership Subsidy Review Committee chaired by D.L. (Don) Hammer is currently evaluating the history of the program to date, and its guidelines, to determine if modifications are needed to improve the functioning of the program. We wish to provide as-needed financial assistance for SEG membership to a widely diverse group of qualified, but financially disadvantaged, economic geologists. The program should both strengthen the Society and provide the benefits of the Society to these geologists. The committee will report to the Trustees at the Fall 1998 meeting in Toronto.

A new fund-raising brochure has been developed by Don Everhart and other Foundation and Society members to be used in soliciting contributions from other foundations and corporations. Later modification of the brochure for SEG members is likely.

Finally, members are asked to consider donations to the SEG Foundation through wills, estate planning, or any of a number of varieties of trusts that are available, in order to provide future support to the Society. T.A. (Tom) Loucks, the SEG and SEG Treasurer, can provide useful information in this area and can be reached through the SEG South Rapp Street office in Littleton.

### Student research grants awarded by SEG Foundation

Forty students received a total of $450,000 in research grants from the Society of Economic Geologists Foundation’s 1998 Student Research Grant Program. The grants will assist students with field and lab expenses associated with thesis research required for advanced degrees. Eleven of the students are enrolled in universities outside of North America; three in Australia, two each in South Africa and Russia, and one each in Italy, Congo, New Zealand, and Austria. Grants from $500 to $3,000 were awarded.

- **Hugh E. McKinstry Student Research Grants** were awarded to students whose research contains descriptive studies of mines and ore districts, and will contribute to improved understanding of ore genesis:
  - **Michael Rescek**, Univ. Nevada (Reno), $1,750
  - Infrusive rocks and ore genesis, Carlin, Nevada
  - **Scott Jobin-Bevans**, Univ. Western Ontario, $1,500
  - Ni-Cu-PGE exploration, Sudbury, Ontario
  - **Jill Hammond**, Utah State Univ., $3,000
  - Structural setting for gold deposits, Bult Mt., Nevada
  - **Peir K. Pufahl**, Univ. British Columbia, $3,000
  - Origin of Jordan phosphate deposits
  - **Kirsten Simpson**, Univ. Tasmania, $3,000
  - Mt. Windsor volcanic rocks, Queensland, Australia
  - **Andrew Davies**, Univ. Tasmania, $3,000
  - Epithermal gold, East Kalimantan, Indonesia

- **Aaron Johnson**, Univ. Missouri, $1,500
  - Basin fluid flow and diagenesis, Irish Midlands

- **Maximino Simian**, Colorado School of Mines, $1,000
  - Jeromin gold deposit, Patocillos, Chile

- **John Shallow**, Colorado School of Mines, $1,000
  - VMS mineralization, Fremont Co., Colorado

- **Worth Cotton**, Univ. Colorado, $1,650
  - Au-Ag-Zn-Pb mineralization, Abine district, Chile

- **Vladimir Ispolatov**, New Mexico Tech., $1,000
  - Sultana Sary gold district, Kyrgyzstan

- **Alexis Cupo**, Colorado School of Mines, $1,000
  - Microbes at the Centenario copper deposit, Chile

- **Patrick Redmond**, Stanford Univ., $1,000
  - Gold in Cn-Au porphries, Bingham Canyon, Utah

- **Katherine Ault**, McGill Univ., $1,000
  - El Mechito Zn-Pb-Ag deposit, Honduras
SEG Research Grants, Cont.

Miroslav Sidor, Univ. Western Ontario, $650
Magnetite-biotite-amphibole and polymetallic sulfides. Northwest Territories

Heldie Torrecalday, Colorado School of Mines, $650
Kansanshi Cu-Au deposit. Solwezi, Zambia

Inna Mudrovska, Lviv State Univ., Ukraine, $650
Loke gold. Savansko-Sinteiskii zone, Ukraine shield

David Boyer, Western Washington Univ., $1,150
West Chance orebody. Sunshine mine, Idaho

Hickok-Radford Student Research Grants support high quality research in areas with "extreme" field conditions such as arctic or high alpine regions. Klaus Peter Robl of the University of Salzburg, Austria, received a grant of $3,000 to support studies of Ag-Pb mineralization and hydrothermal alteration at the high altitude, El Quevar volcano, Argentina.

New this year are BHP Student Research Grants funded by a donation from BHP Exploration. The awards are made to seven students with quality economic geology research projects throughout the world.

Rodney K. Thompson, Colorado School of Mines, $1,000
Mineralized rhyolite. Tonopah, Nevada

Sally Gramstad, Iowa State Univ., $1,000
Au-Ag tellurides. Berners Bay, Alaska

Michael J. Schnieders, Wichita State Univ., $500
Environmental study. Baldy Mt. District. Camaroon, New Mexico

Natalie A. Warren, Univ. Auckland, $1,200
Au-rich precipitates from geothermal power developments. New Zealand

David L. Moore II, Ball State Univ., $1,000
Mineralized skarn. Bancroft terrain. Grenville province, Ontario

Joel Rotert, Univ. Nevada (Las Vegas). $700
Fluid inclusions, epithermal ores. Castle Mt. San Bernardino Co., California

Rene L. Foehl, Univ. Montana, $1,000
Ag-U veins. Sunshine mine, Idaho

Fourteen students received SEG Student Research Grants that will help fund a wide variety of economic geology research topics in a number of countries:

Julia A. Rosdeutscher, Univ. Georgia, $1,000
Grassy Valley gold deposits. Cripple Creek, Colorado

Frederica Zaccarini, Univ. Modena, Italy, $1,000
Platinum group metals in epholites. Egypt

Irina Ekimenkova, Moscow State Univ., $500
Rare metals. Khabiny-Iloczero alkaline igneous rocks. Kola Peninsula. Russia

Joseph W. Kokonyangi, Univ. Botswana. $1,000
Sn-Nb-Ta mineralization. Katanga. Congo

John P. Hunt, Univ. Witswatersrand, $600
F-Fe-Au in granites, western Bushveld complex. RSA

Timothy W. Johnson, Univ. Indiana, $800
Be in topaz rhyolite. Spur M., Utah

Purnima A. Shudasen, Univ. Missouri (Rolla), $1,000
Fluorite ores in carbonatites. Amha Dongai. India and Okotocussi, Namibia

Timothy J. Lee, Univ. Wisconsin (Madison), $1,600
Ore fluids in gold ore. Paddington, Western Australia

Nathan I. Chutas, Univ. Washington (Seattle), $1,400
K-2 epithermal gold veins. Republic, WA

Joseph M. Evensen, Univ. Oklahoma (Norman), $1,200
Be in granite melts

Alexander B. Dewitt, Univ. Nevada (Reno), $600
SSX gold deposit, Independence Range, Nevada

Kell Weaver, Univ. Nevada (Las Vegas), $1,000
Gold mineralization, Getchell mine. Nevada

Jeffrey S. Harrison, Univ. Texas (Austin), $700
Hydrothermal alteration. Grabberg igneous complex. Irian Jaya. Indonesia

Harilaos Tsikos, Rhodes Univ., $700
Houazel Fe-Mn deposits. Kalahari, RSA

The expanded Student Research Grant program has generated much interest. Students are being provided with financial support. In addition, publicity of the program is highlighting concerns of many ore deposit geologists regarding adequate training of future economic geologists. The level of funding for 1999 is expected to be at least the same as 1998. Information and application materials for 1999 Student Grants will be available from the SEG office and SEG Home Page on the Internet about September 1, 1998. Completed applications must be received by February 15, 1999 for grants to be awarded by April 15, 1999. cM
Research at the Mine—Capturing Non-renewable Resources at Navan
by MURRAY W. HITZMAN (SEG 1978) • DEPT. OF GEOLOGY AND GEOREAL ENGINEERING • COLORADO SCHOOL OF MINES • GOLDEN, CO 80401

 Ore deposits are non-renewable resources—both the ore and the information contained within the rocks disappear with mining. While it might seem obvious to study currently mined deposits to ensure that we replenish our resource base, in reality our industry is not as vigorous as it could be in acquiring and utilizing the non-renewable resource of knowledge that can be gained during mining.

The paper by J.K. Anderson, J.H. Ashton, A.J. Boyce, and M.J. Russell entitled “Ore depositional processes in the Navan Zn + Pb deposit, Ireland” (Economic Geology, v. 95, no. 3) shows what is possible when mine geologists team up with academic researchers to capture the information presented through mining. Anderson et al. have used detailed mine mapping, combined with careful petrology, to document morphological and textural evidence elucidating the genesis of the world-class Navan orebody. Through this careful work, they convincingly demonstrate that the majority of the ore was formed below the sediment-water interface by replacement of semi-illitized to illitized shallow water carbonate rocks of Lower Carboniferous age.

This excellent descriptive job, which resulted from years of painstaking work by the Navan mine staff and Dr. Anderson as part of his Ph.D. research, is related to a detailed sulfur isotope study on carefully collected samples. The results of the study support those of previous sulfur isotope studies in Ireland, indicating that the Irish Zn-Pb deposits formed by the mixing of two fluids—one a metal-bearing fluid with relatively minor hydrothermal sulfur, and another containing abundant sulfur derived from bacteriogenic reduction of lower Carboniferous seawater sulfate. In contrast to most other earlier studies, however, the care of sample collection allows the authors to conclude that definite relationships between sulfate texture and isotope composition were governed by the rate of sulfur supply and the degree and method of fluid mixing.

This paper represents one more piece of the Navan puzzle that has emerged since the mid-1980s as the mine’s geological staff and a series of researchers have documented the deposit. Different pieces of evidence are progressively revealed by reading the papers sequentially, providing a fascinating detective story. In the early 1980s, the Navan deposit was envisioned to be a classic syngenetic exhalative deposit. But as the 1980s closed, the papers reveal a clearer understanding of the timing of mineralization. The recent studies on dolomitization, and now the Anderson et al. paper, appear to have resolved the issue of syngensis versus epigenesis. We are now moving toward determination of the paleohydrology of the mineralizing system and the chemical environment of ore deposition.

The mine staff’s continuing dedication to documenting the deposit, their support of outside academic personnel to bring various analytical techniques to bear, and their commitment to publish the results of these studies are a fine example of how to extract the most intellectual knowledge possible from this non-renewable resource. With more examples like those from the Navan team, we will be better able to maintain our resource base through an ever-increasing store of knowledge.

SCIENTIFIC OCEAN DRILLING NEEDS YOU!

NOTICE: To all members of the earth sciences community.

The Ocean Drilling Program will end on October 1, 2003. International scientific cooperative efforts for deep-earth sampling in the marine environment will cease unless our community comes together now to plan a new program for scientific ocean drilling. We've done it before (ODP is the successor to the 1968-1983 Deep Sea Drilling Project)—we can do it again.

SPRING 1999 INTERNATIONAL CONFERENCE: To define the scientific objectives for a future, multi-platform ocean drilling program with two major vessels. This Conference will target the scientific goals of non-riser drilling and will complement the recent Conference for Cooperative Ocean Riser Drilling. CONCORD defined the scientific initiatives for use of a riser-equipped drilling vessel (the CONCORD report is available at http://mstjp1.jamstec.go.jp/jamstec/OD21/CONCORD/report.html).

WANTED: Brief (<1-page) statements of interest that describe a scientific objective, its importance, and the necessity for drilling. Technical details are not necessary. These statements will be used to organize the Conference. This is your opportunity to influence the scientific direction of the new program and to show your support for future scientific ocean drilling.

DEADLINE: September 1, 1998.

SUBMIT TO: JOIDES Office, Department of Geology & Geophysics, Woods Hole Oceanographic Institution, Woods Hole, MA 02543, USA, (508) 289-3481, joides@whoi.edu.

RESPOND TODAY! THE FUTURE OF SCIENTIFIC OCEAN DRILLING IS IN YOUR HANDS.
In addition to a Neogene change in subduction zone geometry, the ca. 27°S transect coincides with a metallogenic discontinuity involving both a N-S change in ore-metal abundances and an E-W concentration of major ore deposits, which has persisted through much of the Mesozoic-Cenozoic Andean orogeny. Sillitoe (1974) and others have documented an empirical correlation between the boundaries of transverse tectonic segments and the location of large ore deposits in the Central Andes, but no petrogenetic or metallogenic models have been advanced to explain this geographic-tectonic association. Moreover, whereas Sillitoe (1972) proposed that Au is concentrated with Cu in a near-trench environment at Andean-type convergent plate margins, Zentilli (1974) and Clark et al. (1976) emphasized, prior to the recognition of the importance of the Maricunga district, that Au exhibits no marked areal or temporal restriction at this latitude. This conclusion was prompted by the already established Au potential of the Farallón Negro district. The area along the 27°S parallel has been the focus of an unusual enrichment in Au since at least the Cretaceous. With the possible exception of the Cajamarca-Ancash region of northern Peru, the transect hosts the largest concentration of gold-rich hydrothermal centers in the Central Andes, including those of the early Cretaceous La Candelaria-Punta del Cobre, the late Eocene-early Oligocene El Salvador-Potrerillos El Hueso, and early to middle Miocene Maricunga districts (Fig. 1). This transect is tentatively interpreted herein as defining the northern boundary of a Cu-Au metallogenic sub province in Chile and Andean Argentina that extends from approximately 26° to 30°S, encompassing the Andacollo Cu-Au porphyry deposit and the epithermal centers of the El Indio-Pascua belt (Fig. 1); Extension of the Cu-Au signature to about 32°S may be required to incorporate the reputedly gold-rich, Middle Miocene Sillitoe (1977) porphyry deposits of the Parrillos district, situated east of the cordilleran axis, as is Bajo de la Alumbrera.

Despite the recent development of the Farallón Negro mining district, knowledge of the fundamental nature of the host volcanic and hypabyssal rocks has expanded little since the studies carried out by González-Bonorino (1965), Llambrés (1970, 1972) and, at Queen’s University, McBride (1972), Zentilli (1974) and Cañelas (1979). Few new petrochemical or geochronologic data have been documented (Allison, 1986) and the factors responsible for the voluminous back-arc magmatism and intense associated hydrothermal activity, and hence, their geodynamic and metallogenic significance, remain uncertain. The present research program (Sasso, 1993, 1995, 1996, 1997; Sasso et al., 1995), some preliminary concepts and conclusions of which were recorded by Jones (1994, 1997), was established to refine and augment the stratigraphic, geochronologic and petrochemical databases of Llambrés (1970, 1972), McBride (1972) and Cañelas (1979), respectively. The igneous rocks were mapped at 1:50,000-scale and stratigraphically constrained, unaltered volcanic rocks were analyzed (mainly by ICP). Newly developed laser-probe 40Ar/39Ar incremental heating techniques were employed to determine the ages of magmatic and hydrothermal minerals. The major ore deposits were studied only at a reconnaissance scale, but numerous prospects were mapped and sampled in detail. TM and MSS satellite images were examined as a basis for the preparation of a new map of the Farallón Negro complex (Fig. 2), and to define its regional relationships with Neogene magmatic centers across the 26° to 28°S transect (Sasso, 1997).
MAGMATIC HISTORY AND PETROGENESIS

The subaerial Farallón Negro Volcanic Complex, together with its outliers, discontinuously crops out in an area of approximately 700 km² (Fig. 2) that formally has been assigned by Sasso (1997) to the Farallón Negro Group. Hypabyssal stocks and dikes making up the Farallón Negro Intrusive Suite (Sasso, 1997) intrude the main volcanic succession, the Farallón Negro Stratovolcano, and constitute the small but richly mineralized Agua Rica center farther east. Llambias (1970, 1972) provides a detailed history of the evolution of the stratovolcano, emphasizing the sequence of minor intrusions, many of which host porphyry or epithermal mineralization. The volcanic rocks overlie (Fig. 2) Miocene continental red beds of the El Montero Formation (Turner, 1962, 1963), which are up to 1,500 m thick elsewhere in the region, but do not exceed several hundred meters in the Farallón Negro district. The underlying crystalline basement predominantly consists of the Upper Ordovician-Lower Silurian Capillitas granite batholith (McBride et al., 1976) and metasilticlastic strata of the Lower Cambrian Suncho Formation.

In agreement with Llambias (1970), the authors believe the volcanic outcrops are the remnants of a vast, continuous field comprising several eruptive foci. We further conclude that volcanism was centered in an extensional sedimentary basin. Our ⁴⁰Ar/³⁹Ar geochronology demonstrates that from ca. 12.56 ± 0.36 to ca. 6.59 ± 0.10 Ma, restricted volumes of basalt, basaltic andesite, and dacite erupted from several discrete volcanic centers, possibly channeled by structures that had earlier controlled the formation of the basin. These rocks were subsequently covered by andesitic to dacitic flows and breccias of the Main Stratovolcano, which accumulated from ca. 8.51 ± 0.35 to 7.49 ± 0.09 Ma from a vent in the Alto de la Blenda area (Fig. 2). Minor pyroclastic activity persisted as late as 6.72 ± 0.08 Ma in association with major erosion of at least the northern flank of the stratocone to form a thick succession of conglomerate (Fig. 2). Stratovolcano construction was accompanied and followed by intrusive activity that peaked between 8.56 ± 0.48 and 6.78 ± 0.15 Ma, but continued locally until 5.16 ± 0.05 Ma. The emplacement of dacite and rhyolite dikes marked the termination of magmatic activity in the region.

The outlying volcanic and intrusive centers in the Cerro Atajo, Agua Rica, and Vis Vis-San Lucas areas (Fig. 2) are herein confirmed to have evolved contemporaneously with the Main Farallón Negro Stratovolcano. Eruption at Cerro Atajo had begun by 8.75 ± 0.07 Ma and persisted at least to 6.41 ± 0.08 Ma. Volcanic strata are absent in the Agua Rica center, but the Melcho monzonite stock was emplaced at 8.56 ± 0.48 Ma. Volcanic units in the Vis Vis area range in age from 8.37 ± 0.08 to 8.18 ± 0.08 Ma, and the associated intrusions were emplaced from 8.37 ± 0.11 to 7.35 ± 0.06 Ma. The entire volcanic field was subsequently dissected by movement along high angle reverse faults related to the thick-skinned Laramide-style tectonism that generated the 5,000 to 6,000 m high horsts of the Sierras Pampeanas (Fig. 1). Uplift was probably diachronous across the physiographic province, but commenced between 5.7 ± 0.4 Ma (recalculated K-Ar data of McBride, 1972) and 5.3 ± 0.9 Ma (fission track data of Tahutti et al., 1989) in the Sierras de Famatina (Fig. 1).

Our new ⁴⁰Ar/³⁹Ar age data support the contention of Crecelles et al. (1971), Zenilli (1974), and Clark et al. (1976) that magmatism in the Farallón Negro district was contemporaneous with that in northern Chile at this latitude. The arc therefore did not merely "shift eastwards" (Davison and Mpdozis, 1991) but, within the limits of error of the ⁴⁰Ar/³⁹Ar dating technique, instantaneously broadened in the Middle
Miocene. We infer arc expansion to have occurred shortly before 12.56 ± 0.36 Ma, simultaneously with the initial stages of the major cordilleran uplift and erosion which generated the enormous Atacama pediplain on the Pacific slope of the Andes (Clark et al., 1967; Mortimer, 1973). Arc contraction took place shortly after 5.16 ± 0.05 Ma.

Kay et al. (1994a) and numerous others have demonstrated that the back-arc region in NW Argentina exposes a wide range of volcanic rocks, many of which exhibit only tenuous relationships to subduction processes. However, the petrology of the Farallón Negro Complex, probably the largest of the back-arc volcanic centers, has received little attention. New chemical data (Sasso, 1997) confirm that the volcanic units are subalkaline and may be classified on the basis of the K₂O-SiO₂ plot of Peccerillo and Taylor (1976) as either shoshonitic or high-K calc-alkaline (cf. Dostal et al., 1977; Caelles, 1979; Allison, 1986; Guilbert, 1995; Jones, 1997), but these rocks are indistinguishable in the field and in their petrographic features. Therefore shoshonitic rocks constitute some of the oldest dated strata, they are interbedded with high-K calc-alkaline flows; the geochemical continuum supports a common magmatic source. Enrichments in LILE (large ion lithophile elements) and LREE (light rare earth elements) and low abundances of HFSE (high-field-strength elements) displayed by all rocks (Sasso, 1997) are consistent with trends observed worldwide for subduction-related K-rich igneous rocks (Müller and Groves, 1995). The LILE and LREE contents suggest that the Farallón Negro magma may have been generated through low degrees of partial melting, and the HFSE depletion suggests that deep asthenospheric magma sources were probably not tapped.

Rare earth element analysis (Sasso, 1996, 1997) provides further evidence of the source of the Farallón Negro magmas, and permits comparison of their compositions with those of other Neoene volcanics at this latitude. The overall slope of the REE trend, represented by the La/Yb ratio (Fig. 3), records the protolith mineral assemblage in equilibrium with the magmas. Low La/Yb ratios reflect hornblende-dominated, garnet-poor gabbroic residual corresponding to depths of melting of <40 km, while high ratios indicate higher pressure, garnet-bearing granulite or eclogitic residua (see Kay et al., 1994b). A plot of La/Sm versus Sm/Yb provides a clearer picture of the relative abundances of the HREE. Neither plot (Figs. 3A, B) records significant HREE (heavy rare earth elements) fractionation for the Farallón Negro suite, whether shoshonitic or high-K calc-alkaline; therefore, we see no evidence for the generation of the parental magmas through the variable partial melting of garnet-bearing source rocks (cf. Dostal et al., 1977). In their REE chemistry (Figs. 3A, B), the Farallón Negro rocks overlap with both the Late Oligocene-Early Miocene Marcungua suite (Kay et al., 1994b) and the Phiocene-Pleistocene arc volcanics of the Ojos del Salado complex (Baker et al., 1987). Although the Farallón Negro rocks are distinctly more potassic than those of the older Marcungua and younger Ojos del Salado suites (Caelles, 1979; Allison, 1986; Sasso, 1996, 1997), the authors infer that all of these suites were generated under similar mantle conditions. In contrast, and as emphasized by Kay et al. (1994b), the Middle and Upper Miocene rocks of the Marcungua district, respectively, exhibit moderate and strong HREE fractionation, a feature particularly evident in Fig. 3B and requiring garnet as a residual mineral.

The Farallón Negro rocks exhibit moderate to high Ba/La ratios (Fig. 3A), suggestive of enrichment in alkaline-earths in the source region. The Farallón Negro La/Ta ratios are the lowest (15.32, not shown) documented for Neoene rocks in this transect. We interpret this to indicate minimal incorporation of slab-derived material. The Ba/La ratios of the Farallón Negro suite are similar to those of the late Oligocene-Early Miocene Marcungua and Ojos del Salado suites but are predominantly lower than those of the other Marcungua suites.

Our geochemical data show unambiguously that the Farallón Negro volcanic and intrusive rocks possess clear arc affinities. Further, the similarity in the trace-element abundances of the Late Miocene Farallón Negro, late Oligocene-Early Miocene Marcungua and Phiocene-Pleistocene Ojos del Salado suites suggest that such
compositions represent a "continuum" for subduction-related Neogene magmatism at this latitude, as the arc first broadened eastward to generate the Farallón Negro magmas and then contracted to the now-active volcanic axis. In contrast, we conclude that the compositionally distinct Middle Miocene and Late Miocene Managua suites record the geochemical evolution of an essentially stationary arc where the site of melting migrated to greater depths as the crust thickened (cf. Kay and Abbuzzi, 1996).

**TECTONIC EVOLUTION**

The Farallón Negro complex (Fig. 4a) overlies the postulated boundary between two basement domains, the Arequipa-Antofalla craton to the north and the Precordillera terrane to the south, delimited largely by Pb isotopic data for Paleozoic and younger rocks (Tosdal, 1996). The southern portion of the Arequipa-Antofalla terrane is dominated by Neoproterozoic-Lower Cambrian greenschist facies metamorphic rocks, whereas the Precordillera terrane comprises Cambrian to Carboniferous marine sediments overlain by Permian, Triassic, and Tertiary continental strata. This basement discontinuity is broadly coincident with the transition from the Puna to the Sierras Pampeanas Neogene tectono-geodynamic provinces (Fig. 1). The authors consider that a contrast in the bulk competence of these terranes may have influenced their response to E-W compression during the Neogene orthogonal convergence of the Nazca and South American plates: the northern block was more resistant to contractional deformation, generating differential shortening along the strike of the orogen. This behavior resulted in localized NE-SW extension, which initiated dextral shear along the NE-striking Tucumán Transfer Zone (Urechini et al., 1996) and is proposed to have created an extensional basin (Sasso, 1995; Sasso et al., 1993) at the latitude of Farallón Negro (Fig. 4A). The Andes at this latitude experienced major cordilleran uplift since at least the early Eocene (Mortimer, 1973), and substantial sediment accumulation in the foreland may have occurred throughout the Cenozoic, we suggest, however, that the Farallón Negro basin formed in response to local back-arc tectonic conditions.
Associated crustal stretching is inferred to have permitted high heat flow and magmatism (Fig. 3). Early volcanic history of the area, from 12.6 to 8.5 Ma, was characterized by isolated extusive events, possibly focused by the intersections of regional structures. Main Farallón Negro stratovolcano construction commenced at ca. 8.5 Ma (Fig. 4C), blanketing the precursor extusive centers with thick flows and breccias. The major period of volcanic, intrusive and hydrothermal activity, extending from 8.5 to 5.5 Ma (Fig. 4D), coincided with a shift in regional compression to NW-SW. This shift resulted from horizontal stresses imposed by the uplift of the Puru plateau (Allmendinger, 1986; Assumpção and Araujo, 1993; Urciuoli et al., 1996) which is superimposed on the southern Arequipa-Antofalla craton. This model differs from that proposed by Ramos (1977), and supported by the recent review of Jones (1997), in which the mineralized centers are considered to be controlled by tensional fractures generated by strike-slip movement along the parallel Tumacán and Huatulín lineaments. Onset of the Sierras Pampeanas deformation at the latitude of Farallón Negro (Fig. 4E) resulted in the rapid uplift of the basement blocks, possibly through reactivation of faults associated with earlier basin development, and in the erosion and partial denudation of the volcanic complex. Finally, erosion during the continued uplift of the basement blocks in the Pliocene (Fig. 4F) resulted in the formation of pediment surfaces in the Capillas Valley, and eventually in the exposure and local supergene alteration (McBride, 1972) of the hydrothermal centers.

MINERALIZATION

Silbin’s (1973a) synthesis of the relationships between porphyry Cu deposits and volcanic-hypabyssal edifices, and between porphyry and epithermal mineralization, drew extensively on the relationships documented in the Farallón Negro district (Hamblin, 1970, 1972; Caeles et al., 1971; Sillite, 1973b). The excellent exposure of varied styles of Cu-Au mineralization within the remnants of an eroded stratovolcano and associated with outlying igneous centers was recognized by these workers as providing an ideal environment in which to study the spatial and temporal relationships between magmatism and hydrothermal activity, and the incentive for the research of McBride (1972) and Caeles (1979).

Bajo de la Alumbrera (Fig. 5) is the best studied deposit hosted by the complex. Alteration and mineralization were intimately associated with the intrusion of hypabyssal bodies of porphyritic dacite into largely andesitic volcanic strata. The central intrusive body, the Main Dacite Porphyry Stock (Proffett, 1995), is shown herein to record a succession of intrusive events from 7.10 ± 0.13 to 6.83 ± 0.09 Ma (Fig. 5). The associated alteration facies (Stulits, 1985; Guilbert, 1995) comprise strong to weak potassic alteration (orthoclase, biotite) and peripheral propylitic (epidote-chlorite) assemblages, both of which were overprinted by phyllitic (quartz-sericite-pyrite) alteration at 6.75 ± 0.09 Ma. Guilbert (1995) noted that the areal configuration of these alteration zones is similar to the classic “inverted-bowl” model elaborated by Lowell and Guilbert (1970) at San Manuel-Kalamazoo, Arizona. Much of the Cu-Au mineralization at Bajo de la Alumbrera is chalcopyrite + pyrite ± magneteite that occurs as disseminations and veins associated with the early, central potassic alteration. Barren pyritic veins, generated during the subsequent phyllitic alteration, extend radially about the central intrusive complex.
metasedimentary and granitic rocks. Alteration and mineralization occur in at least four contiguous hypabyssal centers (Quin and Nikic, 1996) that exhibit multiple stages of igneous and hydrothermal brecciation. Koukharsky and Miné (1976) recognized that this complex deposit includes mineral assemblages characteristic of both porphyry Cu and epithermal mineralization events. Among the four or more porphyry centers that have been recognized, Melcho exposes hypogene assemblages, whereas a supergene enrichment blanket is preserved at Secca, below which hypogene potassic alteration has been intersected at 200 m depth by drilling. Disseminated and stockwork pyrite, chalcopyrite, bornite, molybdenite and magnetite are associated with the porphyry event. The Melcho center includes a precursor monzonite pluton emplaced at 8.56 ± 0.48 Ma and a later andesite porphyry. Both were brecciated and potassically altered (biotite and biotite) at 6.29 ± 0.06 Ma. Stockwork-controlled phyllic alteration (quartz-sericite-pyrite) ensued at 6.10 ± 0.04 Ma. Numerous breccia bodies associated with advanced argillic to alunite alteration cut phyllic alteration zones. Pyrite, covellite, bornite, enargite, molybdenite, galena, sphalerite, marcasite, rhodochrosite and native sulfur are disseminated in veins, cavity-fillings, and breccia cements. This late-stage alteration mineralization event took place at 5.35 ± 0.14 Ma, and we postulate that it was triggered by the thick-skinned tecnonism that produced the uplift of the Aconcagua Range. Our proposed model for the evolution of the hypogene deposit involves collapse of the water table onto the porphyry systems approximately 0.5 m.y. after their emplacement, resulting in an intense high-sulfidation epithermal overprint. In contrast, elsewhere in the Sierras Pampeanas, smaller scale porphyry and high-sulfidation epithermal mineralization in the Sierras de Famatina district occurred essentially simultaneously at 3.8 ± 0.2 Ma (Losada-Calderón et al., 1994), but significantly after large-scale uplift at 5 to 6 Ma (McBride, 1972; Clark et al., 1976; Cañales, 1979).

The Farallón Negro Volcanic Complex is also the site of two small vein mines: Farallón Negro-Alto de la Blenda and Capillitas (Fig. 2). The former, 8 km WNW of Bajo de la Alambre, is hosted predominantly by anastomosing breccias and the Alto de la Blenda monzonite stock, although the most productive portions of the system, within and close to the stock, occur in pyrite-bearing andesite dikes that intrude the monzonite and breccias (N. Montenegro, pers. commun. 1995). The mine exploits subparallel veins with minor cross-over splays. Free Au lines cavities and also is associated with zones of abundant pyrite. Quartz-sericite alteration has been dated at 6.55 ± 0.14 Ma (this study). The hypogene Au-Ag-base metal sulfide veins were intensely oxidized to a Mn-oxide-rich supergene assemblage at ca. 2.7 ± 0.8 Ma (recalculated K-Ar data for cryptomelane, McBride, 1972). The Farallón Negro-Alto de la Blenda deposit may represent a type of low-sulfidation epithermal deposit recognized by Sillitoe (1989) and characterized by unusually intense sericite wall-rock alteration, an intimate spatial relationship with intrusive rocks that are commonly porphyry Cu-bearing, and formation at a greater depth than typical low-sulfidation epithermal deposits. The Capillitas vein deposits are hosted by a rhyolitic diatreme that intruded a granite basement in the Sierra de Capillitas. Late-stage dactite porphyry dikes and a dacite porphyry plug cut the diatreme and are interpreted to be syn- or post-mineralization (Sasso, 1997). Sanidine from one such dike yielded an age of 3.16 ± 0.05 Ma. Mineralization, dominated by Cu, Pb and Zn sulfides in a gangue of rhodochrosite + quartz, is enriched in As, Sb, Au and Ag and contains significant W, Sn, Bi and Ge (Angelotti, 1950; Márquez Zavala, 1988).

The porphyry Cu-Au centers in and adjacent to the Main Farallón Negro volcanic field—Bajo de la Alambre, Bajo el Durazno, Bajo de Agua Tapada, Bajo de San Lucas and Bajo las Pampillas—are remarkable for the occurrence (Fig. 6) of intense, early, magnetite-rich vein and alteration

![Figure 6](image-url)
assemblages. In each deposit, a dense and commonly sheeted zone of magnetite and quartz-magnetite veinslets occupies a broadly central position (Fig. 6). At Bajo de la Alumbrera, Sultis (1985) and Guilbert (1995, p. 655) emphasize the role of silicification, and document early quartz-anhydrite veins “commonly with pyrite, chloropyrite, and magnetite.” However, our studies show that many magnetite-rich veins lack sulfide minerals, including pyrite. In general, a progression is evident from early magnetite-rich to later sulfide-rich vein and disseminated mineral assemblages, but a temporal and spatial overlap between magnetite precipitation and development of the potassium silicate assemblage is evident from crosscutting relationships and map patterns (Fig. 6).

As in comparable settings elsewhere, the hydrothermal magnetite has been assigned to a potassic alteration event even though the voluminous magnetite-quartz alteration largely lacks K-bearing minerals and thus is evidence of removal of potassium from intermediate or felsic igneous host rocks. The observed assemblages strongly suggest Fe-metasomatism, as at least Bajo de la Alumbrera and at Bajo las Pampitas, the latter exhibiting the most well-developed zone of quartz-magnetite alteration in the district. Similar early magnetite-rich alteration assemblages documented in porphyry deposits such as Island Copper and Panguna (Arancibia and Clark, 1996; Clark and Arancibia, 1995) include calcic amphibole and sodic to intermediate plagioclase. The apparent absence of these minerals at Farallón Negro indicates to us stronger alkali leaching and probably the introduction of more Fe. The generation of large volumes of strongly oxidized, SO$_2$-dominated fluids in the initial stages of vapor exsolution from the magmas would have the potential to suppress the precipitation of copper sulfides but would permit the deposition of Au, thereby potentially generating low Cu/Au ratios in the deposit as a whole. However, this model does not address the absolute enrichment of Au that may result from direct Au contributions from underplating mafic melts during the crystallization of the dacitic magmas as proposed for other deposits (Clark and Arancibia, 1995; Keith et al., 1997).

**Relationships between porphyry and epithermal deposits**

Since Sillitoe (1972a) first emphasized the link between porphyry Cu and epithermal precious metal deposits, the temporal and genetic connections between the two deposit types have been widely demonstrated. High-sulfidation epithermal Au-Cu deposits are characterized by above-mineralized porphyry stocks whereas polymetallic low-sulfidation deposits tend to occur distally. Our geochronologic studies show that the host rocks of the low-sulfidation Au-Ag-Mo epithermal veins at Farallón Negro-Alto de la Blenda were sericitized at $655 \pm 14$ Ma, coeval with or slightly after the $675 \pm 0.09$ Ma phyllic alteration at the nearby Bajo de la Alumbrera porphyry Cu-Au deposit. At Agua Rica, however, there was a distinct hiatus between the $610 \pm 0.4$ to $629 \pm 0.06$ Ma porphyry-style stockwork mineralization and the emplacement of the high-sulfidation epithermal assemblages of $5.55 \pm 0.14$ Ma.

The temporal relationships of Bajo de la Alumbrera and Farallón Negro-Alto de la Blenda are similar to those at Nevados de Famatina and La Mejicana in the Sierra de Famatina (Losada-Celedón et al., 1994) and at Lepanto and Far Southeast in the Philippines (Arribas et al., 1995), where coeval porphyry and high-sulfidation epithermal systems are juxtaposed. In contrast, the evolution of the Agua Rica center may be more analogous to that at Chuquicamata, Chile.

where a large scale energy-rich but Au-poor high-sulfidation vein system was superimposed on an extensive zone of potassic alteration and Cu veins during an episode of intense tectonism and uplift (Zentilli and Mikasa, 1995). Reynolds et al. (1997, in press) have identified a hiatus of 2 to 4 m.y. between the two alteration-mineralization events.

The apparent absence of high-sulfidation deposits in the Main Farallón Negro center may reflect the shear bulk of the stratocone. In the absence of through-going intra-mineralization faulting, relatively high pressures were maintained over the hydrothermal field, favoring early Cu-vein formation (Candeias, 1989; Cline, 1995) and inhibiting the development of gas-rich fluids.

**GEODYNAMIC MODELING**

The mid-Miocene broadening of the Andean volcanic arc to encompass the Maricunga and Farallón Negro areas, initially proposed by Clark and Zentilli (1972), Zentilli (1974) and Clark et al. (1973, 1976), is confirmed by compilation maps of the areal distribution of young volcanic rocks in the region between 26° and 28° S (Fig. 7) and the geochronologic data available for the transect (Fig. 8, page 16). Figures 7 and 8 clearly show the restriction of the magmatic arc in an area west of the international border in the late Oligocene and Early Miocene, the abrupt expansion of volcanism into Argentina in the Middle to Late Miocene, and the equally abrupt contraction of the arc since that time.

Building on the suggestions of earlier workers, and particularly of Zentilli (1974), Bonatti et al. (1977), and Caelles (1979), the senior author has proposed (Sasso, 1993, 1995, 1997) an integrated geodynamic model to explain the anomalous behavior of the arc, emphasizing the probable influence of inhomogeneities in the subducted plate. At about 27° S, the Nazca Plate is traversed by a crushly E-W array of extinct and active volcanoes showing no age progression, which Bonatti et al. (1977) called the “Easter Hot Line.” We propose (Sasso, 1993; Sasso et al., 1995; see also Jones, 1994) that such major crustal inhomogeneities and associated structural weakness may have initiated and propagated tears in the subducted slab when it was torqued and extended in the transition from steep to shallow subduction. The tears in the slab may have promoted higher heat flow in the overlying subcontinental asthenosphere, and possibly allowed the upwelling of sub-slab asthenosphere. Postulated perurbations in mantle flow along the Easter Hot Line (Richter, 1973; Richter and Parsons, 1975; Bonatti et al., 1977) would also contribute to a higher heat flow regime. Such processes may have caused devolatilization of the subducted slab to unusual depths, possibly through the breakdown of amphibole and phlogopite in an already extensively devaterated plate.

**SYNTHESIS**

This segment of the Andean arc has been geodynamically anomalous since at least the Middle Miocene, but has been enriched considerably in Cu and Au throughout the Mesozoic and Cenozoic. The association of a strong metallogenic signature with a distinct geodynamic setting strongly implies a causal relationship.

Bajo de la Alumbrera and the neighboring porphyry and epithermal deposits are noted to have been generated during a short-lived but dramatic expansion toward the continent of the Main Central Andean volcanic arc in the Middle to Late Miocene. The intimately associated igneous rocks fulfill all geochemical requirements for supra-subduction zone petrogenesis and are similar to both the late Oligocene-Early Miocene and Miocene-Pliocene
volcanic arc suites at this latitude. The largest known Neogene ore deposits in the region, the lowermost Miocene La Cripa epithermal Ag-Au-Cu and the Retegio Au deposits in the Maricunga district and the Upper Miocene Bajo de la Alumbrera and Agua Rica centers far to the east were emplaced at times of renewed arc magmatism and orogen-wide uplift. The associated magmatic rocks exhibit minimal HREE fractionation, indicating generation in a low pressure, hornblende-stable environment. In contrast, the smaller Middle Miocene porphyry Au centers of the Maricunga district were generated in the initial stages of the progressive deepening of the site of magma generation in an essentially stationary arc, culminating in the extreme Sm/Yb ratios of the Jotabeche suite (Fig. 3b). These relationships between petrogenesis and metallogenesis differ significantly from those documented by Ramos (1995) and Kay et al. (in press) for the more southerly El Indio belt, where the largest epithermal Au-(Ag-Cu) deposits formed in the Late Miocene immediately before a change in arc chemistry, reflecting a transition from hornblende- to garnet-bearing residual assemblages, and in the terminal stages of arc magmatism.

We therefore conclude that (1), as argued by Kay et al., major hydrothermal systems in this region are likely to be associated with igneous rocks exhibiting negligible HREE fractionation; but (2) a change in the depth of magma generation is probably not a critical factor in enhancing fertile hydrothermal activity. These differences emphasize the fact that, unlike those of the El Indio and Los Pelambres-El Pachón districts, the porphyry and epithermal Cu and Au-rich deposits of the Maricunga-Farallón Negro transect were generated at the southern limit of the Central Volcanic Zone rather than in the flat-slab region. Major changes in slab inclination were therefore not necessarily involved in magmatism and associated hydrothermal activity, and may not have occurred in the immediate study area, as proposed by Zentilli (1974) and Clark et al. (1976).

The Farallón Negro transect constitutes an unambiguous example for three time periods: late Oligocene-Early Miocene, Middle Miocene-Late Miocene, and Pliocene-Quaternary. These maps clearly show the location of the magmatic arc west of the International border (dashed line) in the late Oligocene-Early Miocene, the abrupt expansion of volcanism into Argentina in the Middle Miocene, and the equally sudden retraction of the main locus of volcanism in the Pliocene to its present location along the Chile-Argentina frontier. These maps were generated on a 1:500,000 MSS composite image of the region through the compilation of data from Mendoza et al. (1985), Baker et al. (1987), Sasso (1997), Secretaría de Minería (1995), González (1990) and González et al. (1999). Note: salars and lakes are indicated by the diagonal pattern.
of a major transverse tectono-magnetic discontinuity in the Neogene fabric of the Central Andes, and would therefore be predicted to be the locus of major mineralization (Sillitoe, 1974). It is probably underlain by the rifted margin of the Neoproterozoic-Cambrian Arequipa-Antofalla craton, providing an explanation for the transverse metallogenic domain boundary that extends back into the Mesozoic. The nature and longevity of the Easter Hot Line and its role, whether leading to, or contributing to, the fabric of the South American plate, remain problematic, but its coincidence with the present-day flexure of the subducting slab is undeniable. In this context, the occurrence (Fig. 1) of the supergiant (sensu Clark, 1993) Upper Miocene Los Pelambres-El Pachón porphyry Cu deposits (Kay et al., in press), the Middle Miocene Au-rich Pariamillos Sur porphyry center (Sillitoe, 1977) and the Upper Miocene-Phocene epithermal deposits of the San Luis belt (Urbina et al., 1997) in the vicinity of the more abrupt change in slab dip at about 32° to 33° S is intriguing. At this latitude, however, no oceanic features directly comparable to the Easter Hot Line have been documented, and analogies with the Maricunga-Farallón Negro area remain uncertain. We postulate that the combination of anomalous circulation in the asthenosphere and transverse ruptures in the slab (Fig. 9) provides a plausible explanation for the mid-Miocene expansion of the arc at about 27° S. The large-scale attenuation of the continental crust indicated by the pre-volcanic sediment accumulation may have permitted the focusing and rapid ascent of magma generated in this anomalous environment, perhaps minimizing their “contamination” by shallow crustal lithologies and thereby preserving them as potential sources of Cu and Au, e.g., Clark, 1993; Zentilli and Maksic, 1995. Finally, the geometrically simple Bajo de la Alumbrera deposit, hosted by the Main Farallón Negro Schist, may be considered to reflect the inherent fertility of this magmatic-hydrothermal environment, whereas the more complex Agua Rica center may have achieved economic status only as a result of the timely and rapid uplift of the Aconcagua block. The uplift promoted enrichment under late hypogene, epithermal conditions and subsequently through supergene alteration.

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FIGURE 9. Cartoon, looking NW, illustrating a proposed geodynamic model for back-arc magmatism at the latitude of Farallon Negro (from Sasso, 1997). The Easter Hot Line represents a zone of high homogeneities on the Nazca Plate which is inferred to overlie the upwelling limb of a mantle convection roll (Bonatti et al., 1977). As this segment of slab enters the Peru-Chile Trench, trench-parallel extension and warping of the plate to conform to the geometry of steep subduction to the north and shallow subduction to the south cause tears to form in the plate. Upwelling asthenosphere traverses the slab, increasing the temperature of the slab and resulting in its enhanced devolatilization and hence causing intense partial melting in the overlying asthenospheric wedge.

Two former SEG Presidents, Sangster and Skinner, honored by GAC

Two of the most prestigious medals awarded by the Geological Association of Canada (GAC) were presented to former SEG presidents Donald F. Sangster (SEG 1973, Pres. 1994) and Brian J. Skinner (SEG 1960, Pres. 1995) at the GAC Annual Meeting held in Quebec City, May 18–20, 1996.

Donald F. Sangster, formerly of the Geological Survey of Canada, was awarded the Logan Medal, the highest award the Geological Association of Canada bestows. It is awarded annually to an individual who has made an outstanding contribution to the development of Earth sciences in Canada. He was cited as follows:

To simply state that Don Sangster’s work is of international renown, or that he has provided outstanding scientific leadership for over 35 years does not do Don justice. He has been mentor to hundreds of scientists, advisor to Ministers and foreign governments, editor of outstanding journals, advisor and leader of international scientific organizations, and a truly exceptional mineral deposits researcher. Don has the knack for identifying the key issues or problems surrounding the genetic model for a mineral deposit type, applying exactly the correct tools to investigate it, and then succinctly reporting the results and their genetic implications, with elegant simplicity and profound insight.

Don developed a comprehensive database and set of descriptive models for lead and zinc deposits in Canada as his first GSC project. His early work on volcanogenic massive sulfide deposits and the related sedimentary – exhalative (SEDEX) type included succinct reviews that became standard texts for all students of economic geology, and changed the concepts used for discovery of these economically important deposits. Don’s recent research has documented the relationship of palaeokarst basement and reef structures to the genesis of MVT deposits. His collaborative lab investigations, using paleomagnetism and paleontology, are breakthroughs in mineral deposits science. Don is a leader in the technology of assessment of resource potential. He has provided sound advice to environmental panels, and encouraged research into the processes of metal transport and sequestration. As an adjunct professor at Canadian and foreign universities he has encouraged research excellence by many students, using his uncanny ability to see a complex problem in its simplest elements.

Don Sangster remains a provocative and innovative scientist. He gives his time freely, and his enthusiasm and quick wit are inspirational. He is most worthy recipient of the Logan Medal.

Sangster has received numerous other honors and awards during his career, including the prestigious Duncan R. Derry Gold Medal from GAC, and, in 1984, the Society of Economic Geologists’ Silver Medal.

At the same meeting, the GAC Medal, awarded to a non-resident of Canada who is deemed to have made significant contributions towards the understanding of Earth history or processes, was presented to Brian J. Skinner, Eugene Higgins Professor of Geology and Geophysics, Yale University. The citation for the award is as follows:

In research, publication and teaching in economic geology, geochemistry and mineral resources at Yale University and through lectures and presentations at other venues; in editorial duties, society and committee service; and as author, editor or co-editor of a large number of texts on earth resources and environmental issues, we submit that Brian Skinner for the past 45 years has made and continues to make significant contributions toward understanding Earth history and processes. At Yale, Professor Skinner is known as a competent and dedicated researcher and teacher. He showed outstanding ability to lead the world’s foremost mineral deposits journal, Economic Geology, as Editor, 1969-1995. Recently, he has become known as a thinker, synthesizer and geological activist with a formidable knowledge of the Earth, best indicated by his authorship of major texts on Earth resources, physical geology, Earth system science, environmental geology, and geologic hazards, with six major texts on these topics published since 1988. Brian Skinner is one of those rare individuals who excels in Earth science research and teaching, yet is also able to contribute significantly to the broader topical issues of resources, environment, and the future of humankind. We commend him to you as a most worthy recipient of the GAC Medal for 1996.

Colorado School of Mines honors Brian Skinner

On May 8, 1998, at the 124th Annual Commencement of the Colorado School of Mines, in Golden, Colorado, Brian J. Skinner was presented with an honorary Doctor of Engineering Degree. In his citation, it was noted that much of his career has been devoted to ensuring that geological issues are considered in the examination of the long-range availability of the earth’s natural resources, and that his widely applicable concepts have provided stimulus, focus, and direction for the investigations of many other present and future scientists and economists.

Skinner was the first recipient of the Society of Economic Geologists’ Silver Medal in 1981, has served as chairman of the U.S. National Committee on Geology since 1987, was a keynote speaker at the Pacific Rim Conference in 1990, and has received numerous other honors and awards during his career. He held the office of SEG President in 1965, and currently serves as President of the Economic Geology Publishing Company.
Dominican Republic Field Trip Report
SANTO DOMINGO, DOMINICAN REPUBLIC • MARCH 12-14, 1998

JOHN L. NOLD (SEG 1977)

DEPARTMENT OF EARTH SCIENCE • CENTRAL MISSOURI STATE UNIVERSITY • WARRENSBURG, MO 64093 • JLN@CWS.U.CMSU.EDU

The SEG-sponsored “Mineral Deposits of the Dominican Republic” field trip was held from March 12 to 14, 1998, following the SME meeting in Orlando, Florida. Deposits visited included the Pueblo Viejo gold deposit, the Falconbridge nickel laterite deposits, and the Cerro de Maimon massive sulfide deposit.

Mining history in the Pueblo Viejo area predates Christopher Columbus’s arrival—by then, natives already had mined gold in the vicinity. Production from the oxide zone of the Pueblo Viejo deposit was begun by Rosario Dominicana in the 1970s and, in 1979, the Dominican government nationalized the mine. Oxide ores have been depleted and current production continues on a mixture of oxide and sulfide ore termed “transition reserves,” in which gold recovery is less than 40%. Currently Rosario Dominicana is searching for an operating partner to further exploit the sulfide zone, where they report reserves on the order of 50M tonnes at an average grade of 1.989 g/t Au (for a total of 34.6 million oz), 12 g/t Ag, and 0.56% Zn. The Dominican government has authorized Salomon Brothers to assist in the bidding process. One of the bidders companies is reported to have spent in excess of US$8 million thus far in the preparation of its bid.

The Pueblo Viejo gold deposit is hosted by the Pueblo Viejo Member of the Cretaceous Los Ranchos Formation, which is described as having been deposited in a lacustrine environment on the south flank of an emerging island arc terrane. The Pueblo Viejo Member is interpreted by some to be a mix-diarrhenite complex. It includes breccias, lapilli tuffs, and coarse volcanioclastic grading upward into laminated carbonate-siliciclastics.

Previous workers consider the gold deposit to be an acid-sulfate type, given the coexistence of alunite and pyrite. Gold mineralization, thought to have been hydrothermally deposited after the lithification of the sediments, is generally present as electrum or Au-Ag tellurides and is extremely fine-grained, averaging 1 mm diameter. In the sulfide zone, gold mineralization is generally present as inclusions in pyrite. The Ag/Au ratio is typically about 7:1. Associated metallic minerals include pyrite, sphalerite, enargite, Zn-bearing tetrahedrite-telluride, Pb-bearing sulfosalts, silicate, and galena.

Alteration includes pyrite-quartz-pyrophylite, which affects carbonate-sediments, sandstone, siltite, conglomerate, and agglomerates. Alunite and associated gypsum alteration are found deeper in the system and extensive silification occurred in the upper portions of the sediments, which are covered by silicified hillslopes.

The Pueblo Viejo portion of the field trip was led by Rosario Dominicana Chief Geologist Juan José Rodríguez and by field trip participant Carl Nelson, who has done considerable geologic mapping of the deposits and whose work is currently in press with Economic Geology.

The nickeliferous laterite and Cerro de Maimon portions of the field trip were led by Falconbridge Dominicana geologists Julio Espallat, Jorge Jimenez, and Edwin Verdu, and by mining engineer Alex Butler.

These deposits occur in a belt of serpentinized peridotite approximately 100 km long, extending from Sierra Prieta (a few kilometers north of Santo Domingo) to Loma Montana, near the town of La Vega. Falconbridge Nickel Mines Ltd. started a sampling program in the belt in 1956 and their Falconco Plant commenced operation in 1970, reaching full production in 1973. Through 1997, Falconbridge Dominicana has produced about 1.5 billion pounds of nickel. The nickel is produced from garnierite and nickeliferous serpentinite within the talc. The main parent rock is harzburgite, which makes up about 20% of the serpentinitized rock. Chromite pods, dunites, basalts, and diabases are also present, implying that the overall geology is that of an alpine peridotite complex within an ophiolite sequence.

Effective weathering began on the lower Miocene land surface that have been uplifted and block-faulted. The laterization process apparently continues today, but there is no firm evidence that it has been uninterrupted since the early Miocene. Due to changes in the nature of the ore, there has been a deterioration in the nickel grade of the feed to the process plant over the years, and the change has required more careful control of the feed to the reduction plant. This is accomplished primarily by selective crushing of the ore followed by size separation, with the undersize being the higher grade material. Current cut-off grade 1.2% nickel.

The Maimon Formation occurs as a northwest-trending belt about 75 km long and 9 km wide, composed of metamorphosed volcanioclastics and volcanic rocks of lower Cretaceous age, cropping out in central Hispaniola.

The occurrence of gossan at the surface led to the discovery of the Cerro de Maimon massive sulfide deposit on Falconbridge’s initial Quisqueya concession. The deposit was first drilled in 1978. In 1983, Rosario Dominicana obtained the concession rights to explore all the Maimon Formation. Falconbridge Dominicana took over the Maimon Concession in 1990 and in 1991, located and drilled the Loma Pesada deposit. Over the past 20 years, three volcanic-hosted massive sulfide deposits have been found within the Maimon Formation, but only the Cerro de Maimon deposit has economic potential. Falconbridge Dominicana reports that the deposit contains an estimated resource of 3.5 Mt of 3.77% Cu, 2.04% Zn, 45 ppm Ag, and 0.6 ppm Au. Supergene enrichment has significantly enhanced the copper grade of the deposit to a depth of 120 m below the surface. During the field trip, the gossan and the core from one drill hole through the deposit were examined.

Those of us who attended this excellent field trip wish to thank the Society for sponsorship and Dennis LaPoint, Appalachian Resources, for making the arrangements. Also, special thanks go to Julio Espallat, Falconbridge Dominicana, for the work he did in making this trip happen, especially with regard to the guidebook.

Information for this summary was taken mostly from SEG Guidebook in the Mineral Deposits of the Dominican Republic, 1998, edited by P. Geoffrey Feis, and compiled exclusively for field trip participants.
Lee Barker has organized the SEG program for the 1998 annual meeting with the Geological Society of America. See page 22 for registration information for the meeting and page 45 for the pre-meeting Gold Deposits of Northern Sonora, Mexico, Field Conference. For additional information on the SEG program contact:

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website: www.southernera.com

SHORT COURSE

Saturday, October 24, and Sunday, October 25, 8:00 a.m. to 5:00 p.m.

Techniques in Hydrothermal Ore Deposits. Modern geochemistry has produced many techniques that are applicable to the study of hydrothermal ore deposits, and these have been used to determine everything from the date of mineralization to the sources of hydrothermal fluids. However, the results of such studies are too often overlooked as being of academic interest only. The goals of the course are to (1) show that many of the science’s methods are, in fact, quite straightforward, and (2) to provide a basic understanding of data interpretation. The course is designed for anyone with a beginner's interest in modern techniques and how they can be applied to real systems. The short course volume is included in the registration fee.

Limit: 100. Cost: $390 SEG members; $430 nonmembers; $480 certified students. Pre-registration required. Send check, payable to the Society of Economic Geologists, to 5808 S. Rapp St., Suite 209, Littleton, CO 80120. Tel. +1.303.797.0417; Fax +1.303.797.0417; <socgeol@csn .net>. Major credit cards accepted. To register, please use the form on page 46 of this issue of the Newsletter.

SYMPOSIA

- Sunday, October 25, afternoon. The Voisey's Bay Ni-Cu-Co Deposit: A World-Class Ore Deposit at the Junction of Two Former Continents. The Voisey's Bay deposit is the most significant discovery made in North America in the last decade. This symposium will summarize research results to date. Session organizer: A.J. Naldrett, University of Toronto.

- Wednesday, October 28, morning. The Lac De Gras Diamondiferous Kimberlite Field, Northwest Territories, Canada. The discovery of the Lac De Gras diamondiferous kimberlite field in Canada's Northwest Territories in late 1991 represents one of the most significant new mineral discoveries not only in North America, but also worldwide. Exploration and academic studies since discovery will be reviewed in a comprehensive series of papers highlighting regional framework, detailed descriptions of deposits, and interpretations of the nature of the Earth's mantle. Session organizers: Buddy Doyle, Kennecott Canada Exploration Inc., and Jon Carlson, BHP Diamonds, Inc.

THEME SESSION

Gold Deposits Associated with Alkaline Rocks. Under certain conditions of mantle melting, often in back-arc or post-subduction settings, moderately alkaline, hydrous, basaltic magmas may be generated that are associated globally with magmatic-hydrothermal and epithermal gold mineralization. Compared with calc-alkaline porphyry Cu deposits, alkaline Au deposits are relatively rare, but where found, frequently contain bonanza concentrations of Au (e.g., Cripple Creek, Porgera, Emperor). They represent important targets for Au exploration. Session organizers: Jeremy P. Richards, University of Alberta, and Paul G. Spry, Iowa State University.

FIELD TRIP

Monday, October 19, through Saturday, October 24. Gold Deposits of Northern Sonora, Mexico. This six-day trip will feature newly discovered, disseminated gold deposits along the general northwest trend between Santa Ana and Sonora—the so-called Altar Gold Belt—and selected other gold deposits in northwestern Sonora. Limit: 45. Cost: $670. Includes field trip transportation, all meals, accommodations (double occupancy), and guidebook. Pre-registration required. Send check, payable to the Society of Economic Geologists, to 5808 S. Rapp Street, Suite 209, Littleton, CO 80120. Tel. +1.303.797.0417; Fax +1.303.797.0417. Major credit cards also accepted. See announcement, page 45.
PREREGRISTRATION FORM
GSA ANNUAL MEETING • TORONTO, ONTARIO
October 26-29, 1998
Pre-registration Deadline: September 18. Deadline for changes or cancellation is September 25.

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from middle(?) Proterozoic to early Cambrian and include siliciclastic, dolomitic and basaltic volcanic rocks on the eastern coast, and high-grade (partly anatexic) metasedimentary and mylonitic rocks on the west coast. These have been intruded by late Proterozoic and Devonian granites, the latter associated with a world-class scheelite-garnet skarn deposit. The geology viewed during the field trip is briefly summarized as follows.

Steeply dipping Proterozoic metaturbidites are exposed on the western side of King Island. Classical Brana sequences and thick, high-density turbidites have undergone multiple phases of deformation and metamorphism as a result of regional orogenic events that are also recognized on mainland Australia and in Tasmania. Granite plutons, emplaced at ~740 Ma, are accompanied by steep contact metamorphic gradients, culminating in anatexis of the host rocks. Anatexis ranges from incipient, with the development of quartz-graphite-biotite-sericite-tourmaline segregational pods and sills, to intense migmatization and generation of anatexic granite. Several discrete sets of mafic dikes and sills have also been recognized. A major NS-oriented mylonite zone, clearly represented by aerial magnetics, is beautifully exposed around Currie Harbour and at Cataract Point.

Low-grade metasedimentary, sedimentary, and volcanic rocks are exposed along the spectacular platforms on the east coast of King Island. A shallow dipping silstone-diamictite-dolostone sequence is overlain and intruded by basaltic flows, hyaloclastite, sills, and dikes. The diamictic sequence (Cottons Breccia) is a poorly sorted, crudely stratified unit with angular polymict clasts in a carbonate or limonite cement. The presence of sparse dropstones and possible “varved” sediments may suggest a glaciogenic depositional environment. This unit may represent the northeastern outcrop of late Proterozoic glaciogenic sequences exposed throughout the Adelaide Geosyncline, Amadeus Basin, and Kimberley Region of mainland Australia. Overlying the Cottons Breccia is a planar laminated dolomitic unit believed to be the stratigraphic equivalent of Neoproterozoic Cap Dolomites found elsewhere in the world. The overlying theticitic and picritic basalts exhibit excellent volcanic features, including pillows,ropy pahoehoe surfaces and burrowing flows with marginal hyaloclastite and autobreccia breccias.

In the southeastern part of the island, the same dolomitic sequence as that exposed on the east coast has been intruded by Devonian granites. Complicated gneiss skarns are developed along the margins of the granites, and have formed two significant Tungsten deposits — the No. 1/Dolphin and Bold Head deposits. Although neither deposit is being mined, a total of 9.7 Mt @ 0.64% WO$_3$ has been produced over the last 80 years from a total original resource of 17 Mt @ 0.85% WO$_3$. Several hundred thousand kilograms of molybdenum concentrate have also been produced. Further reserves are possible at depth, as the Dolphin orebody has only been tested to 300 m. Only the upper benches of the open cut are accessible, but the complex Tungsten skarn and local ore distribution features are exposed. The mine sequence is a ~200 m thick metamorphosed and metasomatized dolomitic package with numerous concordant lenses of andradite-pyroxene-biotite-calcite-scheelite skarn, separated by barren units dominated by amphibole-biotite-calcite-garnet assemblages. Pyrrhotite, pyrite, magnetite and olivine are also locally

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**King Island Excursion**

The University of Tasmania Student Chapter ran a very successful four-day geological excursion to King Island in March, 1998. The 17 participants included professional geologists and geology students from the University of Tasmania, Adelaide University, Macquarie University, Mineral Resources Tasmania, and the Universities of South Australia, Stockholm, Gottingen, and Luca. King Island, lying midway between mainland Australia and Tasmania, is rarely visited by geologists, yet boasts some of the most diverse and exceptional geology in southeastern Australia. Supracrustal rocks range in age
present. Scheelite generally occurs as fine intergranular masses. The orebody occupies a tight, 100-m-scale anticline-syncline structure, with grade increasing toward the nose of the folds and toward cross-cutting faults.

The local and regional geological framework of King Island is problematic in many respects, and its economic potential is still largely untested. University researchers in Adelaide and Tasmania are considering interactive projects to approach the problems.

Special Lecture

In late February, the student chapter, CODES and the GSA Tasmania branch played host to eminent Australian Proterozoic microbiologist Malcolm Walter, Adjunct Professor at Macquarie University and consultant to the NASA "Life on Mars" project at a well-attended public lecture. He subsequently offered some thought-provoking discussions on relationships between microbial life and the formation of orobarches. The outcome of the visit was that we, as geologists, should be mindful of accommodating a variety of influences in our field of research.

— David Rawlings, Secretary

Field Trip to Cuba: February 21-28, 1998

Cuba has been much in the news, not just for its politics or the Pope's visit, but also for the increasing recognition of a high resource potential (e.g., see the proceedings of the third Cuban Congress on Mining and Geology held in Havana March 24-27 of this year). The geology is fascinatingly complex. Forming the northwest segment of the Caribbean archipelago, it reveals the nature of the Caribbean/North American plate boundary, and has a much more diverse geological makeup and history than the subduction-related neighboring islands. This history has been exceptionally well-documented; the synoptic paper by Burnside-Vincent (1996) is an excellent introduction.

The island's story begins with Late-Cretaceous rifting of pre-Mesozoic "Appalachian" basement, including Grenville-age gneiss, from the Yucatan Peninsula (Hutson et al., 1998). The Jurassic rift deposits that comprise the western end of the island have been dismembered by regional transpressional faults that caused Late-Cretaceous/early Tertiary overthrusting along the outboard margin of the Bahamas platform that is well-exposed along the north-central coast and reappears as a horst in the core of the western Guanacaste terrane.

The rest of Cuba is dominated by allochthonous island arc and related ophiolite assemblages that have been obducted onto the Bahama platform. Olistostromal units at the base of the northern fore-arc ophiolite belt young south to north from Paleocene to Eocene, indicating northeasterward transport of these Caribbean plate elements in the early Tertiary. The northern ophiolite belt shows increasing deformation from east to west. The arc volcanic assemblages demonstrate vastly differing faces across the regional northeast-striking sinistral transform: the central Santa Clara district is constituted by late Cretaceous low-K volcanic rocks interbedded with marine volcaniclastic rocks (a primitive submarine arc assemblage); the east-central Camagüey district comprises a younger, latest Cretaceous high-K shoshonitic suite interbedded by synvolcanic syeno-granite stocks (an evolved subaerial arc related to subduction reversal), whereas the southeast end consists of a similar Paleocene arc assemblage.

The objective of the field trip, which was attended by 8 students and 2 professors, was to achieve a regional-scale appreciation of Cuban geography, geology, and mineral wealth. The group traveled about 2500 km over five days, car rentals, gas, and motel accommodations were very reasonable by Canadian standards.

In Camagüey, Macdonald Mines was our host. High-S electron-microanalytical gold mineralization was observed, as well as Cyprus-type cupro-nickel and pyrite and pyrrhotite sulfides in a tour of the northern ophiolite belt. At Santa Clara, we were hosted by Juete/Queentown Mines, and carried out a regional road traverse from the northern ophiolite
belt across the entire arc assemblage, noting the stratigraphic position of the Cu-Zn massive sulfide deposits that intrude into the southern Escambray complex, a metamorphic dome exposing the underlying Mesozoic rift facies clastics. Our Pinar del Río host was Holmar Gold Mines. At Santa Lucía, we toured a heap-leach operation in the Rosario assemblage (also site of Miramar’s lateritic Cu-Au deposit, recently reopened at the extreme west end of Mantua) and completed a regional road traverse across the Guaniguanico belt, which hosts numerous stratiform Pb-Zn-Ba deposits (Maynard et al. 1995).

From the standpoint of appreciating regional metallogenic controls in terms of tectono-stratigraphic assemblage, the trip was an outstanding success. Explorationists working in accretionary terranes ranging from Archaean greenstone belts through Proterozoic mobile belts, and especially those interested in Phanerozoic continental margin terranes with diverse shelf, rift facies clastics, ophiolite, and arc-derived lithological assemblages (the Yukon-Tanana of the northern Cordilleran is a good late Devonian example), would benefit by considering Cuba as a modern analogue. One insight to be gained concerns the intricacy in the timing of tectonic juxtapositioning and depositional histories along plate boundaries—giving real meaning to tectonostratigraphic construction. Cuba is young enough and well known enough to serve as a useful actualistic analogue for paleo-arc and/or continental margin collisional boundaries. Such plate boundary settings (submarine orogens) are more likely to be preserved in the geological record than are autochthonous island arcs.

In terms of both intensity of exploration and level of mineral deposit research, Cuba has been in a backwater. With the current wave of exploration by Canadian juniors, this situation is about to change. The high-S epithermal systems in the Camagüey district show considerable similarity to such epithermal Au deposits of the southern Appalachians as the Halcyon and Brewer deposits. The Cu-Zn volcanic massive sulfides in the Santa Clara district are classic Noranda-type deposits. The lesser explored northern trend of massive sulfide occurrences,
with its more poly-metallic signature and associated bedded base, may represent a somewhat shallower submarine setting, as has recently been documented by Hannington (1997). The stratigraphic Pb-Zn-Ba deposits of the Guanajuato are hosted within a collapsed continental margin sedimentary succession, similar in most respects to tectonic settings with Irish-type SEDEX environments. The Rosario-hosted Intrusive Cu-Au deposits occur in a transitional oceanic rift environment amenable to Besfide-type cuprous pyrrhotite mineralization, which may be a precursor to lateritic upgrading. Given such high diversity in its regional resource potential, much more will be heard from the Cuban mining sector in the near future.

ACKNOWLEDGMENTS

The student chapter extends its gratitude to Terry Brade and Pedro Vega of Joutie; Mario Miranda, John Watkins and Eugenio Escobar of MacDonald Mines; Tom Neatans and Manuel Vasquez of Holmer Gold; and Dean MacDonald of Miramar for their help in the organization of this trip. The chapter is indebted to SEG Inc. for its financial support, without which this trip would not have been possible. A special thanks to UWO professors Dr. Norm Duke, for leading and organizing the trip, and Dr. William Church, for his assistance.

REFERENCES


—Scott John-Brown, President

UNIVERSITY OF TORONTO

The 1997-98 year was a busy one for the U of T Student Chapter. Twenty-seven corporate sponsors played an integral role, as their contributions provided the chapter with its operating budget for the year, and demonstrates the strong commitment industry has to the chapter. Special thanks are extended to Falconbridge Ltd., for yet again going beyond the call of duty.

This year’s seminars focused heavily on gold and were well-attended by both students and members of Toronto-based companies. The year started off with Lori Walton of Walton Geological Services and WACAM J.V., who discussed a variety of topics regarding exploration geology, including the importance of graduate work, and how to go about setting up a company.

November was dubbed Bre-X month, with two presentations on the doomed company. First, James Whyte of the Northern Miner shared some of the fascinating insights into the Bre-X saga from his new book, co-authored with Vivian Danielson. Bre-X: Gold Today. Gone Tomorrow. The second Bre-X seminar was a joint meeting between the Toronto branch of the CIM and the U of T SEG. Graham Farquharson of Stratcon discussed that company’s role in unraveling the Bre-X fraud, and emphasized the importance of due diligence. This was the chapter’s first joint meeting with the CIM, and we look forward to furthering the relationship.

Fall and winter talks were given by Dr. Larry Cathles of Cornell University, who discussed gas fluxes in sedimentary basins, and Dr. Bob Vallant, President of Tri Origin Exploration Ltd., who discussed exploration techniques for the discovery of Canadian Precambrian gold deposits.

Our presenters are thanked for providing high quality talks, and for sharing their experiences.

The chapter’s efforts this year were centered on the annual short course held at University College in mid-March, following the PDAC conference. This year’s two-day course was given by Greg Cobben and Terry Leach, who discussed “Geology and Exploration of Southwest Pacific Rim Gold-Copper Systems.” The course attracted 33 industry participants and an additional 20 people from U of T. The focus was on field geology, with emphasis on the exploration for these deposits rather than specific genetic models (readers should refer to the course review presented in the April, 1996, vol. 25, SEG Newsletter). Although the title refers to the southwest Pacific, several South American examples were included. Surplus proceeds from the course will be used for a Student Chapter field trip to Chile next February, providing the opportunity to see these deposit types, and others, first-hand.

Finally, I am pleased to announce the new executive for the 1998-99 year. The chapter will be under the direction of Heather MacDonald—President, with Nwojiwa Wachowicki—Vice President, Jamie Bradburn—Secretary, Ryan Weston—Treasurer, and Michael Thompson—Newsletter editor.

—Andrew Cudry, President

JAMES COOK UNIVERSITY

The beginning of 1997 saw the handing over of the executive offices. New offices were for: President, Kirsty Grogan (honors student); Vice-President, Clayton Davys (third-year student); Secretary, Christopher Fischer (third-year student); and Treasurer, Andrew Hann (Ph.D. candidate). Faculty and local SEG sponsors remained the same, with Dr. Patrick Williams serving for the faculty, and Dr. Mark Elliott continuing as local SEG sponsor. There were 33 chapter members.

Meetings were conducted monthly, and more frequently during major or special events, such as when Dr. Hugo Dummett, the SEG Thayer Lindsey lecturer spoke, and for Quiz Night.

Quiz Night was a success, with 60 attendees and prizes donated by local businesses. Students, academics, and industry personnel vied for top position in the competition. The industry team fielded by Terra Search outgunned everyone to finish two points in front of Toast Endangered Species, the students’ team.

Throughout the year, barbecues were given to get students and staff together, and to promote the chapter. Several were held in conjunction with the six EGGFED (Economic Geologists Group for Heated and Energetic Discussion) meetings within the school of Earth Sciences. Most of the meetings provided a forum for discussion of Ph.D projects being undertaken by chapter members. Among the guest lecturers was local SEG Fellow and ICU Honorary Research Fellow, Dr. Bill Laing, whose discussion topic was ore deposit modeling. The many students, staff, and industry personnel who participated were impressed by Bill’s knowledge of the subject matter.

Overall, 1997 proved to be an interesting year for the chapter. The chapter expresses its appreciation to SEG for its help throughout the year.

—Kirsty Grogan, Student Chapter President, 1997
Chile Ore Deposits Field Trip
*Viaje a Yacimientos Metalíferos Chilenos*

The third joint academia-industry field trip, to be held January 3-17, 1999, to visit the mineral deposits of Northern Chile is being organized by the joint SEG Student Chapter of the New Mexico School of Mines and the University of Utah. Northern Chile is host to numerous world-class deposits including Chuquicamata, Cerro Colorado, Quebrada Blanca, El Abra, El Salvador, Candelaria, Manto Blanconos, and Escendida. The trip, lead by Drs. William X. Chávez, Jr. and Erich U. Petersen, will cover aspects of porphyry Cu and Mo deposits, andesite-hosted Cu-Ag and Cu-Au systems, and vein-type gold occurrences, including exploration history, ore mineralogy, wall rock alteration and zoning, mining methods and engineering, and economics to the environmental dimension.

The trip will be conducted in English and Spanish. Industry professionals are especially invited to participate. For further information and trip reservations, please contact either Dr. William X. Chávez, Jr. (Tel. +1.505.835-5317, Fax +1.505.835-5252, e-mail: wxc@mines.nmt.edu) or Dr. Erich U. Petersen (Tel. +1.801.581.7238, Fax +1.801.581.7065, e-mail: eupetersen@mines.utah.edu). Please visit the field trip website at <http://www.mines.utah.edu/~wmp/chile99.html>.

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**UNIVERSITY OF TORONTO**
**Tenure Stream Position in Ore Genesis**

The Department of Geology invites applications for a tenure stream position at the ASSISTANT PROFESSOR level in the field of ORE GENESIS (St. George Campus). The position is made possible through endowed funds donated to the University of Toronto by the Canadians Resident Abroad Foundation and the duties will complement those of the holder of the Norman B. Keewill Chair in Ore Genesis and of related faculty in the broad field of mineral deposits geology. The appointee must have a strong commitment to both teaching and research. He/she will be expected to teach courses within the field of specialization and related areas as well as in general introductory courses. Research interests should focus on processes of ore formation and may include emphasis on one or more of the fields of geochemistry, mineralogy, petrology, structural geology, or computer simulation as applied to state of the art knowledge of element concentration processes.

Applications should include a CV, a statement of research interests and the names and addresses of at least three referees and be sent to:
Professor J.J. Fawcett, Chairman, Department of Geology, University of Toronto, Earth Sciences Centre, 22 Russell Street, Toronto, Ontario, Canada M5S 3B1, by August 15, 1998. The position is available from January 1, 1999.

Applicants should arrange for their referees to send letters directly to the above address by the application deadline. Email to: <chair@irsrix.geology.utoronto.ca>. Departmental information is available on our home page at: <http://www.geology.utoronto.ca>.

In accordance with its Employment Equity Policy, the University of Toronto encourages applications from qualified women and men, members of visible minorities, Aboriginal peoples and persons with disabilities.

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EXPLORATION REVIEW

ALASKA

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The ice is out, the leaves are out, and the prospectors and miners are out attending to business as the 1998 summer season opens in Alaska. Early and advanced stage exploration work is being conducted all over Alaska. New gold resource estimates and the existence of more new mining companies into the Alaska exploration fray attest to the remarkably robust nature of the Alaska mineral industry.

WESTERN ALASKA

Cominco American has announced that construction is on schedule to increase production at its Red Dog mine to 900,000 tonnes of zinc concentrate and 160,000 tonnes of lead concentrate per year. Year-end proven-probable ore reserves at Red Dog were 50.6 million tonnes grading 19% Zn, 5.3% Pb and 99 grams/tonne Ag. Possible reserves stood at 72.9 million tonnes grading 13.6% Zn, 3.7% Pb and 65 grams/tonne Ag. An additional 22.6 million tonnes at similar grades was carried in indicated and inferred resources.

Cominco American also announced revised resources at its Pebble gold-copper project near Lake Illiamna. Inferred resources at this prospect are 1 billion tonnes grading 0.3% Cu and 0.34 grams/tonne Au. This pencils out to a total contained gold resource of nearly 10 million ounces.

The silence hovering over Placer Dome's Donlin Creek gold deposit was shattered in early May with the announcement of a revised resource estimate totaling 61 million tonnes grading 3.1 grams/tonne at a 2 gram/tonne cutoff grade (equivalent to 6.7 million ounces at 0.1 oz/ton), including measured, indicated and inferred resources. A three-rig drilling program is underway at the property.

Bad news came from Dakota Mining, which announced a year-end 1997 net loss of $34.4 million including a $28.9 million write down of assets. In mid-May, the company's Alaska subsidiary, USMX of Alaska, filed Chapter 11 to allow restructuring of the company under bankruptcy protection. On the brighter side, mining at its Illinois Creek heap leach operation totaled 1.2 million tonnes loaded to the leach pads with an average gold grade of 0.072 oz/ton. Through year-end 1997, the mine had recovered 20,111 ounces of gold, with an estimated 52,500 recoverable ounces remaining in the heaps. Cash costs at Illinois Creek for 1997 were $195 per ounce. At year-end, recalculated at $330/oz gold) proven and probable reserves were at 1.9 million tonnes grading 0.076 oz/ton gold and 1.16 oz/ton silver. Leaching will continue during 1998, but no new ore will be loaded on the pads.

Consolidated Nevada Goldfields (CNG) recently released encouraging results from deep core drilling below its C-3300 orebody at its Nixon Fork underground gold-copper mine near McGrath. Intercepts included values as high as 2.5 oz/ton over 9.5 feet and 1.5 oz/ton over 26.3 feet. Mine geologists believe that several high-grade chinnies similar to the Crystal/Garrett extend to depths below current mine workings. At a special meeting, CNG shareholders approved a 10 for 1 reverse share split and changed the name of the company to Real del Monte Mining Corporation, reflecting the corporation's renewed commitment to its Mexican silver properties.

NovaGold Resources Alaska is in the process of mobilizing camp and personnel to its 49%-owned Shogun gold project north of Dillingham. Cominco American owns the remaining interest in the project. Specific plans for the project have not been disclosed.

From Ventures Resource comes word that the company plans to conduct follow-up drilling on its Chicken Mt. gold project near Fair, where 1997 drilling returned encouraging results including a 70-foot intercept grading 0.416 oz/ton. The project is located partially on lands controlled by Doyon Ltd.
EASTERN INTERIOR

As a result of the previously announced merger of Amax Gold and Toronto-based Kinross Gold Corporation, Kinross has become the owner of the Fort Knox mine. Year-end reserves at the mine were at 4.1 million ounces at a grade of 0.025 oz/ton Au. First quarter 1998 production was 87,232 ounces of gold at a cash cost of $189 per ounce. Financial restructuring resulting from the merger will significantly reduce all-in production costs at Fort Knox. The new company will be North America’s fifth largest gold producer at 1.2 million ounces per year with total gold resources of 27.1 million ounces. Cash operating costs are estimated at $210/oz.

Fairbanks District joint venture partners Newmont Exploration (65%) and La Teko Resources (35%) announced the acquisition of the additional acreage from Placer Dome Exploration and the Alaska Mental Health Trust, bringing project land area to 17,500 acres. Recovery rates from hot roll cyanide extraction tests of sample material collected in 1997, from the Hindenberg and Shepard zones, ranged from 83 to 96%. Large diameter column leach testing is underway. Current reserves are 1.3 million ounces of gold grading 0.072 oz/ton.

The plot thickened in the Fairbanks District when Kinross Gold Corporation announced a US$1.7 million private placement in La Teko Resources. La Teko conveyed its first right of refusal to finance the purchase of Newmont Exploration’s interest in the True North deposit in the event such interest is offered to La Teko under the La Teko—Newmont joint venture agreement. If such interest becomes available, Kinross has the right to fund the purchase through a 120-day interest-free loan and either party may elect to repay the loan by conveying the Newmont interest to Kinross. This conveyance is subject to La Teko’s right to withhold up to 15% of the True North interest, thus putting Kinross and La Teko on a 50-50 basis. La Teko stated that Newmont has expressed no interest in selling its interest in True North, but speculated that if such interest did become available, Kinross as owner of the Fort Knox mine, would be the natural purchaser. Any questions?

Freegold Recovery Inc. USA announced that equity funding partner, Barrick Gold Exploration, has elected to increase exploration funding on Freegold's Golden Summit project outside of Fairbanks. Barrick has purchased an additional CDN$1.0 million worth of Freegold stock. Barrick’s planned total investment for 1998 now stands at CDN$2.5 million, 95% of which is earmarked for the 1998 exploration program. Work is in progress, but details have not been released.

Placer Dome Exploration continues its exploration program at Silverado Mine's Ester Dome mineral holdings in the Fairbanks District.

Due to the depressed market conditions, Silverado Mines was forced to terminate its option agreement on the Ryan Lode deposit near Fairbanks. La Teko Resources will maintain the property while exploring other development options.

In the acquisitions news, Golden Phoenix Minerals took on additional lands at its Uncle Sam project in the Goodpaster River District, where
local project area is now 6 square miles. Preliminary exploration will be started in 1998.

La Teko Resources announced closing of its acquisition agreement on the Discovery Gulch property. The company can earn a 100% interest in the property, subject to a 2% NSR, by making certain annual payments and exploration expenditures. The entire interest can be earned if La Teko completes a feasibility study on the property and makes a final payment of $500,000. Plans for 1998 include additional soil sampling followed by trenching and, if warranted, possible drilling.

Tri-Valley Corporation has plans to process a 100,000-ton bulk sample from the Democrat Dike prospect on its 44-square-mile Richardson Project southeast of Fairbanks. The company entered into an agreement with Voyvillia Mining Ventures whereby Voyvillia will crush previously stockpiled material to minus 1/4-inch, and then pass the pulp across a customized sluice box and jig plant. The goal of this $570,000 program is to define the grade and size distribution of both coarse and fine gold known to exist in the Democrat Dike. Plant mobilization and site preparation for this bulk sample are in progress.

Teck Corp. and partner Sumitomo Metal Mining’s have begun their $8 million surface drilling program on the 4.5-million-ounce Pogo deposit in the Goodpaster River District. Permitting for the planned underground access and exploration program is in progress.

Yellow Eagle Mining (70%) and Exploration Orbite (30%) announced the resumption of placer gold mining at their Cripple Creek mine in the Fairbanks District. The unusually warm spring in Interior Alaska has allowed Cripple Creek to reopen earlier than most years. Mine plans for 1998 call for recovery of 12,600 ounces of gold at a cash cost of $178 per ounce. The grade of the block to be mined is more than double that of previously mined ground on the property.

On a gloomier note, Homestake Exploration, citing continuing depressed gold prices, announced closing of its Fairbanks-based exploration offices.

SOUTH CENTRAL

Columbia Yukon Resources announced acquisition of a 100% interest in Liberty Bell Mining Company, whose principal asset is the Liberty Bell gold deposit in the western Bonnfield District. The 47-square-mile property contains resources of 250,000 ounces in two areas and seven other advanced stage exploration prospects. Plans for 1998 were not released.

Grady Resources mobilized two drills and camps to the Bonnfield District in mid-May to initiate exploration on its Dry Creek and Anderson Mt. prospects. A total of 20,000 feet of core drilling are planned on the two volcanogenic massive sulfide prospects. Drilling is designed to expand on encouraging results from the 1997 drilling program and to determine the geometry and grade of the source of massive sulfide boulders, which average 2.25% Cu, 8.5% Zn, 2.2% Pb and 3.5 oz/ton Ag at Anderson Mt.
Grayd also announced that drilling on the Delta project JV with American Copper and Nickel will begin in early June while core drilling on its the Bonnifield Joint Venture with Inmet Mining Co. is scheduled for July.

Alaska newcomer Cannor Resources Ltd. (a Norhair Group company) has acquired six volcanogenic massive sulfide properties and one gold property in the Bonnifield District from Golden Phoenix Minerals. Cannor can earn from 51% to 100% interest in each of the seven properties in the 20-square-mile package by making staged cash and equity payments to Golden Phoenix totaling $2.2 million and 1,450,000 shares, and by completing $2.5 million in staged exploration work on each of the properties. Golden Phoenix retains a 3% NSR after Cannor earns its 100% interest in a given prospect. At the Cirque prospect, a massive sulfide horizon has been traced over 2,000 feet. A 6.5-foot chip channel sample taken on this trend assayed 0.9% Cu, 13.2% Zn, 641% Pb, 1.7 oz/ton Ag and 0.12 oz/ton Au. Arsenopyrite-bearing quartz veins on the Glory Creek gold prospect have returned values up to 2.05 oz/ton Au and are associated with the Kansas Creek stock, a 33 Ma Tombstone Suite granite body. Cannor followed its initial acquisition by staking an additional 22 square miles, covering six additional massive sulfide prospects in the Bonnifield District. Welcome to Alaska!

Toronto-based Fort Knox Gold Resources (no relation to Fort Knox mine) announced plans for a $300,000 phase one exploration program on its Canwell, Fish Lake, and Rainy polymetallic prospects in the Alaska Range. Detailed geophysical surveys are planned for the Canwell and Fish Lake prospects while work at the Rainy prospect will include geological mapping and follow-up on 45 previously defined geophysical anomalies. Fort Knox has retained Inco subsidiary American Copper and Nickel. from whom Fort Knox is earning a 45% interest in the property, to conduct field operations in 1998.

Nerox Energy Corp. is now Nerox Holding Corp., and the company has withdrawn its offer to sell its Jonesville Coal lease near Sutton to London-based Unioil Petroleum. Instead, Nerox has agreed to a change of management and transfer of controlling interest of its stock in favor of Unioil. Company officials indicated development plans for Jonesville would proceed.

**SOUTHEAST ALASKA**

Kennecott (70.3%) and Hecla (29.7%) continued underground operations at their Greens Creek mine on Admiralty Island. First quarter 1998 production totaled 2.1 million ounces of silver at a cash cost of $3.55 per ounce, an increase over the previous year's first quarter due to lower head grades and lower by-product metal prices. The operation also produced 3,993 ounces of gold, 1,412 tons of lead, and 3,574 tons of zinc. Total production cost at the mine during the first quarter was $5.82 per ounce of silver produced. Exploration completed in 1997 indicates significant reserves may be present in the extension of the high-grade Southwest zone. Exploration plans to better define these potential reserves are in progress.

Coeur d'Alene Mines, after a 10-year exploration and permitting period, announced that it has received final permits to begin construction
of the **Kensington** mine near Berner’s Bay. Mine planning studies are under way to reduce operating costs in light of soft metals prices, but mine construction will be delayed until operating economics improve. Current plans call for an underground mining operation designed to produce 200,000 ounces of gold per year from the current reserve of 1.9 million ounces at a grade of 0.10 oz/ton.

**Sealaska Corporation** announced plans to open its **Calder limestone** quarry on Prince of Wales Island later this spring. No details as to production levels or anticipated costs were released.

### NORTHERN ALASKA

**Ventures Resource** reported ongoing acquisition discussions with several parties on its 340,000-acre **Wiseman** property in the Chandalar Copper Belt. The company will benefit from the increase in interest in the area caused by the recent release of airborne geophysical surveys conducted by the State of Alaska and the USBLM.

### OTHER NEWS

The **Dept. of Commerce** has released its preliminary review of 1997 mineral activity in Alaska. State-wide, exploration spending totaled $58 million, $153 million was spent on property development, and production accounted for about $878 million. The combined total of $1.089 billion gave Alaska a record mineral value in 1997.

**Alaska Miners Association** Executive Director Steve Borell reported good progress was made on Alaska Senator **Murkowski’s Mining Reform Bill (SB1102)** during meetings held in late April in Washington. Despite support for the bill, Interior Secretary **Bruce Babbitt** publicized his signing of a patent for 62 acres of mining land on Wake Island in the Tongass National Forest by claiming the land has mineral assets valued at $80 million, whereas the government received $62,000 in patent fees. As usual, Secretary Babbitt did not mention the costs involved in bringing a property through the patenting process or that undeveloped mineral lands are of zero value until they can be brought into production.

### WESTERN CANADA


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### ALBERTA

The front runner in Alberta diamond exploration appears to be **Ashton Mining**, with partners **Pure Gold Minerals** and **Alberta Energy**. The area of interest is the Buffalo Hills district of north-central Alberta, west of Fort McMurray. Ashton has located in
excess of 20 kimberlite pipes of which at least two host micro and macro diamonds. One diamond greater than 1.3 carats is reported from pipe K14, although it is not known if this is a gem quality stone. De Beers, through its Canadian arm, Monopros, has recently joint-ventured adjacent property owned by Troymin Resources.

**BRITISH COLUMBIA**

Misty Mountain Gold is revisiting the Specogna or Cinola gold deposit on Graham Island of the Queen Charlotte Islands. The company has added some appeal to the property by calling it Harmony, but the native people who claim the islands call them Haida Gwai, and might add a dissenting note. Specogna is a hot-spring type, epithermal deposit re-related to hydrothermal breccia. The deposit is situated between the Sandspit fault and a splay to the west known as the Specogna fault: the Sandspit fault forms the western margin of the Tertiary Queen Charlotte basin. Miocene rhyolite has intruded the Tertiary sediments along the Specogna fault. A wedge-shaped, multi-generation breccia zone, about 280 m wide at surface and tapering to 52 m at depth, also developed along the fault as a result of an over-pressured hydrothermal system. Gold and silver mineralization, with anomalous arsenic, antimony, and mercury, is hosted by sediments, breccia and rhyolite. Steeple dipping chalcococic quartz veins contain relatively high-grade mineralization. Pervasive silicification extends east of the hydrothermal breccia and, in turn, is followed by an outer quartzite-ilitic zone. Previous operators had inferred a resource of a few tens of millions of tonnes averaging 1.5 to 2.0 g/t Au.

In the Babine Lake porphyry copper camp, about 20 km north of former producers Granisle and Bell Copper and 220 km northwest of Prince George, Booker Gold is exploring the Hearne Hill and Morrison deposits. Morrison was formerly drilled by Noranda and contains an estimated resource of 190 M tonnes grading 0.4% Cu and 0.2 g/t Au. A resource has not been published for Hearne Hill, although two breccia zones with relatively high grades have been identified, presumably within a broader zone of low-grade mineralization. Drill intersections include 1.7% Cu plus 0.8 g/t Au over a core length of 64 m, and 2.2% Cu over 44 m. Jurassic volcanics and sediments have been intruded by Eocene biotite-feldspar porphyry bodies. Volcanic rocks are mainly Hazelton Group lapilli and crystal tuff, and andesite.

In north-central B.C., Royal Oak has cobbled together enough funds to push the Kenness porphyry gold-copper deposit into production (see Newsletter 28). About 20 km north of Kenness, Stealth Mining is exploring the Pine porphyry gold-copper prospect. Pine is within Jurassic dacite-andesite tuff intruded by coeval, sub-volcanic quartz porphyry. Mineralization at Pine consists of pyrite, chalcopyrite, and trace bornite associated with quartz-sericite-magnetite alteration in broader zones of propylitic-phyllitic-potassic alteration.

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For further information and registration forms, contact:

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CALIFORNIA

Cimarron Minerals has commenced exploration at its Schell Ranch property in Calaveras County. This is a volcanogenic massive sulfide prospect in the Foothills Copper Belt. Previous drilling encountered 17 feet of 0.315 opt Au, 9.782 opt Ag, 3.45% Cu, and 20.5% Zn. Drilling is scheduled to start in early summer.

COLORADO

Sunshine Mining has established a resource of 250,000 tons grading 21 opt Ag, 9.6 opt Au, and 3.9% combined copper, lead, and zinc at the Revenue-Virginius project in Ouray County. Sunshine will require about double the tonnage at those grades before a production decision can be made. Yes, this is small, but I need to report some news for Colorado once in a while.

NEVADA

When we left Great Basin/Cornucopia, John had said to Mars, “We have intersected quartz veins with V.G.; they must be the feeder system.” As we look in on them now, we see that they have assays. “Look, look! The assays prove what I was saying,” said John. “We have found the feeder system to the Ivanhoe deposit in Elko County! See, there is a 33-foot interval that runs 0.152 opt Au, a 10.6-foot interval that averages 4.964 opt Au, and the best one at 4.6 feet with a grade of 11.130 opt Au. Let’s drill more!” Stay tuned for the next episode of As The Drill Bit Turns.

As if they needed more, Franco- and Euro-Nevada Mining Corporations have increased the resource at the Ken Snyder mine, Elko County. The new resource contains 4.0 million ounces of Au and 45.7 million ounces of Ag. The new reserve is 2.1 Mt with an average grade of 1.04 opt Au and 11.65 opt Ag. But that is not all; while drilling the area between the Sleeping Beauty and Snow White veins, two holes cut a new mineralized zone that is three feet wide with grades of 12.91 opt Au - 65.73 opt Ag, and 12.62 opt Au - 80.2 opt Ag respectively. Maybe the new zone should be named after one of the seven dwarfs, since they were miners. Say - Lucky?

In the same area, Romarco Minerals has released the results of 1997 drilling on four properties in the Midas district. Fifty-seven holes totaling more than 61,000 feet were drilled. This work confirms high-grade mineralization along 1.700 feet of strike and a vertical extent of 1,000 feet in the Gold Crown vein over a true thickness of 2 to 10 feet. Romarco has calculated a resource along the Gold Crown vein, two footwall veins, and two hanging wall veins of 743,000 tons with an average grade of 0.51 opt Au and 5.9 opt Ag, at a cut-off of 0.15 opt gold equivalent. Drilling
on the nearby Dixie claims has encountered 15 feet of 6.01 opt Au, and 7 feet of 3.03 opt Au in two separate holes.

Consolidated Nevada Goldfields has decided to place the Aurora mine in Mineral County on care-and-maintenance because of, you guessed it, low gold prices.

Alta Gold is on the move again. They have acquired the Lookout Mountain (tread Ralston Canyon) property in Eureka County. Alta says there are several mineable deposits there, primarily because they have a low threshold as a definition of mineable ounces. At Olinghouse (Washoe County), permitting is completed and construction is scheduled to start this summer. The Olinghouse announced proven and probable reserve is 500,000 ounces of gold with an average grade of 0.042 opt Au.

Newmont Gold Co. is moving forward on two underground projects on the Trend. You know, that geologic feature that every junior’s project in the world is on strike with. Shaft sinking is planned this year for the Goldbug/Deep Post, which is just north of the Bettez-Post open pit. An EIS (which is government for Employment Insured) has been started at the Leeville deposit.

The Kinross Gold Corp. (operator) Exploration Mirador Inc. joint venture is planning another round of drilling on the Railroad project, Elko County. The venture covers about 55 square miles at the southern end of the Carlin Trend. Drilling during the last couple of years has produced significant results and has identified several zones of mineralization. Some of the more significant results are in the POD area where 260 feet of 0.043 opt Au and 170 feet of 0.074 opt Au were encountered. At Bunker Hill, 60 feet of 0.125 opt Au, and 25 feet of 0.139 opt Au were drilled. At Elliot High Ranch, 335 feet of 0.023 opt Au, and 185 feet of 0.020 opt Au are some of the better zones. All of these intercepts are near surface.

OREGON

Tombstone Explorations has completed a drilling program at Grassy Mountain, Malheur County, to test the high-grade Bonanza zone. Past drilling suggests that the zone averages 80 feet in width and is 600 to 750 feet below the surface. Intercepts in holes previously drilled average more than one ounce of gold per ton of rock, representing a resource of more than 900,000 oz. of gold. A geophysical survey indicates that the zone may still be open, and therefore a new drilling program is planned to test this concept.

SOUTHWEST UNITED STATES AND NORTHERN SONORA

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A unemployed exploration geologist casts a weary eye toward the bleak horizon beyond Tucson, listening wistfully for the soothing whir of a Shramm 685 or a Longyear 44. She waits; she listens...
What's that? Listen! Could it be? Have heart ye intrepid explorers, JABA Inc. has turned a deal with Cyprus, of all companies, and they are making cuttings west of Silver Bell in search of a covered porphyry copper deposit. And east of Silver Bell, Valerie Gold Resources has joint-ventured with JABA to explore another porphyry copper target buried beneath pediment gravels. Throughout the land, minerals exploration marches on: Republic Goldfields turned the Congress cash for a quarter million. Silver Eagle Resources Ltd. is still sparring with Bannocate U.S. for potential profits at Three R: Marum Resources should be drilling soon at their Mildred Peak target southwest of Tucson; Minera Frisco has taken Cominco out at Maripulta, Sonora; Grupo de Mexico continues to sweep marbles toward their corner at Cananea and La Caridad by buying up Union Miniere and accumulating stock in ASARCO; Phelps Dodge, reeling like a pit bull to yard intruders, recently swallowed Cobre Mining's Continental Mine near their Chino operations in New Mexico; and BHP's joint venture with AMT International at Copper Creek is expected to enrich mill feed across the valley at San Manuel a wee bit by virtue of a 11.4-million-ton reserve of 1.3% Cu. Brushing aside pink slips and severance negotiations, BHP geologists managed to drill two porphyry copper targets in Arizona and two in Mexico this spring.

Newmont established digs in Tucson; opportunists from Canada have been passing through town looking for bargains; Lowell Exploration has been keeping the Arizona State Lands Department hopping, recording new mineral leases; and silver-flushing Peñoles acquired Milpillas in Sonora from Cyprus. Speaking of Peñoles, why are they drilling 12-meter holes at Humo? No announcement yet out of BHP about their copper oxide discovery at this site. Unfortunately, it's low-grade and under a thick wedge of rock.

The harsh thud of Phelps Dodge's exploration doors slamming shut fingers still, a haunting echo in the ears of BHP geologists who recently greeted their own angel of doom as she descended on the office, laying waste to half the staff and 60% of the budget. The carnage among BHP's Mexico staff was much worse. And across the street, Teck Resources, Echo Bay, Cominco, Cambior, and others have scurried for shelter like tennis fans under a cloudburst.

Adelante! Atrás! Adelante! Atrás! Watch out for that pendulum: it's got a big ugly blade on it, dripping fresh blood. What a career: laid off three times, quit a couple of times, and outright fired twice. How about you? You say you've been laid off twice and quit twice? Even after ten years of college and three degrees? Heck, you're only 33! Do we love this profession or what? Why else endure destructive, wasteful reorganization cycles to achieve the short-sighted objectives of slightly improved balance sheets. (And they say the majors and the juniors are different.) I heard the Area Manager of a major company address his decimated staff the other day, acknowledging the hardship the cyclic downsizing—build up—downsizing has on people. Ahhh, that little-heard word, people! Personal, isn't it—people? (Usually it's Personnel, employees, or human resources.) He went on to
point out that these cycles cause long, destructive, and wasteful retrenching every few years. Furthermore, he stated, they are counterproductive and unnecessary (Did I hear, unnecessary?).

Imagine for a moment sustainable exploration budgets, reflecting some level of consistency without the knee-jerk convulsions, subsequent to fluctuations in metal prices, that send budget numbers tumbling, destroy exploration programs, and sate the dreams of employees and families. What a novel idea! A new dawn of sanity will emerge, brave hearts. Why? Because the health and productivity of the mining industry is at stake. Not to mention the betrayal of trust, dedication, and expectations of the line employees—those who make a company run. (Talk about biting the hand...)

With Cyprus, BHP, and Inspiration facing a possible $100 million Superfund clean-up bill at Globe, and ASARCO forced to spend $68 million to improve water quality in Mineral Creek near Ray, where water quality in the stream was probably worse than before open-pit mining began, it’s no wonder that American companies are treating the United States like a first-century leper and looking elsewhere for exploration and mining opportunities.

Copper deposits have been sequestered like the ore reserve equivalents of inactive homicide files, waiting for new leads or an exuberant champion. ASARCO read the tea leaves at Rosemont and postponed a dubious development project they admitted would require 20 years to first metal production due to extreme baseline requirements and vociferous environmental war. Both ASARCO and BHP have canceled or at least postponed their in situ developments at Casa Grande and Florence, respectively, stalling the advent of environmental-conscious in situ production and low operating costs many had hoped would open the door to a politically-friendlier future. (Teetering in gusty political winds, environmental war master President Clinton capitulated to unknown forces and vetoed federal funding for Casa Grande last year.) BHP announced a 1,000-foot intercept of 1.75% copper beneath a mile of overburden near their Superior operation and in the same breath, proclaimed pumps would be yanked and the newly discovered treasure allowed to sink into the murky deep. The Cyprus Lakeshore operation became a tax write-down in spite of hundreds of millions of tons at 0.74% copper. Production from the sulfide portion of BHP’s Pinto Valley mine was suspended due to low copper prices. And amidst this mess, the overall economic impact of copper on Arizona rose to nearly $10 billion/annum in direct and indirect benefits last year.

The Mexican Hat gold resource is still treated like a bad date at the prom, most recently passed off by Kalahari Resources to any and all takers. Phelps Dodge is reputedly disenchanted with the Hay Mountain gold prospect, southeast of Tombstone. Add the Gold Road on the bench for the rest of the season due to low gold prices. And Cambior, the biggest heartbeat of all, was forced to postpone development plans at Carlotta. Grupo de Mexico was handed a $200 million tab by the citizens of Naco to free taxes, payments, or whatever. Seems the company has been ignoring some incidental property payments over the years. My, how it mounts up! (You can pay me now or you can pay me later.)

Appropriately, employees of the Arizona Department of Mines and Mineral Resources are not allowed to have opinions—Judge Donald F. Daughton has said so. In a lawsuit filed by International Precious Metals against the department and a couple of its professionals, the judge ruled that these naughty boys should stay after school. Maybe they should write on the blackboard 100 times: “I will never have another opinion,” or “I’m sorry, your honor! I performed honest work on an alleged platinum occurrence in my home state and then objectively and unabashedly revealed my
findings!” Ohhh, the shame of it all! And if that weren’t bad enough, this recalcitrant wild bunch talked about it! I don’t know what you think, but weren’t they just doing their jobs?

The air of doom and gloom lies over the office these days like a thick-pile carpet layered with compost.

“Think I’ll stay home tomorrow, Dear. Maybe we’ll go to the lake.”

“What’s that you say. Honey? You’ve been laid off again? Uh-oh, you’re 54, and you’ve yet to be with a company long enough to vest! Oh well, let’s go for a walk. It’s a beautiful night. Maybe we’ll catch a video later.”

Thank God for understanding spouses. Do we love this profession, or what?

GHANA, WEST AFRICA

Regional Correspondent: Henry Appiah
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Touringan Ghana Ltd. has completed 71 holes comprising 10,147 m of diamond drilling at the Riyadh Concession in the prolific Ashanti gold belt near Wassa Akropong, Western Region, Ghana. Auriferous quartz veins occur in shear zones of tightly folded Lower Binnman (Lower Proterozoic) carbonaceous phyllites. Five geochemical anomalies have been located on the structurally-similar and parallel “Pamp” shear. Three of the anomalies have been drilled, indicating approximately 6,975 kg of gold in 1,180,000 tons of ore having an average grade of 5.9 g/t over an average vein width of 2.15 m.

International Tournigan Corporation of Vancouver, Canada, is seeking a partner to continue drilling. William Vanderwall (SEG 1992), VP Exploration, explains that the gold occurs in vertically elongate pods and that drilling to date has been generally less than 100 m deep, leaving all targets open at depth. The pods occur regularly—like gold “ornaments” on a string—at 500- to 700-m intervals. The “ornaments” typically are 200 m in strike-length, with the intervening string composed of barren quartz. Drill targets selected so far have been the three potential mineralized zones closest to a local road(), with future drill sampling expected to test additional targets of similar lithologic and structural setting.

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"In Praise of Understanding Ore-forming Processes"—A Reply

BY MIKE SOLOMON AND KHIN ZAW

In his interesting article in SEG Newsletter no. 32, p. 19-20, John Lydon considers the various pitfalls that await the scientist undertaking model-driven research, and cites the reinterpretation of the significance of some barite veins in the Hellyer VMS deposit by Solomon and Khin Zaw (Economic Geology, v. 92, p. 886-895) as an example of scientific argument that, among numerous other faults, "propagates false conceptions of the process." This grievous imputation calls for a response from the impugned, as well as some discussion of scientific thinking.

In the case of the Hellyer orebody, Solomon and Khin had before them data from two major papers: one focused on the vein paragenesis in the feeder pipe beneath the massive sulfide (Gemmell and Large, 1992), the other on fluid inclusions from these veins (Khin Zaw et al., 1996), as well as other papers and these concerning various aspects of the overlying massive sulfide ore. Accepting that the feeder-zone papers provide reliable information on the nature and history of the original ore fluids, the indicated temperatures and salinities allow us to deduce that the vein fluids would have been negatively buoyant on entering seawater, or would have reversed buoyancy after mixing with seawater. The fluids would thus have ponded in any basins present on the sea floor.

Hellyer is so far the only VMS deposit from which such fluid inclusion data have been obtained, although similar hypotheses for various VMS ores have been put forward by a number of workers over the last 25 years, mostly to explain various geological and morphological features of individual deposits (e.g., Sato, 1972; Green et al., 1981; Campbell et al., 1984; and Solomon and Groves, 1994). These proposals were developed along the lines suggested by Karl Popper (1935), i.e., put forward as conjectures that could be tested or falsified. Few of us believe we are ever approaching the "absolute truth" of Lydon (p. 19), but some hypotheses stand up to testing better than others and thereby persist. So far, the ponding hypothesis for Hellyer is doing pretty well. The kimberlote models postulated for the formation of the Hellyer massive sulfide ore on the sea floor were derived by induction, attempting to use the experience of the massive sulfides of the Hokuriku Basin to explain the formation of the Hellyer deposit. However, this line of argument, often employed by geologists, involved playing down the significance of several prominent features of the Hellyer orebody.

With this preamble, we come to the matter of the barite veins. Because the reduced ponded ore fluids at Hellyer would have cooled rapidly, mineral precipitation is likely to have involved sedimentation in the pond, with younger precipitates largely overlying and onlapping older. A layer of barite directly and conformably overlying the massive sulfide and its apparent younger age is supported by two features, viz. (a) the latest ore-forming veins in the feeder pipe are dominantly barite, having the same sulfur isotopic signature as the overlying barite, and (b) similar barite veins with the same isotopic composition (Sharpe, 1991) cut the intervening massive sulfide ore over parts of the feeder pipe. We acknowledge that the matter of the barite veins in the massive sulfide could have been spelled out more clearly in the paper, but find these arguments still sound and not model-dependent. The conclusion that the ore fluids increased their sulfate content late in fluid history does not in fact "run counter" to earlier suggestions that in dominantly felsic volcanic terrains the supply of reductants may be inadequate to reduce all the aqueous sulfate during the entire history of fluid circulation (Green et al., 1981; Solomon et al., 1988). We did not discuss the relevance of the seawater convection model for Hellyer, as Lydon suggests (p. 19, para. 1), though one of us (MS) has in another paper suggested some ideas for generating the saline fluids (APIMINERAL Conference Proceedings, Lisbon, 1998).

In conclusion, we submit that we have erected a genetic hypothesis concerning the formation of the Hellyer orebody on the sea floor based on deductions from fluid inclusion data, and that there are several features of the orebody that support this hypothesis. We propose, with the help of the staff of Aberfoyle Resources, to carry out further tests of predictions that follow from the model (e.g., more detail of "stratigraphic" metal and mineral variations, and thermochronal calculations), the aims of which are to improve or discredit the hypothesis.

REFERENCES


"In Praise of Understanding Ore-forming Processes"—Reply to Solomon and Khin Zaw

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I am sorry that Solomon and Khin Zaw feel grievously impugned by my contribution to the Commentary column of SEG Newsletter No. 32. Perhaps some of their anguish derives from misunderstanding the context of the article. As the reader may or may not know, the idea behind the relatively new Commentary column is to use a current article published in Economic Geology as a focus or starting point for further comment or ideas that have practical application to mineral exploration. The commentary is not meant to be a critique of the paper. The editor of Economic Geology chooses both the article and the commentator.

An aspect of Solomon and Khin Zaw's paper (Solomon and Khin Zaw, 1996) that caught my attention was their interpretation that the VMS-type Hellyer deposit is a product of hydrothermal brine pool sedimentation (as opposed to the currently popular model of a mound-chimney edifice over the discharge vents of a seawater convection cell). I contrasted their favorable approach, which formulated a genetic model by a rationalization of some actual features of the deposit, rather than following the tendency to try to fit the facts to a model that is in vogue. This concurrence inspired my discussion on the importance of understanding the processes involved in ore genesis in order to end up with a valid exploration model.

I don't think that most readers would interpret the negatives I mention for model-driven interpretation as applicable to Solomon and Khin Zaw's paper (paragraph 1—Solomon and Khin Zaw reply). The one reference to their paper that I did use (their conception that the chemistry of the ore forming fluid changed from low oxidation potential-sulfide stable to higher oxidation potential-barite stable) was cited as an example of "ascertaining capabilities to a process that it simply does not have, and in doing so propagates false conceptions of the process." I still think that this statement is valid, though Solomon and Khin Zaw's paper itself would not inspire the statement.

It has been known for a long time that the chemical composition of natural hydrothermal fluids is controlled by temperature-dependent equilibration with mineral assemblages of the hydrothermal reservoir, and that this characteristic is so consistent that the chemical composition of the fluid can be used as a fairly accurate geothermometer for the reservoir zone (White, 1970). pO2 is buffered by ferrous-ferric mineral assemblages, sulfide assemblages or carbon-bearing compounds. Fluids from the same reservoir will therefore have constant compositions, varying only gradually with fluctuations in temperature, pressure and independent chemical components as such as chloride, as predictable from mineral-solution equilibria curves and chloride-complexing equilibrium constants. A sudden major change in the chemical nature of the fluid must be considered abnormal for a natural hydrothermal fluid generated in a single reservoir. To my knowledge there is no pO2-buffering mineral assemblage that transgresses the boundary from the H2S-dominant field to the SO4-dominant fields as the temperature decreases from 300°C (the average temperature of Stage 2B sulfide veins) to 250°C (the average temperature of Stage 2C barite veins). A hematite-magnetite buffer might serve this purpose if the pH also changed from about pH 7 at 300°C to about pH 2 at 250°C, but this radical pH change would also require a radical change in the silicate mineralogy of the reservoir rocks. This is what I mean by my remark that Solomon and Khin Zaw's (1997) assertion of a radical change in the oxidation potential of the ore fluid between filling of Stage 2B veins and the filling of Stage 2C veins "appears to run counter to the understanding that the chemistry of a natural hydrothermal fluid, including its oxidation potential, is buffered by equilibration with mineral assemblages of the reservoir rocks" (Lydon, 1998, p.19).

In their Reply, Solomon and Khin Zaw cite earlier suggestions in Solomon et al. (1988), that in felsic volcanic rocks the reductant supply may eventually become exhausted by reaction with oxygen-bearing recharge fluids, so that later hydrothermal fluids have a higher oxidation potential than early fluids at their discharge vents. The citation is actually a suggestion by Green (1983) who calculated that a rhyolite with an FeO content of 1.2 percent could become depleted in FeO when the flow-through of seawater reaches an effective water/rock ratio of 14:1. I agree that the depletion of reductants is conceptually possible, and hence is a permissible line of argument. As long as the reader understands that it is only a suggestion or a speculation, then no damage is done. However, if reductant depletion does not normally take place in natural hydrothermal systems, then the concept is false and should not be used in realistic genetic models of ore deposits. Great care should be therefore taken not to propagate what was originally only a suggestion in terms that may be taken as a validated hydrothermal process. For greater understanding, the suggestion should also perhaps be coupled with some of its relevant repercussions. For example, most copper and zinc in igneous rocks are contained in ferrous-containing minerals or sulfides, whereas most barium and lead are contained in K-feldspar, or in the fine-grained groundmass (Stanton, 1996). If all the ferrous-containing minerals are destroyed by hydrothermal flow-through of a saline fluid, then in all probability the rock will also have been leached of its copper and zinc content. Similarly, it is quite likely that the K-feldspar and matrix would have largely been albited before reductant depletion by the highly saline brine (presumably NaCl rich) envisaged for Hellyer, with the resultant loss of barium and lead from the rocks. In other words, by the time ferrous-bearing minerals of the reservoir rocks have been oxidized by hydrothermal flow-through, the reservoir rocks will also likely have been leached of their ore metal content and therefore incapable of supplying any more ore-forming metals.
In the case of the Hellyer deposit, the reductive depletion hypothesis does not explain why the stage 2C barite veins and the barite cap have such heavy sulfur isotope values of 34 to 50 per mil. Solomon and Khin Zaw (1995, p. 693) ascribe these heavy values to partial reduction of seawater sulfate during cycling, presumably through the subsurface. If there are sufficient reductants in the subsurface to reduce sulfate to sulfide, it means a pO2 buffer within the sulfide stability field was operating. Because fundamentally the same mineral assemblages, though in different proportions, occur in the 2C veins (barite, pyrite, galena, sphalerite) as in the 2B veins (pyrite, sphalerite, galena, barite, chalcopyrite, sulfosalts), Gemmell and Large (1992), the pO2 of both veins, and hence the nature of the pO2 buffer in the reservoir zone, were probably the same. In other words there was likely no increase in the oxidation potential of the ore fluids at the beginning of Stage 2C. Following the adage that the best models explain the most features, there would seem to be room for modifying Solomon and Khin Zaw’s model.

To return to the remaining issues brought up by Solomon and Khin Zaw’s Reply:

I used the term “absolute truths” (Solomon and Khin Zaw Reply paragraph 2) in the sense of incontrovertible fact. For example, a few absolute truths about the Hellyer deposit seem to be that the sulfide portion of the deposit is overlain by a barite cap; the main infilling of some veins is barite; and that the sulfur isotope ratios of barite in both cap and veins are about the same. In contrast, Solomon and Khin Zaw’s reference to Pother (1935) appears to use “absolute truths” in the context of intellectual concepts. In this context, I would have to agree that an absolute truth becomes more a matter of faith than verifiable fact.

As I implied in my Commentary, to any one fact there are many permissible interpretations. A case in point is the assumption that the law of superposition is applicable to hydrothermal sediments lying above their discharge vents (Solomon and Khin Zaw Reply, paragraph 3). An upwards and outward zonation of increasing Ba/(Fe+Zn+Pb) ratios, culminating in a barite cap and fringe to the sulfate-dominated portion of the deposit is a common feature in Sedex and VMS-type deposits. This stratigraphic and lateral segregation into a barite-rich facies is most commonly interpreted to be the result of a zone refinement process that redistributes the components of the original metalliferous sediment (e.g., Lydon, 1996). Subsurface diffuse flow of hydrothermal fluids away from the focused upflow channels forms in effect a subsurface diapir of hydrothermal fluid which rises through previous deposited hydrothermal precipitates. If this fluid is in reduced state (as it must be in a sulfide-precipitating system), barite will be dissolved from the subsurface and the barite re-precipitated near the sediment/water interface when it reacts with downward diffusing sulfate of the overlying water column. Similarly, older veins can likewise be depleted of an original barite filling by the later flow-through of reduced hydrothermal fluids. In other words, the appearance that most of the barite is paragenetically or stratigraphically late does not necessarily comment on the chemical evolution of the primary ore fluids.

I would like to take this opportunity to thank Solomon and Khin Zaw for the opportunity for this brief discussion, and also to publicly congratulate them on their article. I had the privilege to read their manuscript as a pre-publication version and I hope that some of the very creative ideas and concepts expressed in that version will also appear in published form in the future.

REFERENCES


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To participate, please respond with a tentative title no later than August 1, 1998 to:

DIANE WOLFGRAM
Dept. of Geological Engineering
Montana Tech, Butte, MT 59701
Dwolfgram@pol.mtech.edu (406) 496-4353

* The late Donald H. McLaughlin, a distinguished alumnus of the University of California, Berkeley, was Chief Geologist at Cerro de Pasco and of the Homestake Mine, Professor of Mining Geology at Harvard University, and Dean of the College of Mines and of the College of Engineering at Berkeley before becoming Chairman of the Board and CEO of Homestake Mining Company; a position he continued to hold emeritus until his death in 1981.
19th International Geochemical Exploration Symposium
APRIL 11-16, 1999 • HOTEL VANCOUVER • VANCOUVER, BC, CANADA

This symposium will be the last major Geochemical Exploration meeting of this Century. In keeping with the theme, Exploration Geochemistry into the 21st Century, the conference will aim to stimulate and disseminate new ideas and innovations.

If you would like to receive more information, please complete the Reply Form and mail or fax the IGES Secretariat Office.

TECHNICAL SESSIONS
Technical Sessions will be held on April 12-13, 15-16. April 14th will be a mid-symposium break to give delegates and guests the opportunity of enjoying the many attractions offered by Vancouver and the surrounding area.

Topics include:
- Integrated exploration case histories — discoveries and disappointments
- Search for concealed deposits (including diamonds)
- New sampling methodologies at all scales
- Data presentation & interpretation
- Analytical methods (including quality control)
- Lithogeochemistry
- Envirogeochemistry related to the minerals industry

Anyone interested in submitting a paper for the 19th IGES should complete the Reply Form for more information. Deadline for Abstracts is October 1, 1998.

SHORT COURSES
Short Courses will take place April 10 - 11th before the symposium.

FIELD TRIPS
Field trips will take place after the meeting, starting April 17th. The field trips are intended to complement short course and technical session themes by providing applied demonstration of methods and interpretation.

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Techniques in Hydrothermal Ore Deposits

JEREMY RICHARDS (SEG 1985) and PETER LARSON (SEG 1986)
University of Alberta • Washington State University

SEG is sponsoring a two-day short course, "Techniques in Hydrothermal Ore Deposits," in conjunction with the GSA Annual Meeting in Toronto, Saturday and Sunday, October 24–25.

Modern geochemistry has produced many techniques that are applicable to the study of hydrothermal ore deposits, and these have been used to determine everything from the age of mineralization to the sources of hydrothermal fluids. However, the results of such studies are too often overlooked as being of "academic" interest only. The course aims to lift this veil, by showing that many of the methods are in fact quite straightforward, and by providing a basic understanding of data interpretation. The course is designed for the end-user, and will provide a grass-roots understanding of these techniques and how they can be applied in real systems. The presenters will start with the basics of their specialties, and work through hands-on applications. The course is designed for anyone with a beginner's interest in modern techniques, and will provide a foundation for pursuing applications beyond the course.

The Short Course Volume will be available by the time of the meeting. The Volume's chapters and authors correspond to the Short Course presentations (the Short Course presenter is shown in italics):

1. The Thermodynamics of Hydrothermal Systems: Greg Anderson
3. Calculation of Activity-Activity and Log pO2-pH Diagrams: Scott Wood
4. Magmatic Contributions to Hydrothermal Ore Deposits: An Algorithm (MVPart) for Calculating the Composition of the Magmatic Volatile Phase: Phil Gandello, Phil Piccoli
5. Modeling of Geochemical Processes in Hydrothermal Systems: Mark Reed
6. Fluid Inclusion Techniques of Analysis: Tom Shepherd, Andy Rankin
7. Fluid Inclusion Modeling for Hydrothermal Systems: Phil Brown
8. Introduction to Stable Isotope Applications in Hydrothermal Systems: Andy Campbell, Peter Larson
10. The Influence of Geochemical Techniques on the Development of Genetic Models of Porphyry Copper Deposits: Jeff Hedenquist, Jeremy Richards

The cost of the course for SEG members is $390 per person; for non-members, $539 per person, and for certified students, $200 each. Price includes the short course volume and coffee breaks. Payment may be made by check or credit card – accept VISA, Mastercard, American Express and Discover. Please provide credit card type, number and expiration date below. Include your name, address, telephone, fax, and email.

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Please submit registration information and payment to: SEG 1998 Techniques Short Course • 5808 South Rapp Street, Suite 209 • Littleton, Colorado 80120 • Tel: +1.303.797.0332; Fax: +1.303.797.0417 • Email: socceconegol@csn.net

PET98 seeks to bring to international attention the importance of the Pacific as a region for mining exploration, the exciting new developments taking place in Pacific mining today, and the challenges that face the region. The meeting is relevant to all involved in the mineral sector and geoscientists interested in economic geology and mineralization in the Southwest Pacific. It will focus on new science, technology and new frontiers in Pacific mineral exploration and development, with invited speakers, industry representatives and government researchers highlighting:

- world-class orebodies and new discoveries in the region,
- development of conceptual models in regional geology and metallogeny,
- technological developments including remote sensing, data handling and prospecting techniques,
- the interrelationships between mining, society and the environment.

Presentations, posters and workshops will encompass new airborne geophysical data sets, case studies of major deposits and exploration successes in the region, and research results applicable to regional prospectivity assessments. Pre- or post-conference field trips to the significant deposits in Fiji—the Tuvatu gold prospect and the 8 Moz Emperor Gold Mine—will complement and amplify the meeting presentations.

An abstracts volume, including maps, will be available at the meeting and selected papers will be considered for publication in Economic Geology. Registration fees are within the lower part of the range for international meetings. Deadline for submission of titles of papers, May 15th and for abstracts July 31, forwarded to the address below.

To receive further information, please complete and fax, or, post the form below to:

PET98 Secretariat, SOPAC - South Pacific Applied Geoscience Commission, Private Mail Bag, GPO, Suva, Fiji. Email: belen@ sopac.org.fj Fax: (679) 370 040 Tel: (679) 381 377 or visit the PET98 web site at http://www.sopac.org.fj/pet98/

Registration fee is $300 Fijian or $US150; includes traditional Fijian welcome ceremony, lunch 23rd to 25th, morning and afternoon tea 23rd to 25th, cocktail evening 23rd, buffet dinner and meke (Fijian dance and song) 25th, abstract journal, morning and afternoon speakers 23rd to 25th and Fiji Aeromagnetic Workshop 25th. Guests of conference attendees fee is $150 Fijian or $US75; programme to be arranged. The registration fee will be waived for certified students on proof of student status (does not include abstract volume).

☐ Tick this box if you are interested in submitting a paper for the conference.

Subject of paper: __________________________________________________________

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Early registration is advised as places are limited. A processing fee of $20 Fijian will apply to all cancelled registrations. No refunds will be made after September 22nd 1998. Cheques to be made payable to PET98 Secretariat.

☐ Tick this box if you would like to receive Fiji resort and tour information. Fiji is an international tropical holiday destination, with a wide variety of resort accommodation for all budgets. The weather in September can almost be guaranteed to be superb, the beaches, diving, snorkelling are breathtaking so why not combine work with pleasure?
This publication, edited by Donald E. Sangster (SEG 1973), comprises 50 papers that were presented orally or as posters at the Society of Economic Geologists International Field Conference on Carbonate-Hosted Lead-Zinc Deposits, held in St. Louis, Missouri, June 3-6, 1995. The volume honors SEG's 75th Anniversary and is dedicated to Ernie Ohle.

DIVIDED INTO 8 SECTIONS:
1. Special Contribution by Ernie Ohle
2. District or Thematic Overviews (20 papers)
3. Deposit Descriptions (6 papers)
4. Paleohydrology/Fluid Flow (7 papers)
5. Ore Fluid Chemistry (3 papers)
6. Dating of Mineralization (6 papers)
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8. Practical Aspects—Exploration and Mining (3 papers)

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- Fluid flow dynamics in relation to deposits in the Upper Mississippi Valley, southeast Missouri, Tri-State, southern Appalachians, and in regions of continental extension such as France.
- Ore fluid chemistry; ore fluids derived from evaporated seawater, the solubilization of lead and zinc in basin brines, and constraints on the genesis of high-temperature carbonate-hosted Pb-Zn-Ag deposits.
- Three different methods of dating carbonate-hosted lead-zinc deposits
- Mineralogy of MVT deposits in the southeast Missouri Viburnum Trend, USA.
- Bioleaching of east Tennessee ores, oxidation processes in ore tailings in Russia, and lithogeochemical exploration methods in Spain conclude the volume.

Available for $60 (includes U.S. surface mail; other countries add $5 per book ordered).
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# Membership Application

Membership in the Society is open to all geoscience graduates holding the bachelor's degree. Student Members must be full-time students. Annual dues for 1997 are US$85 for Members and US$42.50 for Student Members. Subscriptions to Economic Geology, the quarterly SEG Newsletter and SEG Membership Directory are included in the membership. Application may be made by completing this form and submitting it with the appropriate sponsor signature to Society of Economic Geologists, Inc., 5808 S. Rapp St., Suite 209, Littleton, CO 80120, USA, phone: 303-797-0332; fax 303-797-0417

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Practical Application of Exploration Geochemistry. S. Amor and L. Bloom, PDAC ‘98 short course. PDAC, 34 King St., East, 9th Floor, Toronto, Ontario, Canada MSC 2X8, Fax +1.416.362.010. CS50 plus postage—accept VISA.

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GUIDEBOOK VOLUME #29
Geology and Ore Deposits of the Quirkir and Wasatch Mountains, Utah: David A. John and Geoffrey H. Ballamhne, Editors; 1997 (revised 1998), 208p., 19 colored figures, 2 oversized color plates (in pocket); US$40.

The revised edition of this blockbuster guidebook, prepared for the SEG Field Conference held in Salt Lake City on October 24–26, 1997, has just been released. The volume, now in a 2-volume, bound format, includes 15 new geological papers reflecting the three one-day segments of the field trip: (1) intrusions of the central Wasatch Mountains, (2) the Bingham Canyon porphyry copper deposit, and (3) the Melco gold deposit and the Pb-Zn-Ag halo of the Bingham copper deposit. Much new research, presented at a half-day symposium prior to the field trip, is incorporated in the guidebook. Detailed road logs, together with new descriptive material, including oversized color plates (prepared by Kenneally), are included.

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Oct 19–24, Gold Deposits of Northern Sonora, six-day field conference, Tucson, Arizona and Northern Sonora Mexico. Kenneth F. Clark, Tel. +1.915.747.5843, Fax +1.915.747.5073; email: <clark@geo.utep.edu> (See announcement p. 45 this issue.)

SEG pre-meeting short course “Techniques in Hydrothermal Ore Deposits” (see announcement p. 46 this issue), research symposia “Voisey's Bay Ni-Cu-Co Deposit” and “La de Gras Diamonds” (full day), and two days of technical sessions. For registration information, see p. 22 this issue.

Mar 1-3, 1999, SEG Annual Meeting with the Society for Mining, Metallurgy and Exploration (SME), Denver, CO. For information contact: Donald Thompson, BHP Minerals, 1157 Cole Blvd., Ste. 250, Golden, CO 80401, Tel. +1.303.235.4414, Fax +1.303.235.4435, email: <don.thompson@bhp.com.au>

OTHER EVENTS

Oct 13–18, 1998, III Seminario Minero Sonora 2000, “Mining Development of México in the XXI Century”, Hermosillo, Sonora, México; sponsored by the Sonora Chapter of the Association of Mining, Metallurgical and Geological Engineers of México (Technical sessions and pre-meeting fieldtrip “Gold of the Desert” and “Copper of the Sierra”). Mario Campos, President of the Chapter, Calafia #73, Col. San Benito, Hermosillo, Sonora, México. Tel. +011.52.62.105510, Fax +011.52.62.141666, email: <fquerol@rtlnuson.mx>

Oct 20–23, Focus on Industrial Minerals 1998, Sheraton Wall Center, Vancouver, B.C., Canada. Canadian deposits markets, bulk transportation and investment opportunities. Contact: S. Dunlop, CEO, University of Victoria, P.O. Box 3055, Victoria, B.C., Canada, V8W 3P6, Fax +1.250.472.4100; email: sdunlop@uvic.ca

Nov 16-20, Fifth Annual African Mining Investment Symposium and Arab Mining Investment Symposium, Marrakech, Morocco. Sponsored by MIGA (World Bank). Field excursions before and after symposium. For information contact Ms. S. Persaud, MIGA, Washington, D.C., Fax +1.202.322.2650; email: spersaud@migawbg.org

Nov 29-Dec 4, Northwest Mining Association 104th Annual Meeting and Exposition, Spokane, WA. For more information contact: Hazel Hoelt, Northwest Mining Assoc., 10 N. Post St., Ste. 414, Spokane, WA 99201, Tel. +1.509.624.1158, Fax +1.509.623.1241, email: hhoelt@nwma.org

May 26-28, 1999, Geological Association of Canada—Mineralogical Association of Canada, Joint Annual Meeting, Sudbury, Ontario. Contact: Dr. P. Copper, Dept. of Earth Sciences, Laurentian University, Sudbury, Ontario P3E 2C6, Tel. +1.705.675.1151 (ext. 2267), Fax +1.705.675.4898, email: <gacmac99@mickle.laurentian.ca>

Aug 22-25, Society for Geology Applied to Mineral Deposits (SGA) 5th Biennial Conference. "Mineral Deposits: Processes to Processing," Imperial College/Natural History Museum, London. Contact: Dr. Chris J. Stanley, Associate Keeper of Mineralogy, Department of Mineralogy, Natural History Museum, Cromwell Road, London SW7 5BD, UK, Tel. +44.171.938.9361, Fax +44.171.938.9268, email: cjs@nhm.ac.uk