Late timing for high sulfidation cordilleran base metal lode and replacement deposits in porphyry-related districts: the case of Colquijirca, central Peru*

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1Section des Sciences de la Terre, Université de Genève, Switzerland and 2Sociedad Minera El Brocal S.A.

Introduction

"CORDILLERAN base metal lode" deposits (Einaudi, 1977 and 1982) or "cordilleran veins" (Sawkins, 1972) depicted as parts of the upper construct of porphyry copper systems, have the following main characteristics (e.g., Einaudi, 1982): (i) high sulfidation state of the mineral assemblage with associated advanced argillic to sericitic alteration, (ii) strong zoning from Cu cores to external Zn-Pb(Ag) ores, (iii) massive texture and sulfide content of up to more than 50% in volume, considerably higher than in other porphyry-related ore type, and (iv) basically a common suite of enriched metals, that is, Cu-Zn-Pb(Ag-Au).

We are pleased to announce that several changes are being made to *Mineralium Deposita*. These changes include:

**Volume increase to 1000 pages per year**

In order to maintain a relatively short time between acceptance of an article and final publication in *Mineralium Deposita*, Springer-Verlag and SGA Council agreed to increase the number of printed pages per year from 800 to 1000 pages. This change reflects the continued increase in the number of manuscripts submitted to *Mineralium Deposita* for possible publication. We now receive about 100 papers per year, of which about one third are accepted for publication. Each year we also publish one to three thematic issues that contain invited papers.

The current backlog of papers waiting to be printed is about eight months. These papers are available electronically and accessible via the Springer online service.

**Color plates**

Springer announced a new policy and pricing schedule for color plates. A flat rate of 485 EUR (approximately 440 USD) is now charged per article for as many color illustrations as necessary. Members of SGA can request that the charge for color plates be waived. However, the decision to waive these charges resides with the Chief Editors. It should be noted that only one article per issue can have free color illustrations.

**Subsidized journal subscriptions**

SGA Council will grant a limited number of free subscriptions of *Mineralium Deposita* to institutions and, under special circumstances, to individuals in an economically challenged position. The grant period is for two years. The informal written request for such free subscriptions should be addressed to the Executive Secretary (Dr. Jan Pasava, Czech Geological Survey, Klárov, 11800 Prague 1, Czech Republic) outlining the need for the free subscription and how the journal will be used. This letter must include the names of two SGA members who are willing to support this request.

**Springer online**

All journal subscribers have access to the Springer online system on which you can read all issues of *Mineralium Deposita* printed since 1997, plus the *Electronic supplementary material*, and the electronically published manuscripts currently in print. Access requires registration with the Springer LINK system at <http://link.springer.de/helpdesk/helpoder.htm> using your subscription number which is written on the mailing label of the Journal. The subscription number consists of seven digits, a slash, followed by two digits, such as 0123456/05. If the first number has less than seven digits, add the corresponding number of zeros in front. You will receive a personal access code and password by e-mail within two days.

**Missing issues/address change**

Address changes and all inquiries regarding problems with the delivery of *Mineralium Deposita* should be addressed to <sga@mineral.tu-freiberg.de> with a copy to <tiks@springer.de>.

Bernd Lehmann/Rich Goldfarb
News of the Council

Report of the President

P. Fenoll Hach-Al reported on the period from January 1, 2002 (when she became the SGA President) to April 27, 2002. She welcomed all newly elected officers and thanked officers whose term expired at the end of 2001.

Report of the Treasurer

The SEG Treasurer apologizes for any inconvenience which has resulted from problems with the former SEG Treasurer’s secretary. As of May 1, Sabine Lange, M.Sc., has replaced Dr. Judith Vogtmann in the Treasurer’s Office.

In order to improve the process of membership to SGA, the Treasurer’s Office, in agreement with the Council, has designed some new strategies. The Treasurer’s Office will inform all new applicants, either through e-mail or fax, when the application process has been completed. Springer-Verlag will assign an ID number to the new member for electronic access to MD, and will begin sending MD.

The SGA Treasurer’s Office will also check the possibility of paying membership fees through INTERNET with a printout of receipt (or email which confirms payment).

Report of the Chief Editors, MD

R. Goldfarb will retire from his position with the end of 2002. The Council approved that Larry Meinert from the Washington State University, who joined the Editorial Board in 2001, will replace him. The Editors will discuss positions on the Editorial Board with suitable candidates (9 vacancies for 2003) and will inform the Council on the status of these negotiations at the next Council Meeting. The Council approved an increase of the number of pages of MD from 800 to 1000 effective from 2003.

Report of the SGA Promotion Manager

G. Borg presented new developments for the public promotion of SGA.

SGA Student Chapters

The SGA Council is open to Student Members to form Student Chapters. The Council approved the creation of a joint Prague-Freiberg SGA Student Chapter. Participation in SGA Student Chapter activities does not necessarily entitle the member to SGA Student fees.

Proposal for creation of SGA Awards

The Council approved the creation of the SGA Young Scientist Award. The award will be given biannually to a young scientist for research in economic geology published before his 35th birthday. The award consists of a citation, 1500 EURO and travel to the Biennial meeting for the presentation.

Sponsoring of SGA membership in less economically developed countries

The Council approved a special subsidized subscription program for institutions, and under special circumstances, also for individuals in an economically challenged situation.

7th SGA Biennial Meeting

The progress report was given by D. Eliopoulos. The 7th Biennial SGA Meeting "Mineral Exploration and Sustainable Development" will be organized by Society for Geology Applied to Mineral Deposits in Athens (Greece), August 24-28, 2003. The meeting will be co-organized by the Institute of Geology and Mineral Exploration, Athens Technical University, Geological Society of Greece, Society of Economic Geologists and others.

CHANGE OF ADDRESS FORM

If you have changed (or will change in the near future) your address please fill in this form and send it to:

Peter M. Herzig, SGA Treasurer - Institut für Mineralogie, TU Bergakademie Freiberg, Brennhausgasse 14 - D-09596 Freiberg, Germany; phone: +49 3731 39-2662/2626; fax: +49 3731 39-2610; e-mail: herzig@mineral.tu-freiberg.de

Old address:........................................................................................................................................................

Complete new address (including phone, fax and e-mail) ..............................................................................................................................

SGA NEWS MAILBOX

Département de Minéralogie, Rue des Maréchaux 13 CH-1211 Genève 4, SWITZERLAND

fax: +41 22 320 37 32
e-mail: SGANEWS@terre.unige.ch

We expect your letters with comments, news, criticisms, ...
Applications to SGA for meeting sponsorship have to be submitted to Jan Pasava, SGA Executive Secretary, on appropriate forms developed and approved by the SGA Council which are available at the SGA home page on Internet:

http://www.min.tu-clausthal.de/sga.html

Other requests will be not considered.

The SGA Council thanked D. Eliopoulos for the excellent organization of both the SGA Executive Committee and Ordinary Council Meetings in Athens and the great hospitality provided by IGME. A personal welcome by Director General, IGME, and Head, Mineral Deposit Department, were highly appreciated. The Council approved that D. Leach will act as a technical liaison within the Organizing Committee. The registration fees for the congress have been fixed as follows:

<table>
<thead>
<tr>
<th>Registration</th>
<th>Early</th>
<th>Late</th>
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<tbody>
<tr>
<td>Member SGA/SEG</td>
<td>EUR 250</td>
<td>EUR 350</td>
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<tr>
<td>Non-member</td>
<td>EUR 350</td>
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<tr>
<td>Student member SGA/SEG</td>
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<tr>
<td>Student non-member</td>
<td>EUR 150</td>
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The second circular will be sent to only those people who responded to the 1st call or will make a request for a copy.

Status of SGA-SEG collaboration
The Council approved the organization of the SGA module – session on “Cutting edge advancements in economic geology” for the 2004 SEG meeting in Perth, Australia (already approved by SEG Council).

Status of SGA-IAGOD collaboration
The Council approved that SGA should take a larger role in the organization of the 12th IAGOD Quadrennial Meeting (St. Petersburg – August 2006) and recommended to discuss more on SGA-IAGOD collaboration during a possible joint IAGOD-SGA Council meeting in Windhoek, Namibia.

Meeting sponsorship
The Council approved the following requests for meeting sponsorship by SGA:
- 4th Fennoscandian Exploration and Mining (FEM), December 3-5, 2003, Rovaniemi, Finland. H. Papunen will act as SGA keynote speaker.
- 12th IAGOD Quadrennial Symposium, August 2006, St. Petersburg, Russia.
- World class mineral deposits and earth evolution, August 19-21 2003, Cardiff, UK. Ch. Heinrich will act as SGA keynote speaker.

Various
J. Cabello (Regional Vice-President for South America) will launch a promotion campaign of economic geology in South America.
Jingwen Mao offered to organize the next SGA Biennial Meeting (2005) in Beijing (China).
THE SOCIETY FOR GEOLOGY APPLIED TO MINERAL DEPOSITS

Report of the Executive Secretary about membership

regular members, 44 student members, 1 senior member and 2 corporate members applied for membership from August 23, 2001 to April 24, 2002

list of new SGA members (August 23, 2001-April 24, 2002)

regular members

Djamal Aissia, University of Ab-Enzaoua, Algiers, Algeria
Omar Koll, USTHB, El Alia, Bab Ezzouar, Alger, Algeria
Raul Pablo Andrade de Palomera, Rio Gallegos, Santa Cruz, Argentina
Phillip Blewin, Tuggeranong, ACT, Australia
Marek Wendorff, University of Botswana, Gaborone, Botswana
Sylvia Araujo, Universidade de Brasilia, Brasilia, Brazil
Jose C. Frantz, Porto Alegre, RS, Brazil
Alan Clark, Queen’s University, Kingston, ON, Canada
Patrice Gossele, Quebec City, Canada
David Lentin, University of New Brunswick, Fredericton, NB, Canada
Pierrotte Tremblay, St-Remigius, Quebec, Canada
Bo Peing, Changsha Institute of Geotechnology, P.R. China
Yi-Tian Wang, Institute of Mineral Resources, Beijing, P.R. China
Richard Mark Spencer, Quito, Ecuador
David Cassard, Orleans, France
Kristo Sundsland, FIN 200 14 Turunniitty, Finland
Kerr Anson, Ormonde Mining PLC, Navan, Ireland
Mohd Ghaderi, Tarbiat Modares University, Tehran, Iran
Tserenjav Tsengedorz, Ulaanbaatar, Mongolia
Andrey Coote, St. Anuald, New Zealand
Dylan Jeffries, C/O OSGCRT Roxolus S.A.C., Lima, Peru
Chris Louder, AngloGold Exploration Peru S.A.C., Lima, Peru
Friedrich Spidel, Lima, Peru
Bobos Iuliu, Universidade de Porto, Porto, Portugal
Antonio Soares de Andrade, Universidade de Aveiro, Aveiro, Portugal
Tatiana Anatolevna Baraboshkina, Moscow, Russia
Michael Buxton, Johannesburg, Marshalltown 2107, South Africa
Wolfgang Mai, University of Pretoria, Pretoria, South Africa
Zhiglev Savlovich, Krakow, Poland
Bernhard Dold, Universite de Lausanne, Lausanne, Switzerland
Jean Vallance, Universite de Geneve, Geneve, Switzerland
Howard Davies, Spital, Wirral, Merseyside, UK
Kip Jeffrey, University of Leicester, Leicester, UK
Charles Mooney, University of Leicester, Leicester, UK
Cameron Allen, Cominco American inc., Spokane, WA, USA
William W. Atkinson, Jr., University of Colorado, Boulder, USA
Omar El-Mahdy, Mays landing, NJ, USA
John Dilles, Oregon State University, Corvallis, OR, USA
Joff Doerriech, USGS, Reno, NV, USA
Lawrence Drew, Otscon, VA, USA
Brian Hoal, Society of Economic Geologists, Littleton, CO, USA

Erik Melchoriue, DePauw University, Greencastle, IN, USA

Student Members
Silvia Irene Carrasquero, Museo de Ciencias Naturales, La Plata, Argentina
Sebastian Gonzalez Chiozza, FCEN-UBA, Palacion, Argentina
Pilar Moreira, La Plata 1905, Argentina
Karina Mykittux, La Plata, Buenos Aires, Argentina
Julie Hunt, ECRU, James Cook University, Townsville, Australia
Neil Martin, Margate, Tasmania, Australia
Andrew Stewart, University of Tasmania, Hobart, Tasmania, Australia
Andrew Wurst, Lone Bay, Tasmania, Australia
Sijin DeBawele, Leuven, Belgium
Wouter Heijlen, Leuven, Belgium
Paula Alves, 1690 Miner Circle, ROLLA-MO 65409, Brazil
Sibila Borojevic, Zagreb, Croatia
David Dolejs, McGill University, Montreal, Quebec, Canada
Daniel Layton-Matthews, Toronto, ON, Canada
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Peter Cerny, Prague, Czech Republic
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Karel Maly, Tachov, Czech Republic
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Michel Ponaic, Prague, Czech Republic
Luminita Groancea, Université Henri Poincaré, Vandoeuvre-Les-Nancy, France
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Chris Bindall, Institute for Mineralogy, Frankfurt/Main, Germany
Claudia Buley, Freiberg, Germany
Samuel Famiyen, Freiberg, Germany
Andreas Kindermann, Institut für Mineralogie, Freiberg, Germany
Emmanuel Sup, Technical University of Clausthal, Clausthal-Zellerfeld, Germany
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Carmen Conde Rivas, I.G.M.E., Salamanca, Spain
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Omar Gündüz, Karadeniz Technical University, Trabzon, Turkey
Michael Lee, Leicester, UK
Michael Moggeridge, Leicester University, Leicester, UK
Patrick Carr, Cornell University, Ithaca, NY, USA
Joseph Fabrizio, Collegeville, PA, USA
Sebi Mueller, USGS DFC, Denver, CO, USA
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!!! NEW !!!

SUBLICITED SUBSCRIPTION PROGRAM

The SGA Council offers a limited number of free subscriptions to Mineralium Deposita to institutions and, under special circumstances, also to individuals in an economically challenged situation. The grant period is for 2 years. Please send a letter of justification for the need and specify how the journal will be used. The written SGA membership including contact details of two SGA members supporting this request should be sent to the SGA Executive Secretary, Geological Survey, Klárov 13/13, 118 21 Praha 1, Czech Republic, EUROPE.
Report on SGA Booth at the SEG 2002 Meeting

The SGA was extremely visible and active at the international SEG 2002 Global Exploration Conference in Denver this April. SGA was a co-sponsor of this highly successful meeting that included more than 750 attendees from dozens of countries.

Among the more noteworthy presentations at the meeting, was an outstanding overview of recent developments regarding the exceptional and still controversial Witwatersrand goldfields by Hartwig Frimmel, the SGA distinguished lecturer for this meeting. The SGA certainly appreciated the effort by Hartwig, who flew from Cape Town to Denver to deliver this important talk just 24 hours after becoming a new father and we congratulate Hartwig on both successes.

The SGA also had a highly visible exhibit booth that highlighted to many attendees the benefits of joining the society. Important activities, including the biennial meetings, were highlighted and there was extreme interest in many recent issues of Mineralium Deposita, particularly the thematic issues on China, Brazil, alkalic gold, and intrusion-related gold. As a result, almost 50 new members joined the society at this one meeting. (Actually, it would have been exactly 50, but Neil Phillips gave us a wrong credit card type, so if you read this Neil, we need you to try again!). There was also a great deal of interest in the upcoming 2003 SGA meeting in Athens from old and new SGA members alike, and it clearly seems like we can look forward to a well-attended meeting next year. The booth also continually served as a meeting place for many SGA members from around the globe and for dissemination of information regarding New databases on European Metallogeny

A GEODE initiative

Derek Blundell, Chair, GEODE Steering Committee (e-mail: d.blundell@gl.rhul.ac.uk)

Want to find information about one of the largest ore deposits in Europe, quickly and easily? Then go to the GEODE database web-site http://www.gl.rhul.ac.uk/geode/register.html and consult its new ore deposit database LODE (Largest Ore Deposits in Europe). Here you will find reports on each of 58 ore deposits or districts that describe the geology, mineralogy and ore deposit type, together with metal contents and economic information, supported by a short bibliography. Many of the reports contain illustrations (photographs, maps, cross-sections). The database is on open access and the individual ore deposit reports are accessed via a basemap of Europe showing the locations of all the ore deposits or via a list of ore deposits relating to one of the five main projects undertaken by GEODE: the Alpine–Balkan–Carpathian–Dinaride belt (ABCD), basin-hosted deposits, Fennoscandian and Ukrainian Shield, SW Variscides and Uralides.

LODE was put together to underpin the research activities of GEODE but we hope that it will be of much wider use, since it is
the first time that basic information on the largest ore deposits of Europe has been assembled in an easily accessible way. The format for the reports is based on a GIS developed at BRGM (French Geological Survey) that has been used to compile detailed information about metallogenic provinces in various parts of the world. The main compilation of LODE was undertaken by Miss Leena Rajavuori during a month-long visit to BRGM in Orleans, supervised by Dr. Jean-Pierre Milesi and his colleagues. LODE uses the terminology of the BRGM lexicon and the BRGM classification scheme so that the ore deposits and economic information are described in a systematic and universal manner. We are extremely grateful to BRGM for all their help. Additionally for GEODE, BRGM is currently developing a more detailed GIS database of all the mineral occurrences of central Europe, which will only underpin research in the ABCD project but will also provide a database of real potential in exploration.

Having established the five main projects three years ago, GEODE researchers have been collaborating in a number of well-focused, multidisciplinary, multinational research projects across Europe. Their efforts are beginning to come to fruition and already groups of related papers have been submitted for publication in Mineralization Deposits, Economic Geology and a volume in the Geological Society Special Publications series. More are to follow. With all this research activity, GEODE needed to build a database of people and research institutions working in relevant areas, so the GEODE database website includes a second database, called RESOURCES. This is subdivided into two interlinked files set up on Filemaker Pro 5 (© Filemaker Inc.) called “people” and “institutions”. The “people” file holds a set of records about individuals giving address, e-mail and phone number, their area of expertise, research interests, collaboration and a list of recent publications. The “institutions” file includes an internet site, a list of research facilities and a list of the people in the institution who are included in the “people” file. The RESOURCES database can be viewed interactively so that, for example, you can search for everyone working on a particular ore deposit or for every institution that has facilities for fluid inclusion analysis. Because of its interactive nature, the RESOURCES database is not on open access but is password protected. However, if you have been asked to gain access for essential reasons you can do so by contacting me by e-mail and I will give you a password. Of course, I may try to persuade you to allow me to include you in the database! At present, 89 people from 46 institutions are listed and we still have a long way to go to complete the database. But we hope that it is already sufficient to be of real value in finding out who is doing what and where, and how to contact them.

7th Annual European Short Course on Metallogeny
L’Aber W'rach, Brest, France, October 1st to 5th 2001

The most recent edition of the European short course on metallogeny took place from October 1st to 5th 2001. Speakers and students were welcomed à la Breton by course organizers Thierry Juteau (UBO), Yves Fouquet (IFREMER), Nick Arndt (University of Grenoble) and Steve Scott (University of Toronto/UBO). The course attracts an increasingly international range of participants and this year was no exception. Delegates arrived from Portugal, France, Germany, United States, United Kingdom, Canada, Russia, Morocco and Mexico. Talks were held at the Centre de la mer in the picturesque coastal town of L’Aber W'rach (Landes) near Brest, France.

Course instructors included: Yves Fouquet (IFREMER), Steven D. Scott (Univ. Toronto/UBO), Thierry Juteau (UBO/IUEM), Roger Hekinian (Kiel University), Mary Ohnenstetter (CRPG), Harold Gibson (Laurentian Univ.), Kim Juniper (UQUAM), David Leach (USGS Denver), Eric Marcoux (Univ. Orleans), Fernando Barriga (Univ. Lisbon) and Christian Mustin (CRPG). The course was separated into two main portions. Firstly, two days were dedicated to ancient ore deposits and ore depositional processes. Secondly, the last two days focused on modern seafloor processes from hydrothermalism to biomineralization. Laboratory sessions took place each day after the talks. Samples from various worldwide ore deposits (ancient and modern) were put on display as hand samples and thin sections. These sessions also provided a forum for further discussion with course instructors. Several unsolicited talks were given in the late afternoons and introduced participants to current research being done in various international institutions. Day 3 was a field trip that included several geological stops on the Crozon peninsula. Some of the best preserved volcanic and sedimentary sequences in France were examined and discussed as the group made their way along the spectacular Brittany coast.

The 8th annual European short course on metallogeny will mark a change of venue as Lisbon, Portugal, was announced as the next host city. With ever increasing international collaboration related to both ancient and modern ore depositional processes, the 2002 edition of the course promises to be an exceptional opportunity for various scientific communities to come together in a setting that promotes discussion and learning.

Yannick Beaudoin (University of Toronto)
The SGA Young Scientist Award

The SGA Young Scientist Award is offered biannually to a young scientist who contributed significantly to the understanding of mineral deposits. The award consists of a citation, prize money of EUR 1500, and travel to the Biennial meeting for the presentation, is not restricted to the candidate's nationality, place of employment, or membership in the Society. The award is given for contributions to economic geology. The SGA Young Scientist Award is awarded for research in economic geology published before the author's 35th birthday. The awardee must be less than 37 years of age on January 1 of the year in which the award is presented.

Any Society member in good standing may nominate candidates for the award. Nominees who are not selected in their first year of nomination, but are still eligible, will be considered for awards in following years.

How to Nominate

A brief biographical summary in the style of American Men and Women of Science or other similar biographical listing should be submitted by the person making the nomination to the SGA Executive Secretary by January 1 of the year of Biennial Meeting (1993, 1995, 1997...). The following information should be included:

1. Name of nominee
2. Date of birth
3. Education (degrees, institutions, dates) and previous awards
4. Past and present professional affilliations
5. Reference citation(s) to publication(s) for which the award is to be made, and to other published works. Indicate critical paper(s) and provide a copy of the abstract, if possible. An individual's contribution in co-authored papers is difficult to evaluate; such papers should be avoided unless the nominee is a senior author whose contributions can be clearly identified.
6. Brief statement explaining the significance of the research, including its pertinence to economic geology, its demonstrated effects, the originality and creativity shown in the research, the clarity of presentation, and its impact on scientific theory or technology.
7. Additional pertinent or related scientific contributions such as other accomplishments, advisory or consultant activities, and recognition of research stature elsewhere by others.
8. Names of individual making the nomination.

Supporting letters are helpful and may be attached to the letter of nomination or sent separately to the Chair of the Junior SGA Award Committee.

SGA Executive Secretary
Czech Geological Survey
Klarov 131/3, 118 21 Praha 1, Czech Republic


Understanding Mineral Deposits
by
Kula C. Mlsra
Dept. of Geological Sciences, The University of Tennessee, Knoxville, USA

The challenge of finding new orebodies to satisfy the ever increasing demands for mineral commodities has to be met, in addition to improved techniques of exploration, mining, extraction, and management, by a better understanding of the genetic setting and genesis of the various classes of mineral deposits. A substantial part of the book is devoted to a discussion, with appropriate examples, of principles that govern the formation of mineral deposits and the various kinds of field and laboratory data that can be used to interpret their genesis. The rest of the book discusses the characteristics of selected classes of deposits, their relationship with the crustal evolution in space and time, and on the application of available data to the formulation of viable genetic models that provide the basis for exploration strategies.

Price: EUR 273.50 / GBP 186.75 / USD 350.00
Available at a reduced price for course adoption when ordering six copies or more.
Special Price: EUR 88.00 / GBP 53.00 / USD 90.00
Please contact Customer Services (services@wkap.nl) for further details.

AusIMM 2002: 150 Years of Mining
1-4 September 2002, Auckland, New Zealand

This international conference will examine the geology, mining, metallurgical, economic, and environmental aspects of mineral deposits in Australia and the SW Pacific. Because of New Zealand's setting on an active plate boundary, the conference will have special emphasis on orogenic lode Au and epithermal Au-Ag deposits, with invited speakers presenting papers on topics from worldwide occurrences.

The conference will be linked with field trips to epithermal Au deposits and active geothermal fields in the North Island, and orogenic lode Au deposits in the South Island. There will also be a short course on exploration for mineral deposits in arc settings, and a short course on the environmental impacts of mining.

For more information:
AusIMM 2002
PO Box 32-072, Devonport, Auckland, New Zealand
Email: conference2002@ausimm.co.nz
Tel: +64-9-373-5917, Fax: +64-9-307-0331
For program developments visit www.ausimm.co.nz
It is documented from different parts of the world that numerous sulfide-rich veins, some of them that can be classified as "cordilleran base metal lodes", are superimposed on the upper parts of porphyry copper deposits and cut earlier veins of the potassic and phyllic alteration assemblages (e.g., Meyer and Hemley, 1967; Brimhall, 1979; Fréaut et al., 1997; Brathwaite et al., 2001). Binaudi (1977, 1982, 1994) points out the late stage character of the fluids that form this type of base metal-rich deposit within the moderately deep porphyry-skarn environment.

At shallower environments, these fluids can also generate different styles of high sulfidation cordilleran base metal lodes and replacement bodies. This is the case of the polymetallic belt of central and northern Peru, specifically in the Colquipirca, Cerro de Pasco, and Hualgayoc districts where important parts of the base metal mineralization are spatially related to Au high sulfidation epithermal ores (Fontboté and Bendezú, 1999; Bendezú and Fontboté, 2002; Baumgartner et al., 2002).

One of the open fundamental questions is to determine when cordilleran base metal lodes and replacement deposits are formed in the evolutionary history of porphyry-related hydrothermal systems. Are these ores formed from late stage fluids, as those responsible for sulfide-rich "D"-veins in porphyry copper

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**MINERALIZATION TYPE**

- Zn-Pb-Ag calcic skarn
- (Zn-Pb-Cu-Ag±Au-Bi) "cordilleran base metal" deposits
- Au±Ag volcanic-hosted high sulfidation epithermal

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**GEOLOGICAL UNITS**

- Quaternary deposits
- Diatreme-dome complex (Miocene)
- Dome complex (Late Eocene-Oligocene)
- Pocobamba Formation (Eocene), mainly limestones and marls
- Chiclin limestone (Cretaceous)
- Basalt flows (Cretaceous)
- Goylllarizquigza Group (Cretaceous), sandstones
- Pucara Group (Upper Triassic-Lower Jurassic), limestones and dolostones
- Miño Group (Permian-Triassic), sandstones
- Excelsior Group (Devonian), phyllites

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*Figure 1: Geological map of the Cerro de Pasco, Colquipirca, and Atacocha districts showing the distribution of the different porphyry-related mineralization types. Geology compiled from Angeles (1999), Johnson et al., (1955), Bricoal S.A. staff and own data.*
determinations from Figure 2: North-south longitudinal section of the Colquijirca district with main ore and alteration associations. "Ar/39Ar determinations from Bendezzi et al. (submitted).

Figure 2: North-south longitudinal section of the Colquijirca district with main ore and alteration associations. "Ar/39Ar determinations from Bendezzi et al. (submitted).

The economically more important cordilleran base metal lodes and replacement deposits represent the other distinctive type of mineralization in the district. The ores consist of at least 150 Mt of Cu-Zn-Pb-Ag(Au-Bi) high sulfidation, carbonate-hosted, massive replacement (Fontboté and Bendezzi, 1999, 2001). Replacement temperatures range from about 300°C, near the diatreme-dome complex, to 150°C, in external positions. The ores

Geometric and temporal relationship of ore types at Colquijirca

In the center of the Colquijirca district, a 4 km², Miocene, mainly dacitic, diatreme-dome complex intrudes a >300-m-thick sequence of folded carbonate rocks, continental Eocene limestones, marls and detritic sediments (Pocobamba Formation) to the north, and marine, Triassic-Jurassic, nearly pure limestones and dolostones (Pucará Group) to the south (Figs. 1, 2). The entire sedimentary pile surrounding the diatreme neck, including red beds of the Permo-Triassic basement, has subsided about 400-500 m (Fig. 2). A high precision "Ar/39Ar survey (Bendezzi et al., submitted) reveals two pulses of high sulfidation hydrothermal activity at 11.6±0.1 to 11.3±0.1 Ma (precious metals) and at 10.8 to 10.6 ±(0.06-0.1) Ma (base metals). They post-date formation of the volcanic complex (12.9-12.4±0.1 Ma) as determined from "Ar/39Ar dating of biotite samples from less altered adjacent dacitic domes. Previous K/Ar dating from other areas of the volcanic complex is consistent with the new data (Vidal et al., 1984).

The precious metal high sulfidation epithermal mineralization includes pervasive alteration of almost the whole diatreme-dome complex to assemblages of quartz – alunite – dickite – kaolinite ± (pyrophyllite – zenyite – illite) in mineralized areas and to kaolinite – illite ± (smectite) – sericite – chlorite – calcite beyond them. Shallow Au-(Ag) "vuggy silica" orebodies, as much as 100 m in vertical extent, exist mainly in the central portion of the complex, mostly within the diatreme breccia and pyroclastic infill, following a morphology apparently controlled by permeability (Fig. 2). As in other Au high sulfidation epithermal deposits (e.g., Summitville, in Gray et al., 1994), deep portions of non-oxidized ores contain characteristically <5 vol% of finely disseminated sulfide minerals, mainly pyrite-ename and very minor sphalerite. The "Ar/39Ar ages (11.6 to 11.3±0.1 Ma) on alunites from different parts of the diatreme-dome complex, including a strongly altered dome 2 km south of the diatreme vent, indicate that the precious metal high sulfidation epithermal mineralization constitutes the first recognizable hydrothermal pulse within the Colquijirca district.

The economically more important cordilleran base metal lodes and replacement deposits represent the other distinctive type of mineralization in the district. The ores consist of at least 150 Mt of Cu-Zn-Pb-Ag(Au-Bi) high sulfidation, carbonate-hosted, massive replacement (Fontboté and Bendezzi, 1999, 2001). Replacement temperatures range from about 300°C, near the diatreme-dome complex, to 150°C, in external positions. The ores
contain typically between 20 and 40 vol.% sulfide minerals, mainly in the form of flat, elongated mantos and irregular stacked bodies that extend from the external margins of the diatreme vent into the carbonate rocks (Figs. 1 and 2). Exploration drilling indicates that the bodies have their roots within the diatreme complex, in deep subvertical narrow veins composed mainly of enargite-pyrite-quartz-alunite and minor pyrophyllite (Fig. 2). The veins have been intercepted between 500 m and >750 m depth with a mineral association similar to that of the core of the mantos (see below).

Early Mineralization

Late Mineralization

Very late Mineralization

Early Barren Quartz Alunite Ledges

Metamorphic Vapor

Banded Quartz Veinlets

Magmatic Brine

Magma

Ore-bearing quartz-alunite veins (1)

Sector Collapse?

subsidence-collapse?

D veins

Supercritical Magmatic Fluid

Magmatic brine?

Maricunga belt, Chile; Muntean and Einaudi (2001)

Colquijirca District, Peru; Bendezú and Fontboté (2002)

Approximate Time Range (m.y)

(1) typical of the precious metal high sulfidation epithermal environment (Muntean and Einaudi, 2001)

Figure 3: Extension of the diagram of Muntean and Einaudi (2001), which represents the timing of A veinlets, D veinlets and precious metal high sulfidation epithermal veins in the Maricunga belt, to the high sulfidation cordilleran base metal environment, using the data of the Colquijirca district.

Hosted by carbonate rocks of the Tertiary Pocobamba Formation, the mantos extend continuously for almost 4 km in length to the north, where they virtually attain the same shallow topographic level of the precious metal high sulfidation epithermal ores. Along this extension, the mantos are zoned in all directions from a Cu core of high sulfidation mineralization composed of enargite - pyrite - quartz - alunite ± (luzonite, colusite, barite; Zone I). The surrounding economic ore zones include pyrite - chalcopyrite - dickite - kaolinite - siderite - quartz± tennantite, Bi-Ag sulphosalts, bornite, alunite, barite, quartz; Zone II; pyrite - sphalerite - galena - chalcopyrite - dickite - kaolinite - quartz ± (siderite, hematite, magnetite, alunite; Zone III); and an outermost known zone of pyrite-galena-

spalerite-siderite±(kaolinite, dolomite, Zn-bearing carbonates; Zone IV). A similar zoning is also present to the south (Fontboté and Bendezú, 2001), where ore bodies develop not only within the Pocobamba Formation, but mainly in Lower Jurassic carbonate rocks of the Pucará Group, which constitutes the host rock of San Gregorio, one of the biggest Zn-Pb deposits in Peru (> 70 Mt @ Zn+Pb-10 %). Replacement at San Gregorio took place at very low temperature (≤150°C), yielding fine-grained and not easily recognizable ores.

The superimposition of the cordilleran base metal lodes and replacement deposits on the Au-(Ag) high sulfidation epithermal mineralization is evidenced from crosscutting relationships. In the northern flank of the diatreme vent, alteration selvages from
the massive enargite-quartz-alunite ores overprint weakly argillized/propylitized dacitic domes and phreatomagmatic breccias related to the Au-(Ag) mineralization. To the east of the diatreme vent, the argillic associations related to the Au(Ag) ores are cut by narrow sphalerite-galena-pyrite veins. These geometrical relationships are totally consistent with \(^{40}\text{Ar}/^{39}\text{Ar}\) absolute ages obtained on alunite associated with the enargite-pyrite and sphalerite-galena zones of the "cordilleran base metal lodes", which have ages between 10.8 and 10.6 ±(0.06-0.1) Ma, i.e. about 0.6 My younger than the precious metal mineralization.

**Discussion**

On the basis of the current knowledge on the lifespan of a single intrusion related hydrothermal system (<40000 years; e.g., Marsh et al., 1997), the total duration of the hydrothermal activity recognized in each of the pulses in the Colquijirca district (in the range of 0.2-0.35 My, Bendetti et al., 2002) is representative of a relatively long-lived hydrothermal activity which probably was sustained by multiple pulses of shallow intrusions (Cathles et al., 1997), as indicated by the existence of several hundreds meter-wide stocks, specially on the immediate edge of the diatreme vent.

In the Maricunga belt, Chile, based on detailed mapping and \(^{40}\text{Ar}/^{39}\text{Ar}\) geochronology, Muntean and Einaudi (2001) favor a model whereby high sulfidation epithermal ores and porphyry-related late stage "D" veins are temporally and genetically linked and both postdate by several hundreds of thousands of years the early A veining (Fig. 3). At Colquijirca, the long time gap (0.5 to 0.6 My) between the precious metal epithermal mineralization and the younger cordilleran high sulfidation base metal ores indicates that the latter formed by even later hydrothermal fluids, and combining with the results from the Maricunga belt, they would also postdate the hypothetical "D"-vein stage (Fig. 3).

The formation of cordilleran base metal lodes in the Colquijirca District seems to represent a late phase of the complex evolution history of a magmatic cycle active for at least two million years through multiple intrusions related to a single intrusive center.

**Conclusions**

The relative sequence of events and the absolute ages available in the Colquijirca district firmly establish, for the first time, a late timing for cordilleran base metal ores, which are mainly epithermal and display high sulfidation mineral assemblages. They postdate the early precious metal-bearing, high sulfidation epithermal mineralization. Based upon the sequence of events at Colquijirca, it can be hypothesized that similar crosscutting relations present in epithermal ores at other districts (e.g., Hualgayoc, Cerro de Pasco) represent high-level equivalents of the superimposition of deeper mineralization events noted by Brimhall (1979) and Einaudi (1982, 1994) in the upper part of porphyry copper and/or skarn deposits.
The results presented here have important implications for exploration, because many classic districts known for their porphyry copper and/or Au-(Ag) epithermal deposits may host concentrations of "cordilleran base metal lodes" at any spatial position upward from the porphyry environment. These may occur at levels as shallow as the epithermal environment, which in carbonate rocks may be characterized by fine-grained and not easily recognizable Zn-Pb mineralization (e.g., San Gregorio) and for lateral distances as far as more than 4 km from the intrusive center.

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References


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ANNOUNCEMENTS

MEETINGS, CONFERENCES, FIELD TRIPS AND SHORT-COURSES

16TH AUSTRALIAN GEOLOGICAL CONVENTION
Adelaide, Australia
1-5 July, 2002

The theme of this Convention “Geoscience 2002: Expanding Horizons” endeavours to capture the rapid increase in our geological knowledge of the environment as well as the recognition that most of us live, work and play in a global environment, and the importance of looking outward to the unknown beyond the horizon. One sub-theme is devoted to “Metallogenesis and Ore Discovery”.

Field trips
Field trips cover specific aspects of Proterozoic geology and mineralisation, and Palaeozoic to Cenozoic basins.

Convention Venue
The Technical Sessions of the Convention will be held at the Adelaide Convention Centre on the bank of the Torrens Lake.

Language
The official language of the Convention is English. Simultaneous translation will not be provided.

Registration fees (after 28 February 2002)
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11TH IAGOD QUADRENNIAL SYMPOSIUM/ GEOCONGRESS 2002
Windhoek, Namibia
22-27 July, 2002

COMPRESSIONAL AND EXTENSIONAL TECTONIC ENVIRONMENTS AND THEIR ASSOCIATED ORE-FORMING PROCESSES, with a focus on Africa

HOSTS: The Geological Societies of Namibia, South Africa and Zambia
CONFERENCE VENUE: Safari Hotel, Windhoek
FIELD TRIPS
16 – 21 July, Pre-Conference Excursions
27 JULY – 2 August, Post-Conference Excursions

Most conference fees have been significantly reduced, e.g. for members of hosting and sponsoring societies the “early bird” delegate fee (until 31 March 2002) has been reduced to US$ 325 (international) or NS2700 (residents of SADC countries). Please consult our Web-site for details.

The conference incorporates the 11th Quadrennial Symposium of the International Association on the Genesis of Ore Deposits (IAGOD) and GEOCONGRESS 2002 of the Geological Society of South Africa, and is hosted by the Geological Societies of Namibia, South Africa and Zambia. The conference is as much sedimentary, magmatic and tectonic as it is economic. Besides creating a platform for the exchange of the latest geological research results, the conference provides also exposure to mining investment opportunities in the Southern African region. An exhibition allows the presentation of investment opportunities, and services and goods for the mining industry. Various workshops and/or short courses and a wide selection of geological excursions are also being offered. The conference is sponsored by the Geological Survey of Namibia, the Council for Geoscience of South Africa, IUGS/UNESCO, The Society of Economic Geologists (SEG) and The Society for Geology Applied to Mineral Deposits (SGA).

You can register via our web-site:

The final announcement contains full details on the conference including details on our invited speakers:

- Keynote speakers: Dr. Richard Siljiloe, Consulting Geologist, UK; “Iron oxide-copper-gold deposits an Andean perspective”, and Prof. Ross Large, Director, CODES Special Research Centre, University of Tasmania on "Stratifom Sediment Hosted Zn-Pb-Ag Deposits: Ore deposit Models and Exploration Criteria”.
- SEG lecturers: Dr. Steve Walters, Director GeoDiscovery Group, Australia, “An overview of world-class Broken Hill-type Pb-Zn-Ag deposits: new lessons from old ore bodies”, and Prof. Lluís Fontbote, Department of Mineralogy, University of Geneva; “Zn-Pb mineralization in high sulfidation epithermal environment - examples from Peru”.
- Plenary speakers: Prof Uwe Reimold, President Geological Society of South Africa 2002 on “Mineralisation associated with impact structures, with special reference to the Vredefort-Witwatersrand system” and Dr. Erik Hammerbeck, President IAGOD 2002 on "Topical aspects of the geotectonic and metallogenic evolution of Africa”.
- The 2002 Alex L. du Toit Memorial Lecturer, Prof. Bruce Rubidge, Department of Mineralogy, University of the Witwatersrand on "Re-uniting lost continents - fossil reptiles from the ancient Karoo and their wanderlust”.

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**September 9-11**

**IRON ORE 2002, Perth, Australia - Contact address: website: www.ausim.com**

**September 10-11**

**INTERNATIONAL WORKSHOP, URANIUM DEPOSITS: From their Genesis to their Environmental Aspects (IAGOD), Prague, Czech Republic - Bohdan Kribek, Czech Geological Survey, Geologicka 6, 15200 Prague 5, Czech Republic; phone/fax: +420 2 581 7390; e-mail: kribek@ecg.cz; web-site: http://xrd.cgu.cz/uranium.htm**

**September 15-21**

**URANIUM MINING AND HYDROGEOLOGY III, INTERNATIONAL MINERAL WATER ASSOCIATION SYMPOSIUM - MINERAL WATER AND THE ENVIRONMENT, Freiberg, Germany - Contact address: Prof. Dr. B. Markel/Dr. Simon Wolfgang, Lehrstuhl für Hydrogeologie, Gustav-Zeuner-Strasse 12, D-09596 Freiberg/Saxony, Germany; phone: +49 3731 393399; fax: +49 3731 392725; web-site: http://www.geo.tu-freiberg.de/www/IMWA.de**

**September 16-18**

**5TH INTERNATIONAL SYMPOSIUM ON ANDEAN GEODYNAMICS, Toulouse, France - Contact address: ISAG, IRD, LMTG, 38 Rue des 36 Ponts, 31000 Toulouse, France; Att.: Patricia Baby, Gerard Houri, Alain Leuen; e-mail ISAG@ctcfr**

**September 16-18**

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**September 18-20**

**INTERNATIONAL SYMPOSIUM "METALLOGENY OF PRECAMBRIAN SHIELDS", Kyiv, Ukraine - Contact address: Symposium Secretariat, 13A Tynshenska str. 128, Kyiv, 04212 Ukraine; phone/fax: +380 44 295 77 98; e-mail: bt@ukrgrig.gov.ua**

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**2002**

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8TH INTERNATIONAL KIMBERLITE CONFERENCE, Victoria, British Columbia, Canada — Contact address: Dr. Roger H. Mitchell, Geology Department, Lakehead University, Thunder Bay, Ontario, Canada P7B 5E1; phone: +1 807 343 8297; fax: +1 807 623 7526; e-mail: roger.mitchell@lakeheadu.ca; web-site: www.venuemec.com/8KC

**August 19-31**

THE GEOLOGICAL SOCIETY FEMORUM FLAGSHIP MEETING: WORLD CLASS MINERAL RESOURCES AND EARTH EVOLUTION, Cardiff University and the National Museum and Galleries of Wales, Cardiff, Wales, U.K. Contact address: Iain McDonald, Department of Earth Sciences, Cardiff University, P.O. Box 914, Cardiff CF10 3YE, U.K; e-mail: mcdonald1@cf.ac.uk; web-site: http://www.mndg.org.uk

**August 29-September 3**

THE 21ST INTERNATIONAL GEOCHEMICAL SYMPOSIUM (IGES) OF THE ASSOCIATION OF EXPLORATION GEOCHEMISTS, Dublin, Ireland — Contact address: Eibhlín Doyle; e-mail: eibhlin.doyle@galsi.ie; web-site: http://www.aog.org/Symposia/21stSymposiumTrp/21st_internationa_l_iges2003.htm

**August 31-September 3**

NORTH ATLANTIC MINERALS SYMPOSIUM (NAMS-2003), Dublin, Ireland — Contact address: web-site: www.gov.na/nams/

**September 7-11**

6TH INTERNATIONAL SYMPOSIUM ON ENVIRONMENTAL GEOCHEMISTRY (ISEC), Edinburgh, Scotland — Contact address: John Farmer, Department of Chemistry, The University of Edinburgh, Joseph Black Building, Kings Buildings, West Mains Road, Edinburgh EH3 3JF, Scotland; phone: +44 131 650 1000; fax: +44 131 650 4573; e-mail: J.G.Farmer@ed.ac.uk

**September 7-12**

13TH V.M. GOLDSCHMIDT CONFERENCE, Kureshiki, Japan — Contact address: Organizing Committee of Goldschmidt 2003, c/o International Communications Specialists, Inc., Sabo Kikaen-bekan, 2-7-4 Hirokawa-cho, Chiyoda-ku, Tokyo 102-8646, Japan; e-mail: gold2003@ics-inc.co.jp; web-site: http://www.ics-inc.co.jp/gold2003/

**September 10-11**

MANTLE PLUMES: PHYSICAL PROCESSES, Chemical Signatures, Biological Effects, Cardiff, Wales, UK — Contact address: Dr. Andrew C. Kerr, Department of Earth Sciences, Cardiff University, Main Building, Park Place, Cardiff, Wales, UK. CF10 3YE; phone: +44 (0)29 2087-4376; fax: +44 (0)29 2087-4326; e-mail: kerri@cf.ac.uk; web-site: http://www.geosoc.org.uk/template.cfm?name=Plumes

**September 15-18**

INDUSTRIAL MINERALS AND BUILDING STONES, INTERNATIONAL SYMPOSIUM (IAEG), Istanbul, Turkey — Contact address: Prof. Dr. Erdogan Yüzer, Istanbul Teknik Universitesi, Modern Fakultesi, Ayazaga Kampüsü 06026-Maslak, Istanbul, Turkey; phone/fax: +90 212 2656 146; e-mail: yuzer@itu.edu

**September 28-October 3**

SOCIETY OF EXPLORATION GEOPHYSICIANS (SEG), INTERNATIONAL EXPOSITION AND 73RD ANNUAL MEETING, Dallas, TX, USA — Contact address: SEG Business Office; phone: +1 918/497 5520; fax: +1 918/497 5557; web-site: http://www.seg.org

**October 5-10**

THE XXIII INTERNATIONAL MINERAL PROCESSING CONGRESS, Cape Town, South Africa — Contact address: Mrs. Meg Winter, Dept. of Chemical Engineering, University of Cape Town, Rondebosch 7700, South Africa; phone: +27 (0)21 689 7579; e-mail: mwchemeng@uct.ac.za; web-site: http://www.imp2003.org.za/

**November 1-5**

19TH WORLD MINING MINING IN THE 21ST CENTURY - WHAT next? CONGRESS & EXPO - 2003, New Delhi, India — Contact address: The Institution of Engineers (India), indian National Committee of World Mining Congress, 8, Golkhale Road Calcutta -700020; phone: +91 33 2238311, 2238314, 2238316; fax: +91 33 2238315; e-mail: leihgs@vsnl.com; web-site: http://www.19wmnc2003.com

**November 2-5**

GEOLOGICAL SOCIETY OF AMERICA; ANNUAL MEETING, Seattle, Washington, USA — Contact address: GSA Meetings Department, P.O. Box 9140, Boulder, CO 80301-9140, USA; phone: +1 303 447 2020; fax: +1 303 447 0648; e-mail: meetings@geosociety.org; web-site:...
THE SGA HOMEPAGE ON INTERNET

The SGA homepage has a new address on INTERNET. From this homepage you can get information about biennial scientific meetings in Europe, worldwide field trips and workshops, membership application form for the SGA and authors and titles of this year contributions to Mineralium Deposita as well as the electronic edition of SGA News.

http://www.min.tu-clausthal.de/sga.html
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The Society of Geology Applied to Mineral Deposits was established in 1955 by an international group of economic geologists. Its Journal Mineralium Deposita is now recognized as a premier international journal.

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- Organization of scientific meetings, field trips, workshops. For these events, SGA members have reduced registration fees and in certain cases may apply for travel grants
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Seventh Biennial SGA Meeting

Mineral Exploration and Sustainable Development

August 24-28, 2003
Athens (Greece)

Co-organizers

INSTITUTE OF GEOLOGY AND MINERAL EXPLORATION (IGME)
ATHENS TECHNICAL UNIVERSITY (NTUA)
ATHENS UNIVERSITY
UNIVERSITY OF THESSALONIKI
SOCIETY OF ECONOMIC GEOLOGISTS (SEG)
GEOLOGICAL SOCIETY OF GREECE - SECTION OF ECONOMIC GEOLOGY AND GEOCHEMISTRY

Preliminary Information

The 7th Biennial SGA Meeting will be held in Athens, Greece, August 24-28, 2003. Athens is the historical capital of Greece, a scientific and cultural center and the Host City of the Olympic Games of 2004.

Under the general theme “Mineral Exploration and Sustainable Development” the conference will bring together economic geologists from industry, government and universities to discuss current issues on ore geology, exploration and sustainable development. Participants are kindly invited to offer papers for oral and poster presentations in the following topics:

- Sustainable development and geo-environmental impact models
- Supergene metallogenic processes
- Seafloor hydrothermal systems
- Porphyry/alkaline granites and the magmatic-hydrothermal transition
- Epithermal systems
- Mafic-ultramafic magmatism and ore deposits
- Basin evolution and mineral deposits
- Orogenic hydrothermal systems
- Organic matter and mineral deposits
- Industrial minerals
- Laurium, 3000 years of silver mining
- Open session

Several post-meeting field trips will be organized and the participants will have the opportunity to visit different metallogenic provinces of Greece and neighboring countries, including Milos Island, Santorini Island, Cyprus etc.

For more information, please, visit our website: www.igme.gr/sgaconference.htm

Deadlines

September, 2002, Pre-registration
October, 31, 2002 Second Circular
January 31, 2003 Abstract submission
April 30, 2003 Registration for Conference and Field trips

Contact address

7th Biennial SGA Meeting
Secretary: Dr. Demetrios Eliopoulos
Institute of Geology and Mineral Exploration
70 Messoghion Str.

GR-115 27 Athens, Greece
FAX: 00 30 1 77 73 421
e-mail: eliopoulos@igme.gr