



# SGA

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Number 29

# News

## An Overview of Chilean Economic Deposits

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### INTRODUCTION

Chile is a country of enormous mineral wealth, and has world-wide fame as the biggest copper producer. In the year 2009, Chile produced 5,320 thousand metric tonnes of copper, representing 33.7 % of the world total production (Table 1). In addition to copper, recent development of technology requires Chilean mining to explore other metallic and nonmetallic elements. As listed in Table 1, Chile is the first-ranked country in annual productions of rhenium (25,000 t), iodine (16,000 t) and lithium (7,400 t). Furthermore, Chile has significant positions in productions of silver, molybdenum, boron and selenium. All these elements occur predominantly in subaerial hydrothermal deposits (Cu, Mo, Ag, Re, Se) or in superficial brine-salt deposits (Li, I, B). Thus, their geologic enrichments are regarded to have been closely related to the Andean Cordillera-forming arc magmatism and the associated climate change. Geologically, Chile is composed of Phanerozoic formations, and thus the deposits typical of Precambrian ages could not be discovered.

In order to gain insight into the Andean orogeny including coastal Cordillera formation in Northern to Central Chile, it is necessary to look back to geologic events since Early Mesozoic ages (e.g., Boric et al., 1990). Chilean plutonic intrusions since Early Mesozoic ages correspond mostly to the oxidized magnetite-series granitoids

(Ishihara, 1998), and so Chile has many Cu-Au (-Mo) deposits characteristic of the series. In the following, we mention briefly the geological characteristics of Chilean economic deposits in temporal order, emphasizing the principal Cu-Au (-Mo) deposits of Northern and Central Chile.

### MAJOR Cu (-Mo) DEPOSITS Manto-type deposits

Numbers of volcanic-hosted stratiform deposits termed "manto-type" occur in the Coastal Cordillera of Northern Chile (north of Santiago, <34°S), forming an economically important metallogenic copper belt (Ruiz et al., 1965, 1971; Camus, 1990). Similar deposits are also distributed in North America, and are named "volcanic redbed" (e.g., Kirkham, 1996; Cabral and Beaudoin, 2007). Most of the Chilean deposits occur in andesitic to basaltic rock-dominated monoclinical volcano-sedimentary piles of Mesozoic ages, and are regarded to have formed in intracontinental rift zones near the plate margin with continental-arc volcanism (Lefebvre and Church, 1996). Thus, nearly all deposits are hosted in thick volcanic piles of several thousand meters formed under an extensional regime with a steeply dipping Mariana-type subduction (Sato, 1984).

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# From the Chairman of the 11th SGA Meeting

Eduardo Campos (edcampos@ucn.cl)

The 11th SGA Biennial Meeting, hosted by the Universidad Católica del Norte, is going to be held in the coastal city of Antofagasta, northern Chile between 26 and 29 September, 2011 at the Enjoy Hotel & Convention Center. The meeting, the first of its kind to be organized in South America, represents a unique occasion for SGA to promote its activities, particularly in this part of the world where SGA is not well represented.

The conference will provide an international forum for the presentation of new research and scientific advances in the study of mineral deposits. It will also be a great opportunity for the exchange of ideas and experiences, and for students to interact with leading scientists, industry professionals and other students in a relaxed and informal atmosphere. The SGA2011 editorial committee has received more than 340 abstracts, and at the end of the early registration period we have more than 350 registered attendees (23% SGA-members, 40% non-SGA members, 21% SGA students and 6% non-SGA students) and expect to reach a total of about 450 participants.

The Central Andes of Chile, Perú, Argentina and Bolivia is known for its rich abundance of diverse mineral resources and its long mining history. For decades the region has been regarded as an ideal place to study mineralization associated

to a subduction zone; it is also one of the most important mining areas with some of the largest mineral deposits in the world. The region is home to a large number of geologists dedicated to the exploration and mining of mineral resources, and has served as a natural laboratory to countless students and researchers from all over the world. We are offering pre and post conference courses and field trips, with about half of the field trips already fully booked.

Our commitment is to make this meeting an enjoyable experience for all attendees, and to contribute to the understanding of mineral deposits. This event will be an outstanding experience for all participants and an exceptional opportunity to discuss the future of economic geology worldwide.



# SGA News

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Please always send a paper copy and indicate the format you are using.

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# News of the Society

SGA Ordinary Council Meeting, April 8, 2011, Madrid, Spain

J. Pašava (SGA Executive Secretary), Czech Geological Survey, Prague, jan.pasava@geology.cz

## Minutes of Previous Council Meeting (August 22, 2010, Budapest, Hungary)

After checking actions the Minutes were unanimously approved.

## Reports of Officers on Council and Matters Arising from These Reports

Reports were submitted by the SGA Executive Secretary, Treasurer's Office, Promotion Manager, Editors of SGA News, Editor of SGA Website, Regional VP for Australia/Oceania, Regional VP for North America and orally given by the Regional VP for South America.

After discussion, Council approved the reports with great thanks and took the following motions:

H. Frimmel to organize production of SGA flag (regular size) that could be used for various workshops/meeting/courses. H. Frimmel will send a list of promotional items to all RVPs and to determine the locations of both types of SGA booths (contacting both previous and new RVPs).

H. Frimmel to proceed with organizing the African Metallogeny Course according to suggested project vehicle (at the moment approved financial co-sponsorship by IUGS and IRD).

H. Frimmel will provide a list of items (promotional and booth supplies) that should be included in every SGA exhibit.

M. Chiaradia will inform D. Leach on requested budget for the improvement of SGA News which was approved by Council. M. Chiaradia was approved as a Chief of SGA News Committee. The deadline for all contributions to the upcoming issue of SGA NEWS is May 1, 2011.

G. Beaudoin to ask C. Bendall from Springer to post a Mineralium Deposita table of contents to the SGA Facebook page.

J. Relvas to thank F. Marques for managing SGA facebook and to encourage her to proceed with her ideas for further development of this application (e.g., to launch photo gallery for student activities).

D. Huston to offer SGA support to organizers of the Symposium 8.3. "Probing the Earth from near-surface to the mantle – techniques, modeling software and case histories to aid mineral exploration" under condition that SGA will be a visible sponsor of this symposium.

A. Conly to inform GAC-MAC-SEG-SGA organizers about a decision to not have extra printed copies of Abstract Volume 2011 for a reduced fee. Those Council members who will be participating in this meeting are asked to help with manning SGA booth (please get in touch directly with A. Conly).

Jan Pašava greatly appreciated efforts of E. Ferrari – RVP for South America – SGA is thankful for his extreme hard work, dedicated to SGA and his reliable efforts to promote SGA in South America.

## Editorial matters including a proposal for the best paper in MD-2009-2010 (B. Lehmann, P. Williams)

The report was presented by B. Lehmann and P. Williams. Journal production is on time and runs smoothly. The principal issues currently facing the journal are (1) Substantially increased rate of submissions compared to historical trends is increasing the workload on editors and requires an increased rejection rate in order to avoid

increased delays between on-line and printed publication, and (2) the increased work for editors and reviewers are resulting in increased processing time for manuscripts. A list of nominated articles for the Best Paper in MD was presented. The electronic vote will be distributed by J. Pašava to Council members by April 15 with a deadline of April 30. The result of the vote will be announced by Chief Editor, MD to the first author of selected article in May.

All Council members are asked to think of a suitable person who might appreciate invitation to join Editorial Board of Mineralium Deposita and who would be expected to do a good job as Associate Editors (inform Chief Editors, MD).

## Proposal for SGA Guidebook series and update on revival of SGA Special Publications (R. Foster et al.)

J. Pašava presented on behalf of R. Foster - Publication Manager's report. After discussion Council approved the report and encouraged R. Foster and E. Campos to secure preparation of Excursion Guidebooks for SGA 2011. Field trip leader must be provided with a template and firm deadline for the submission of the texts that will be going through editorial (R. Foster) and technical (L. Gustkiewicz) formatting and then final printing (E. Campos). In addition to printed copies for field trip participants and pdfs of individual guidebooks, SGA will need to have intermediate files. Council approved to encourage R. Rodríguez and J.C. Arranz from IGME to submit a book on "Mining Waste and Environmental Risk..." as a SGA Special Publication (F. Tornos).

## Status of Planning for SGA 2011 in Antofagasta (E. Campos and F. Tornos)

The report was presented by E. Campos. By April 7, 337 abstracts were submitted for the conference (target no. is 350). The process of soliciting conference sponsorship is developing well. Council greatly appreciated hard work of the LOC under the leadership of Eduardo Campos and after discussion accepted the following motions:

- Completion of registration and payment for the conference has to be offered electronically through conference website (E. Campos).
- Reserve 45 min for the presentation of SGA awards at the opening ceremony and 1 hour for the SGA General Assembly on Wednesday, September 28 (the precise venue and time will be announced in the Conference Program - E. Campos).
- E. Campos to reserve 3 rooms for SGA award recipients.
- Reservation of rooms for SGA Council members was made by E. Campos from Sept 25-29. Any requests for changes (e.g., extension of the stay) have to be communicated ASAP to E. Campos (J. Pašava to remind all Council members).
- Vymazalová to provide E. Campos with requirements for both student's events (1.meeting of students with sponsors and 2.meeting of students without sponsors).
- E. Campos to include basic information regarding safe taxi operations, instruction on possible hazards in the Final Program.
- Field trip leaders to provide info on expected maximum altitude

and temperatures (E. Campos to inform Shoji Kojima to implement this request).

- Student's grants will be paid in cash in USD (E. Campos with SGA Treasurer's office).
- Necessary number of Books of SGA 2011 Conference Papers (based on registration requests) will be published by a local printing house. Memory stick will be provided to each registrant, copyright and distribution rights for books and digital publications stay with SGA. A price of USD 100/printed copy for the set was established.
- It is important to proceed with well coordinated effort to seek industry and other conference sponsorship (LOC with D. Leach and E. Ferrari).

#### **Status of planning for SGA 2013 in Uppsala (P. Weihed)**

J. Pašava briefly reported on behalf of P. Weihed. Next meeting of the LOC will be held in late September 2011. SGA 2013 will be introduced and advertised through leaflets at the SGA 2011 in Antofagasta.

#### **Suggested changes in SGA Constitution (J. Pašava)**

J. Pašava summarized recent development on various decisions taken by Council regarding changes in SGA statutes. Council discussed a proposal to lower the number of members of the SGA Executive Committee (in relation to the number of all Council members) to make the work of the EC more efficient. It was also emphasized that the Society does not have any professional staff and thus it is essential to have more people to share various responsibilities among them. Council agreed to create a new position of "Vice-President for Student Affairs". F. Tornos and J. Pašava to prepare a proposal for Constitutional and By-Laws changes for Council comments.

#### **Report of Nominating Committee for SGA 2011 ballot (F. Tornos)**

The report was presented by F. Tornos. The Committee asked for more time to complete the final list of officers for SGA 2011 ballot for Council approval (F. Tornos to send the final list to J. Pašava who will organize a Council vote).

#### **Report from Award Committee (D. Huston)**

The report was prepared by D. Huston and presented by J. Pašava and F. Tornos. Council then discussed various candidates for different SGA awards and approved the following motions:

- Nominations and supporting material will be emailed by J. Pašava to Council members by April 15, with votes to be emailed to Jan Pašava, with copies to David Huston, on or before 30 April. Jan Pašava and David Huston will compile the votes and inform the President by 7 May, who will then inform awardees.
- Prepare a proposal for the improvement of a procedure for the final vote (F. Tornos, D. Huston).

#### **Proposal for creation of SGA Educational Foundation (D. Leach)**

Both the legal framework and proposal for the organization of a non-profit SGA Educational Foundation were presented by D. Leach. The purpose of this foundation is to facilitate donations from corporations, institutions and members to provide sustained financial support for students and economically disadvantaged professionals to participate in SGA sponsored workshops and short courses, meetings and field trips. Council approved the suggestions

in the documents with great thanks and asked D. Leach to report on the progress on this important issue at the next Council meeting. **Progress report on membership drive from the last SGA Council meeting (P. Eilu, J. Pašava, A. Vymazalová)**

The report was presented by J. Pašava. During the past 7 months SGA got a record of 243 new members. The total number of members has risen from 913 in 2009 to 994 at the end of 2010. Council greatly appreciated efforts of K. Kelley, D. Leach, D. Groves, A. Cheilietz, D. Dolejš, E. Naumov and L. Fontboté who significantly contributed to membership increase.

Despite "personal reminders" introduced in 2010, unfortunately, the loss of members remains a big issue. Council approved the report with great thanks and recommended to continue with already implemented "reminding process" that is coordinated by Sabine Lange from SGA Treasurer's office.

All Council members should help with correcting names and/or other coordinates of new SGA members that are regularly published in SGA News (this is very important for future communication with our membership).

#### **Status of development of SGA Student and Young Scientist network – Reports from Prague and Baltic Chapters (A. Vymazalová and J. Relvas)**

A. Vymazalová presented a report of the Prague Chapter and also reminded the SGA Students Conference (April 15-18, 2011, Prague, Czech Republic). Council greatly appreciated the broad activities of the Prague Chapter and approved requested budget of EUR 2500 for 2011.

#### **Past activities**

- SGA promotion at SEG Biennial Meeting (Sept-Oct, 2010 Keystone) – D. Leach, K. Kelley, S. Roberts report
- XXIX UNESCO-SEG-SGA Metallogeny Course (October 11-22, 2010 Concepcion, Chile) – B. Dold, L. Fontboté
- SGA promotion at the RST meeting (Réunion Annuelle des Sciences de la Terre) (October 28, 2010 Bordeaux, France) – A. Cheilietz, M. Pagel
- PROEXPLO 2011 "Peru Country for Exploration" (February 6-8, 2011 Lima) – E. Ferrari, F. Tornos
- Prospectors and Developers Association of Canada (PDAC) (March 6-9, 2011 Toronto) – C. Andrew et al.

Council greatly appreciated efforts of all organizers and other SGA members who were helping with SGA promotion at the listed meetings. These activities also resulted in getting numerous new members. Leading organizing persons are encouraged to prepare a brief info for the upcoming issue of SGA News (deadline May 1, 2011).

#### **Future activities**

- SGA Student Conference (April 15-18, 2011 Prague) – K. Schloglova, A. Vymazalová et al.
- GAC-MAC-SEG-SGA (May 25-27, 2011 Ottawa) – C. Andrew, G. Beaudoin
- Mineral Deposit sessions within the Theme 11 "Earth Resources: Ores" at the Goldschmidt 2011 Conference (August 14-19, 2011 Prague) - J. Pašava et al.

Council approved that A. Conly (in collaboration with E. Ferrari) will apply for the registration of booth for next PDAC (Toronto 2012).

### Requests for sponsorship

- Ore Deposits Models and Exploration (May 24-29, Beijing, China) – D. Leach SGA keynote – travel 1200 EUR – approved
- SGA sessions at Goldschmidt (to grant a certain amount as in the case of SGA sessions at IGC 2012) – Council approved up to 4000 EUR to support keynote speakers at various sessions of the Theme 11 (under patronage of SGA)
- Geological Society of Bolivia Anniversary Meeting (La Paz 2011) – Osvaldo Arce-President – they wish to have 2-3 keynote SGA speakers on ore deposits, geochemistry, modeling etc. – Council asked F. Tornos to offer SGA keynotes (ask B. Lehmann and F. Barra if they would be willing to act on behalf of SGA).

SGA Council nominated E. Ferrari to negotiate SGA participation in other future South American events and to inform Council about results.

### Any other business

*Proposal for SGA-IRD-UNESCO-IUGS-SEG Metallogeny Courses in Africa - update (H. Frimmel, J. Pašava)*

J. Pašava informed about negotiations with IUGS and IRD. Council approved proposal by H. Frimmel to proceed with organizing the African Metallogeny Course according to suggested project vehicle (at the moment approved financial co-sponsorship by IUGS and IRD).

*Insurance for SGA (update from D. Leach, G. Beaudoin and F. Tornos)*

Council decided to wait for additional quotation from G. Beaudoin and then will decide with which company the insurance will be organized (has to be completed before SGA 2011 meeting). E. Campos should find out what kind of insurance the LOC/University has in relation to the organization of the SGA 2011 meeting and field trips.

*Online membership fee payment*

Council noted that it is important that every SGA member gets printout of his/her receipt for the payment (G. Beaudoin).

*SGA-SEG Agreement on exchange of modules (case: SEG at SGA 2011 vs. SGA at SEG 2012) – F. Tornos*

Information was provided by F. Tornos. SGA approved that SEG will have in Antofagasta a keynote speaker, special session and a field trip and waits for the confirmation from SEG for similar treatment at SEG 2012 (Lima).

*SGA award for recognition of special services to the society - update (H. Frimmel)*

H. Frimmel apologized for not being able to progress on this issue – a report will be given at the next Council meeting.

*Specification of items that should be available at SGA booths (H. Frimmel)*

Council recommended that H. Frimmel will work jointly with E. Campos to secure sufficient amount of promotional materials for and manning the SGA booth at Antofagasta.



Participants of the SGA Council hosted by IGME in Madrid in April 8, 2011 (from left to right: B. Lehmann, D. Leach, E. Campos, P. Williams, E. Ferrari, F. Tornos, J. Relvas, G. Beaudoin, A. Cheilletz, S. Lange and A. Vymazalova (photo by Jan Pasava)).

*SGA lecturers (F. Tornos et al.)*

Council approved this concept and emphasized that SGA should be using active and the former SGA members. F. Tornos will suggest a list of SGA lecturers to be discussed at the next Council meeting.

*Collaboration with other societies (J. Pašava et al.)*

Except of IAGOD and SEG, SGA wishes to develop relationship with other societies on both national and international level through various activities and exchange of products. J. Pašava will prepare a proposal for MOU for the next Council meeting.

*Program of the SGA General Assembly (J. Pašava)*

Council decided that the SGA General Assembly will be held on Wednesday, September 28, 2011 in Antofagasta, Chile. The precise venue and time will be announced in the Final Conference Program. Council also approved the following Program:

- Agenda
- Report of the President
- Report of the Treasurer with financial outlook for 2012
- Report of the Executive Secretary on SGA past and future activities

- Report of the Chairman of the Nominating Committee
- Invitation to the SGA 2013 Meeting in Uppsala, Sweden
- Various

**Date and Place of the Next Council Meeting**

The next Council Meeting will be held on Sunday, September 25, 2011 from 13.00 to 17.00 (the precise venue and agenda will be announced in due time).

## PRICES FOR ADVERTISING IN SGA NEWS

1 page	400 EUR
1/2 page	200 EUR
1/4 page	125 EUR
1/8 page	70 EUR

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Vice-President	P. Weihed (Sweden)
Executive Secretary	J. Pasava (Czech Republic)
Treasurer	D. Leach (USA)
Promotion Manager	H. Frimmel (Germany)
Chief Editors	B. Lehmann (Germany) - MD European Office P. Williams (Australia) - MD Australian Office M. Chiaradia, C. Heinrich (Switzerland) - SGA News G. Beaudoin (Canada) - SGA website
Student Represent.	A. Vymazalová (Czech Rep.)

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North Africa	S. Bouhlel (Tunisia)
North America	A. Conly (Canada)
South Africa	J. Kabete (Tanzania)
South America	E. Ferrari (Peru)

## Councillors: term ending on December 31, 2011

F. Bierlein (Australia)
K. Kelley (USA)
P. Williams (Australia)
R. Foster (UK/Turkey)
R. Presnell† (USA)
V. Shatov (Russia)

## Councillors: term ending on December 31, 2013

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S. Diakov (Canada, East Asia)
P. Eilu (Finland)
A. Piestrzynski (Poland)
F. Hongrui (China)
J. Relvas (Portugal)
R. Smith (Australia, China)
E. Campos (Chile)

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Executive Director	B. G. Hoal (USA)

## Ex officio Members, IAGOD

Secretary General	S. Cherkasov (Russia)
Publication Manager	R. Seltmann (U.K.)

## LIST OF NEW SGA MEMBERS (October 31, 2010 - April 30, 2011)

46 Regular, 113 Student, 4 Senior and 1 Corporate Members applied for membership (31/10/2010-30/04/2011)

## REGULAR MEMBERS

- Mr. Juam Manuel GARCIA San Jose de Calasanz 740, No 7 Ciudad Autonoma de Buenos Aires 1424 ARGENTINA
- Mr. Zhaoshan CHANG ARC Centre of Excellence in Ore Deposits CODES, University of Tasmania Hobart, Tasmania 7001 AUSTRALIA
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>>> page 1 **Chilean economic deposits**

Table 1: Recent economic productions of Chile (USGS, 2010).

Element	Production (t) in 2009	World ranking
Ag	2,000 (9.3%)	4
Au	40 (1.7%)	14
B	580 (12.9%)	3
Cu	5,320,000 (33.7%)	1
I	16,000 (59.3%)	1
K	600 (2.4%)	9
Li	7,400 (41.1%)	1
Mo	32,000 (16.0%)	3
Re	25,000 (48.1%)	1
S	1,600 (2.3%)	12
Se	70 (4.7%)	5

Percents in brackets are relative to world's total production.

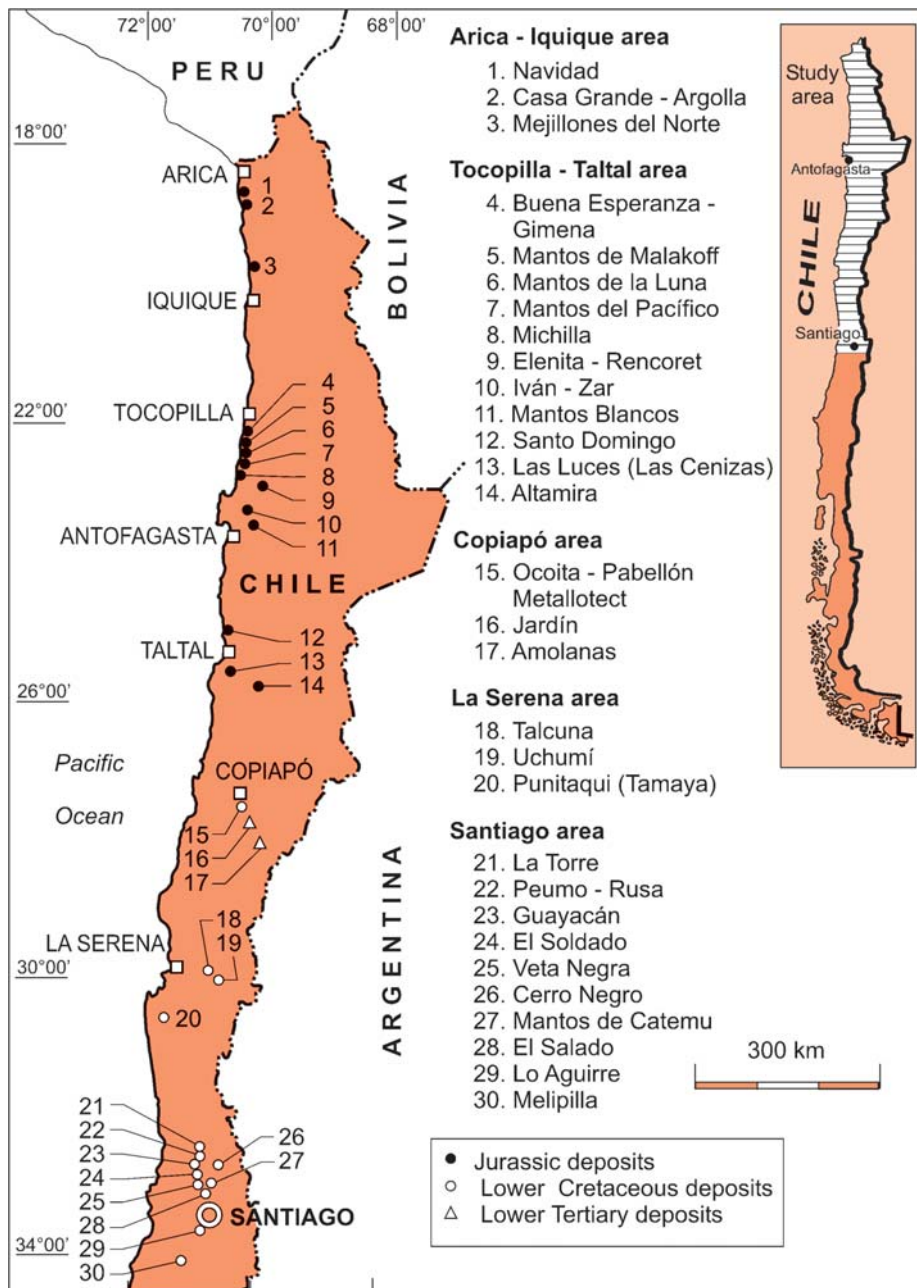


Figure 1: Spatial distribution of principal manto-type copper deposits in northern Chile. Modified from Sato (1984) and Kojima et al. (2009).

As illustrated in Fig. 1, principal Chilean manto-type copper deposits show a temporal and spatial distribution, being divided into Jurassic deposits developed laterally along the coastal range (Arica-Iquique and Tocopilla-Taltal areas) and Early Cretaceous deposits in the intracontinental back-arc basins (Copiapó, La Serena and Santiago areas). The host rocks of all these areas underwent low-grade regional (or burial) metamorphism, and are intruded by calc-alkaline granitic rocks of the magnetite series (Ishihara, 1998; Kojima et al., 2003). However, in several areas such an intrusion is not observed near deposits (Camus, 1990). Primary copper zones are generally developed in host rocks that locally experienced propylitic alteration with albite, chlorite, epidote and calcite. Sato (1984) divided these deposits into the following three types on the basis of modes of occurrence: (1) tabular orebodies in a particular stratigraphic horizon (Talcuna, Cerro Negro), (2) stacked tabular orebodies in lithologically permeable parts (Buena Esperanza, Michilla), and (3) structurally-controlled irregular orebodies (Mantos Blancos, El Soladado, Lo Aguirre). The main orebodies consist of a primary zone composed mainly of chalcocite-digenite, bornite, and chalcopyrite, which are partially altered to secondary sulfides (secondary chalcocite-digenite, covellite) and oxides (atacamite, chrysocolla, black copper).

Genetic models of the manto-type deposits are recently reviewed by Kojima et al. (2009), and can be generally classified into: (1) volcanic-derived syngenetic, (2) pluton-derived epigenetic, and (3) host rock-derived epigenetic. In the third case, metamorphic water generated during low-grade regional (burial) metamorphism and surface-derived fluids such as meteoric water and seawater including deeper basinal brine are assumed as the origin of ore-forming fluids.

**Iron oxide-copper-gold (IOCG) and related deposits**

The IOCG type of deposits is widely distributed along the Jurassic coastal range to Early Cretaceous intrabasin areas of Northern to Central Chile, which are included mostly in the NS-trending (> 700 km) iron zone (Central Iron Belt). These deposits are considered to be structurally controlled, and are generally distributed along the NS-trending Atacama Fault and related strike-slip faults (Maksaev et al., 2007). As observed in the manto-type deposits, the host rocks in the vicinity of mining areas are frequently

intruded by subvolcanic stocks and dykes (Sillitoe, 2003), but the affinity between the host rock and intrusion is not clearly observed in many districts. The iron belt consists of numerous magnetite (-apatite) deposits hosted in Lower Cretaceous meta-volcanics (e.g., Cerro Imán, Los Colorados, El Algarrobo, El Tofo, El Romeral, El Dorado), which are regarded as the Kiruna-type magnetite deposits. Geologic characteristics of the IOCG deposits of Chile are reviewed by Sillitoe (2003), who classifies them into the vein-type (Gatico, Montecristo, Julia, El Soldado), skarn-type (Farola, San Antonio, Panulcillo), breccias-type (Carvizalillo de las Bombas, Teresa de Colm) and composite-type (Candelaria, Punta del Cobre, Mantoverde).

The Candelaria-Punta del Cobre mining district near the Copiapó City, which corresponds to the Olympic Dam type proposed by Williams et al. (2005), occupies economically the highest rank among the Chilean IOCG deposits. The orebodies are hosted

by the Lower Cretaceous Punta del Cobre Formation, which is composed predominantly of andesitic to dacitic volcano-sedimentary members (Marschik and Fontboté, 2001). The Atacama Kozan deposit, located on the east side of the Candelaria deposit, characteristically is a layered stratiform orebody. The host rocks experienced a complex sequence of widespread pervasive and locally fracture-controlled hydrothermal events, which are characterized by extensive sodic-calcic (sodic plagioclase, scapolite, tourmaline, actinolite, epidote, calcite) and potassic (orthoclase, biotite) alterations (Marschik and Fontboté, 2001). Most Cu-Au orebodies occur as massive lenses, breccias, veinlets, and stockworks, and comprise mainly magnetite (and/or hematite), chalcopyrite and pyrite. Mushketovite occurs characteristically as the pseudomorphous magnetite replacement of columnar hematite aggregates (Marschik and Fontboté, 2001).

For the origin of IOCG deposits of Northern and Central Chile, the following three genetic models are proposed: (1) subvolcanic magma-derived epigenetic, (2) burial metamorphic-derived epigenetic and (3) surface water and basinal brine-induced epigenetic (Williams et al., 2005).

**Porphyry and exotic copper deposits**

Porphyry copper deposits represent spectacular concentrations of metals such as Cu, Mo and Au in the Earth's crust, and Chile possesses several porphyry-type deposits of economic importance (Table 2). Spatial and temporal distribution of porphyry copper deposits in northern Chile are characterized by the laterally eastward migration of magmatic arcs from the Early Cretaceous (coastal range) to the Eocene-Early Oligocene (Eastern Precordillera) belts (Fig. 2). This feature would be attributed to a decrease of the subduction angle of the Farallón (Nazca) Plate (e.g., Davidson and Mpodozis, 1991; Camus, 2003; Cooke et al., 2005). Accordingly, the extensional regime typical of the Mesozoic gradually changed into a compressive mode favorable for the emplacement of shallow intrusions and porphyry ore formation. The Eocene-Early Oligocene belt has huge deposits such as Escondida, Chuquibambilla and Collahuasi, which are situated along the Domeyko Fissure system (e.g., Cornejo et al., 1997). Furthermore, recent studies suggest that these huge deposits are located in the vicinity of the intersection between the Domeyko Fissure zone and NW-trending cross-orogen lineaments (Richards et al., 2001). A younger porphyry Cu-Mo deposit, named Caserones, which is located outside the Eocene-Early Oligocene belt, was recently discovered in the Miocene Andean belt (Fig. 2). On the other hand, major porphyry deposits in Central Chile (Los Pelambres, Río Blanco-Los Bronces, El Teniente) are included in the Late Miocene-Early Pliocene belt, and a southward temporal shift of porphyry-related magmatism occurs in the belt (Fig. 2). This is attributed to the southward migration of the NE-trending arm of the Juan Fernández ridge (e.g., Yañez et al., 2001). Recently, a large porphyry Cu-Mo prospect, named Los Sulfatos, was discovered to the south of Los Bronces deposit.

Porphyry emplacement at shallow levels has induced late-magmatic potassic (K-feldspar, biotite) alteration, which is overprinted by phyllic (sericite-quartz), and later argillic to advanced argillic alterations. Principal hypogene mineralization is related to the late-magmatic to hydrothermal

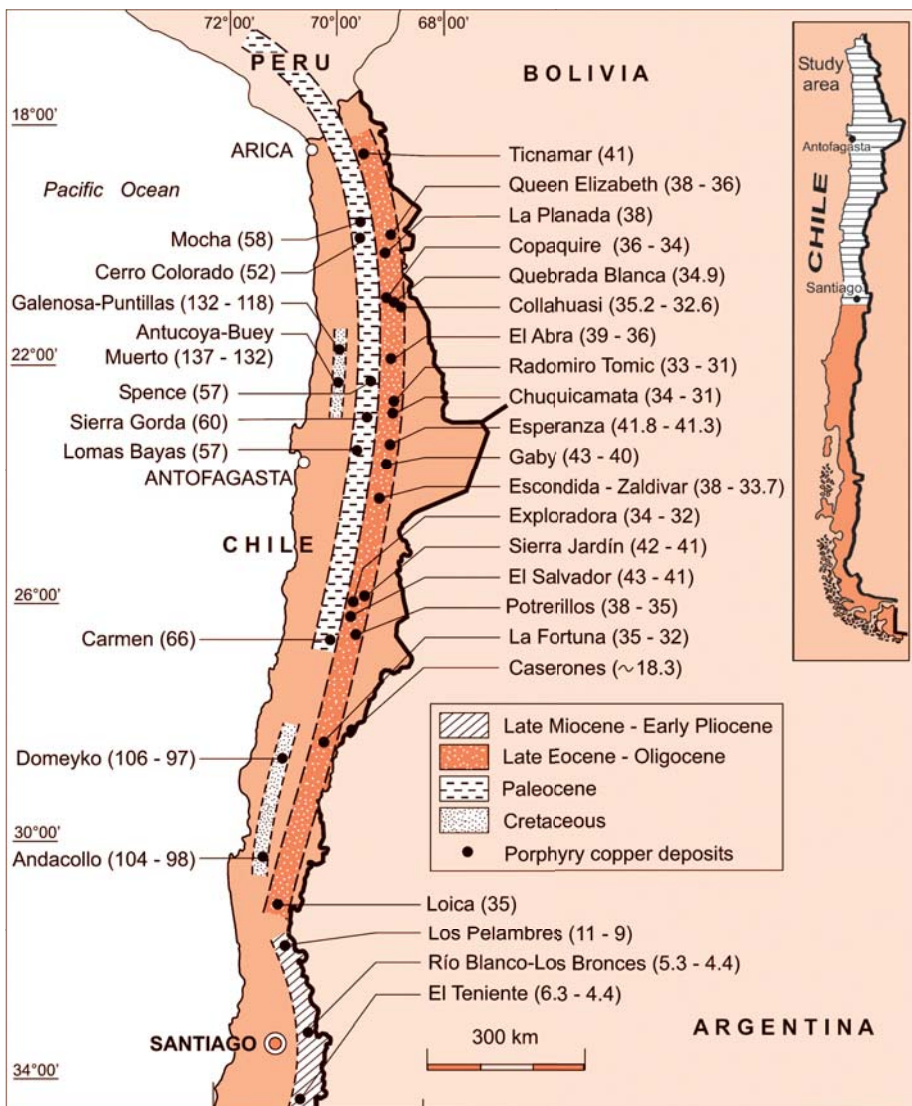


Figure 2: Locations and primary mineralization ages of principal Chilean porphyry copper deposits. Numbers in brackets are absolute ages in Ma. Modified from Camus (2003) and Kojima (2005).

stages, occurring as veinlets, stockworks and dissemination of economically important sulfide minerals, such as chalcopyrite, bornite and molybdenite. Based on mode of occurrence and mineral association, Gustafson and Hunt (1975) distinguished veins in the El Salvador porphyry deposit into “A” vein (quartz-K-feldspar-anhydrite-sulfide vein with perthitic halos), “B” vein (quartz-anhydrite-sulfide vein without halos) and “D” vein (sulfide-anhydrite vein with sericitic halos). With additional vein types, this classification is currently used in porphyry copper deposits worldwide, to establish time-space relationships within the primary mineralization. Recently, precise age data have been obtained for the hydrothermal alterations and associated hypogene mineralization on the huge deposits of the Chuquicamata and Escondida-Zaldívar areas, using various geochronologic methods (e.g., Ballard et al., 2001; Padilla-Garza et al., 2004; Campos et al., 2009; Romero et al., 2011). The occurrence of large, poorly-mineralized, biotite-tourmaline-rich breccia pipes is characteristic of the Late Miocene-Early Pliocene deposits of Río Blanco-Los Bronces and El Teniente (e.g., Skews and Stern, 1994; Kay and Mpodozis, 2001).

Extensive secondary enriched zones occur particularly in the porphyry districts of northern Chile. This type of mineralization is characterized by an irregular vertical zonation with an oxidized subzone (chrysocolla, atacamite, antlerite, brochantite) and a sulfurized subzone (supergene chalcocite-digenite, covellite) in descending order. Alpers and Brimhall (1988) and Sillitoe and McKee (1996) obtained ages of 18-15 Ma and 19-15 Ma for the formation of the main secondary oxidation zones in the Escondi-

da and Chuquicamata porphyry deposits, respectively, from K-Ar age data of supergene alunite. These data are considered to suggest the timing of descent of the groundwater level caused by the Andean uplift and related change from semiarid to extremely arid climate (Münchmeyer, 1996).

If copper mineralization occurs due to lateral migration of copper-leached surface water controlled by fault-related structural and geomorphologic factors, exotic copper deposits are formed in the vicinity of parental porphyry systems (< 6-8 km distance; Münchmeyer, 1996). The Huiniquintipa (Collahuasi), Mina Sur (Chuquicamata) and Damiana (El Salvador) are representative of this type, but there are several deposits the parental porphyry orebodies of which are still unknown (e.g., La Cascada, El Tesoro). The orebodies of the exotic deposits are generally characterized by interstitial cements in Neogene conglomerates or impregnation of supergene copper oxides in older basement rocks, and consist mostly of chrysocolla, atacamite and black copper (copper wad). In contrast to the secondary enrichment of parental porphyry deposits, the sulfide minerals are not present in exotic copper deposits.

**MAJOR Au DEPOSITS  
Porphyry gold**

Porphyry-style gold deposits are defined by large-scale and low-grade gold mineralization, and contain more elevated gold contents (50 to 1000 Mt, 0.5-2 g/t) compared with porphyry copper deposits. This type of deposit occurs characteristically in the Maricunga gold belt of the Miocene Andean area (Fig. 3). The Maricunga belt has been

employed informally to denote a geographically restricted metallogenic unit, and is formalized as a north-south elongated area, roughly 200 x 50 km in extent (Vila and Sillitoe, 1991). This belt is composed of Late Oligocene to Miocene volcanic dome complexes and porphyritic rocks, mainly with medium- to high-K calc-alkaline suites with andesitic to dacitic compositions (Kay et al., 1994; Mpodozis et al., 1995; Kay and Mpodozis, 2002), in addition to Paleozoic to Triassic igneous basement distributed in the western margin. Two types of gold deposits occur in the belt: porphyry gold (not shown in Fig. 3) and high-sulfidation epithermal gold. The former is related to dioritic to dacitic porphyries, and is represented by Refugio, Marte-Lobo and Aldebarán (Cerro Casale) deposits (Muntean and Einaudi, 2000, 2001). The latter is represented by Esperanza, La Copia and La Pepa (see Fig. 3). In these deposits, two lateral sub-belts of primary mineralization are clearly observed in association with the eastward migration of the magmatic front (Vila and Sillitoe, 1991; Sillitoe et al., 1991): the western Lower Miocene sub-belt (24-20 Ma: Refugio) and the eastern Middle Miocene sub-belt (14-13 Ma: Marte-Lobo, Cerro Casale).

Three alteration zones (deeply-located potassic alteration with K-feldspar and biotite, extensive phyllic alteration with quartz, sericite, chlorite, and peripherally-developed advanced to intermediate argillic alteration with quartz, hypogene alunite, kaolinite) occur, similar to typical porphyry copper deposits. The gold mineralization is represented by gold-bearing quartz veinlets extensively distributed in the upper parts of the host rocks, which contain small

Table 2: Major copper mines by capacity (2010), in terms of production in thousand metric tonnes (data from ICGS).


	Mine	Country	Capacity (t)	Owner(s)
1	*Escondida	Chile	1,300	BHP Billiton (57.5), Rio Tinto Corp. (30), JECO (12.5)
2	*CODELCO Norte (includes Chuquicamata and Radomiro Tomic)	Chile	920	CODELCO (100)
3	* Grasberg	Indonesia	780	P.T. Freeport Indonesia Co. (PT-FI), Río Tinto
4	* Collahuasi	Chile	520	Anglo American (44), Xstrata (44), Mitsui+Nippon (12)
5	* El Teniente	Chile	454	CODELCO (100)
6	Taimiyr Peninsula (Norilsk/Talnakh Mills)	Russia	430	Norilsk Nickel
7	Antamina	Peru	400	BHP (33.75), Teck (22.5), Xstrata Plc (33.75), Mitsubishi (10)
8	* Los Pelambres	Chile	400	Antofagasta Plc (60), Nippon Mining (25), Mitsubishi Materials (15)
9	* Morenci	USA	390	Freeport McMoRan (85), Sumitomo (15)
10	* Bingham Canyon	USA	280	Kennecott (Río Tinto) (100)

\* Porphyry copper deposits. Values in parentheses stand for percentage.

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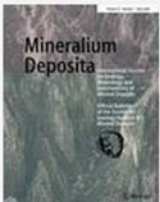
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amounts of chalcopyrite and magnetite altered into specular hematite (Muntean and Einaudi, 2001).

**Epithermal gold**

Chile has both low-sulfidation (LS) and high-sulfidation (HS) epithermal gold deposits, with the latter being nowadays economically the most important. The LS deposits are distributed on the older westernmost region of the Precordillera, with mid-Cretaceous to early Eocene ages (Fig. 3). In the Patagonian district of southern

Chile (not shown in Fig. 3), the Fachinal-Chile Chico vein-type LS deposits occur in Jurassic ash-flow tuffs (Sillitoe, 1991). By contrast, principal HS deposits are concentrated in two narrow belts within the central Andes (Maricunga and El Indio-Pascua) except the El Guanaco and Choquelimpie deposits (Fig. 3). Their time-space relationships, similar to those of the porphyry copper deposits, are closely related to the mode of plate subduction, as mentioned earlier. Figure 4 shows that the Chilean LS and HS deposits

are associated with the regional stress regimes of transtensional oblique subduction and weakly-compressive normal subduction, respectively (Kojima, 1999).

The El Peñon is the only currently-operating LS deposit in Northern Chile, and contains > 100 total tonnes of Au with average grades of 6.7 g/t Au and 217 g/t Ag in the production of the year 2010. The deposit consists of NS- or NE-trending veins, which are hosted by Paleocene to Eocene volcanic piles of dacitic to rhyolitic compositions (Warren et al., 2004). The hydrothermal alteration of the deposit is characterized by a near-neutral pH mineral association of quartz, adularia, albite, illite, calcite, chlorite and smectite, and the veins contain electrum, chalcopyrite, galena, sphalerite, acanthite, tetrahedrite, Ag-sulfosalts, and Ag-halides.

The HS deposits of the Maricunga belt are associated with dacite domes of Miocene ages, and are represented by the Esperanza, La Coipa and La Pepa deposits. In the Refugio and Aldebarán district, HS epithermal gold deposits locally occur in proximity to porphyry-type deposits (Muntean and Einaudi, 2001). The El Indio-Pascua auriferous belt is closely associated with medium- to high-K calc-alkaline volcanic and porphyritic suites with andesitic to rhyolitic compositions (e.g., Bissig et al., 2003). The large volume of dacitic rocks erupted after ~13 Ma display “adakitic” minor element geochemical characteristics, and are regarded to have been produced by high-pressure melting in a thickened crust (Bissig et al., 2003). As illustrated in Fig. 3, it is clearly recognized that the mineralization ages become younger southwards over the two belts (Vila and Sillitoe, 1991; Bissig et al., 2002). This temporal difference is considered to partially reflect the southward migration of the NE-trending arm of the subducting Juan Fernández Ridge, which affected the Chilean flat-slab construction (Yañez et al., 2001; Kay and Mpodozis, 2002). The El Indio-Pascua belt has huge HS deposits, including Pascua-Lama (500 t Au) and El Indio-Tambo (300 t Au), but porphyry gold deposits have not yet been discovered in the belt. Main hydrothermal alteration zones in these deposits are characterized by widespread advanced argillic alteration and intense silicification. Deposits such as fault-controlled vein (El Indio, La Pepa) and breccia-hosted dissemination (Esperanza, El Tambo, La Coipa, Pascua) occur in the Maricunga and El Indio-Pascua belts, and contain native gold, pyrite, chalcopyrite, enargite and alunite as principal

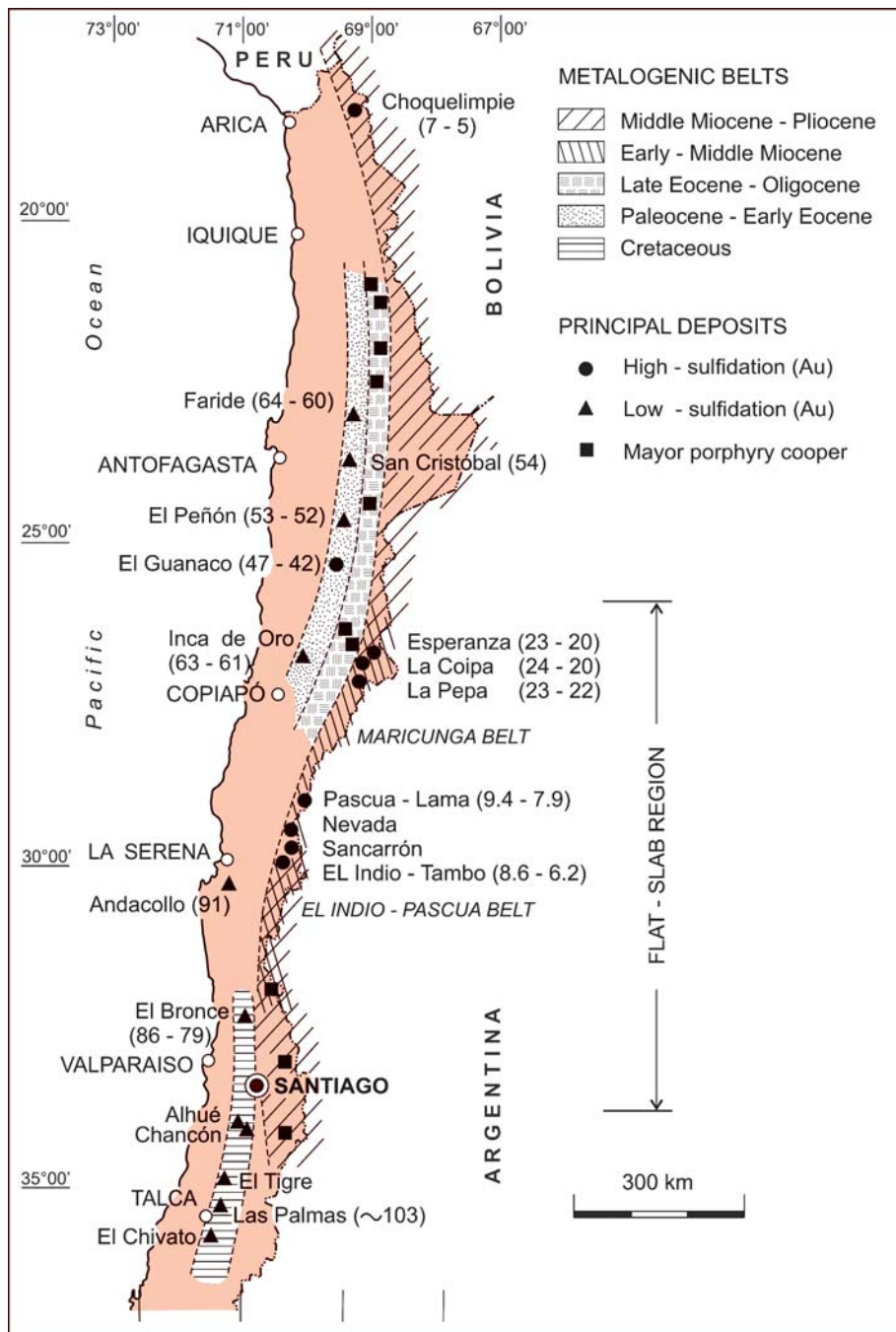


Figure 3: Spatial and temporal distribution of principal high- and low-sulfidation epithermal gold deposits in Chile. The porphyry gold deposits (Refugio, Marte-Lobo and Cerro Casale) are located near the La Coipa and La Pepa deposits in the Maricunga belt. Numbers in brackets are ages in Ma. Modified from Kojima (1999).

minerals (Maksaev et al., 2007; Fogliata and Hagemann, 2010).

**Rare metal and nonmetallic deposits**

As mentioned earlier, the economic importance of rare metal and nonmetallic deposits currently becomes higher because of industrial requirements. Chile has a variety of industrial reserves, among which Li, I and B are particularly reviewed in this section.

Li is the lightest metallic element with a high ionization tendency, and thus tends to concentrate in brine phases as chlorides. The principal Li deposit is Salar de Atacama located on the Andean platform of the Atacama Desert, where brines contain Li concentrations up to 0.14 – 0.17 wt.% higher than those of other brine deposits such as Salar de Uyuni (Bolivia) and Salar de Hombre Muerto (Argentina). Many geologists regard the surrounding Tertiary volcanic as the Li origin, because they are enriched in Li (33.4-35.3 ppm) compared to the average crustal abundance (Vila, 1986). Various formational ages of the brine deposit has been presented using distinct methods, and their results range from Early Miocene to Pliocene.

Borates occur as thin layers interbedded with fine-grained sediments in Salar de Ascotán, North Andean Cordillera, and as

brine solutes in Salar de Atacama (Chong et al., 2007). The Salar de Ascotán contains a variety of borates, but the only economic mineral is ulexite.

Iodine occurs principally as iodates in the nitrate salt deposits. The nitrate and iodate deposits are distributed uniquely along a NS-trending desert belt in the Precordillera, and are hosted by the Neogene Tertiary volcanoclastic rocks. The orebodies occur as irregular cements (“caliche”), stratiform layers and veinlets, and contain iodate minerals such as lautarite, hectorfloresite and fuenzalidaite (Chong et al., 2007). A variety of models are proposed for the origin of the nitrogen in the nitrate and iodate deposits, and could be classified into the following three theories: (1) volcanic origin (oxidation and precipitation of volcanic components through catalytic reactions), (2) atmospheric origin (fixation of atmospheric N<sub>2</sub> by electrochemical or photochemical reactions), and (3) biogenic origin (nitrification of NH<sub>4</sub> derived from seaweed and vegetation in saline lakes or transportation of leached bird “guano”).

**Other types of deposits in Chile**

In addition to the aforementioned deposits, other types of ore deposits occur in Chile. Among them, the El Laco magnetite depo-

sit, located in the principal Andean Cordillera, has been historically debated regarding its origin, as subaerial magma vs. hydrothermal origin (see Naranjo et al., 2010). Recently, many geologists suggest close affinities between El Laco and deposits in the Cretaceous Central Iron Belt, and then the El Laco deposit could be regarded as the youngest (Plio-Pleistocene) Kiruna-type iron deposit. North of the Salar de Atacama, red-bed type copper deposits of Paleozoic (Tuina) and Miocene (San Bartolo) occur in continental clastic sediments.

The metallic deposits of Southern Chile are represented by Paleozoic Besshi-type copper deposits (Mina Vieja, Casa de Piedra, Trovolhue, Hueñalihuén, Piren) in the Tirúa-Valdivia coastal Cordillera, by the Paleozoic Ironstone deposits (Mahuilque, Relún) in micaceous metamorphic rocks, and by the Mesozoic El Toqui Pb-Zn skarn deposit.

**CONCLUDING REMARKS**

North-Central Chilean economic deposits comprise principally hydrothermal to surface water-related deposits formed during the Andean tectono-magmatic cycle since the Mesozoic. They include the Mesozoic coastal-range deposits (manto-type, IOCG, Central Iron Belt), Cretaceous to Oligocene

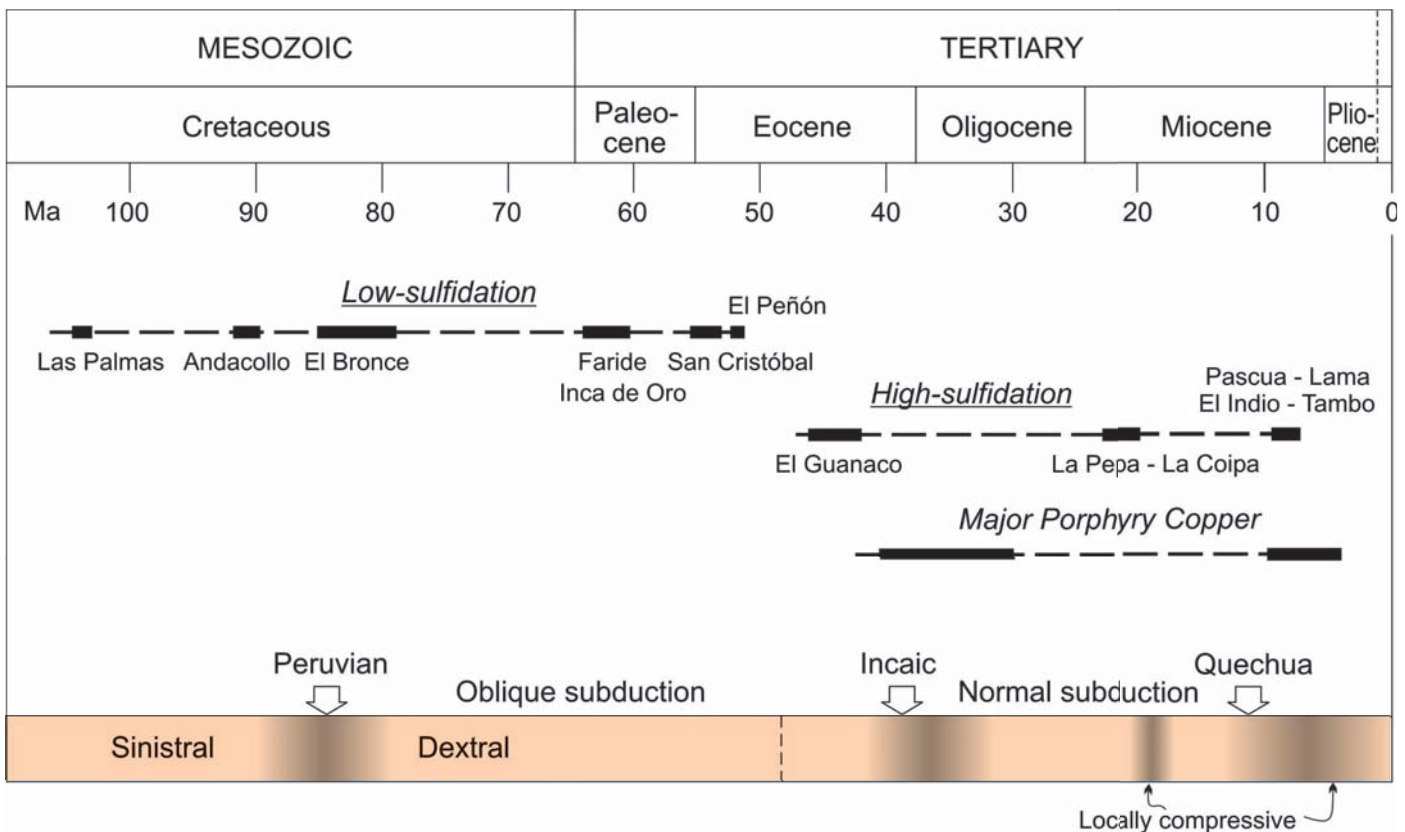


Figure 4: Age of formation of principal epithermal gold and porphyry copper deposits in Chile and its relation to regional mode of plate subduction. Modified from Kojima (1999).

subaerial deposits in the Precordillera (porphyry copper deposits of Northern Chile, LS epithermal gold deposits), Miocene Cordillera-type deposits (porphyry gold, HS epithermal gold, porphyry copper in Central Chile) and Plio-Pleistocene deposits (Salar de Atacama, El Laco). The deposits display a temporal and spatial distribution that is closely linked to temporal and spatial shifts of subduction-related arc magmatism and associated Andean orogenic cycles. This could possibly provide a practical guideline for Chilean mineral exploration.

**ACKNOWLEDGEMENTS**

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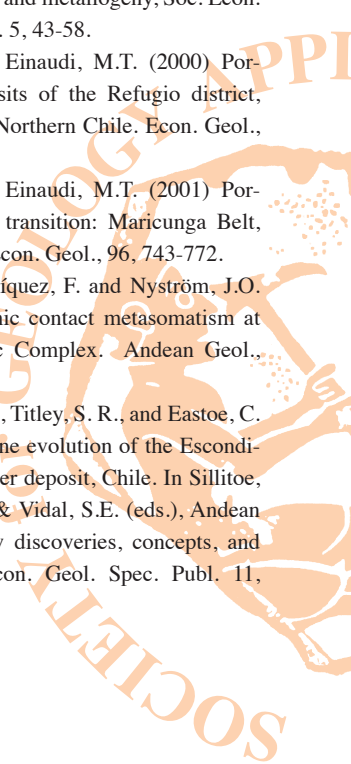
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## SGA booth at the SEG conference

Keystone, Colorado, October 2-5, 2010

Karen Duttweiler Kelley <kdkelley@usgs.gov> and David Leach <dleach@usgs.gov>

The SGA booth at the SEG conference in Keystone, Colorado (October 2-5, 2010) drew a lot of interest, not only for existing publications, but also handouts and information about the upcoming meeting in Antofagasta, Chile. The booth was attended throughout the three day meeting by various SGA members including Steve Roberts, David Leach, Karen Kelley, Garth Graham, and Nieves G. Miguélez (particularly helpful because many of those that stopped by were Spanish-speaking). Memberships were offered at a discount price if purchased at the meeting. A total of 56 new memberships were received, including 18 regular members and 38 student members.



David Leach (bottom left) and SGA student members, Qingtao Zeng, Lu Yongjun and Huixiao Wei at the SGA booth.

# Ore deposits associated with the Variscan orogeny in the Bohemian Massif, central Europe Field trip report from the SGA Student Chapter Prague

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The SGA Student Chapter in Prague, Czech Republic, is expanding its educational activities in economic geology and mineral deposit research with every new semester. The annual autumn field trip of the student chapter concentrated on the mineralization styles in the southwestern Bohemian Massif, namely in the Slavkovský Les Mts. and along the Czech–German border in Bavaria. During the 3 days, we visited mining sites in the Czech Republic and Germany, along with localities of geological or mineralogical interest. The highlight was a visit to the German Deep Continental Drilling site at Windischeschenbach. The field trip was led by Kateřina Schlögllová and David Dolejš and was attended by student chapter members, with other participants from the Charles University in Prague as well as the Masaryk University in Brno.

The field excursion started in the museum of the historical mine Vilém in Krásno and by visit the open pit of the Hub stock. The Hub stock is known for its Sn–W greisen mineralization hosted in the apical part of highly evolved Variscan Li – F granites that intruded into overlying gneisses. The upper part of the hidden granite cupola was replaced by greisens with high-grade cassiterite mineralization. The greisen zone is underlain by greisenized albite granite, and, further in depth, the intensity of greisenization decreases in favour of feldspar-rich granites with lenses of hydrothermal feldspathites. The sequence is a classic example of vertical alteration zoning associated with hydrolytic leaching during fluid ascent through the granite cupola. In addition, the granite intrusion penetrated its own roof with numerous dykes, locally forming superb magmatic breccia enclosing gneiss xenoliths. We had the great opportunity to explore the pit of the Hub stock for greisen samples, wolframite, cassiterite, and topaz. Our second stop, the Soos nature reserve, is located near the town of Františkovy Lázně, and it is situated in a

tectonic basin with fresh water sediments. During the Tertiary, the basin was partially fed by highly mineralized waters from hot springs, related to intracontinental rifting in central Europe (since the Tertiary). The environment was favorable for diatomite algae; the remains of their shells accumulated on the lake bottom and now form a diatomaceous layer several meters thick, unique in Europe. The whole area is still known for the occurrence of mineral water springs and mofettes. The dry effusions of carbon dioxide come from cracks in altered granite that constitutes the crystalline basement of the basin. The CO<sub>2</sub> then trapped in the Tertiary basin fill is continuously released to the surface along crack and joint structures in the bedrock and escapes through the diatomaceous layer by creating small mofettes. During our visit we were lucky that the weather was rainy and water level was quite high so that we were able to observe gas bubbles escaping through water and mud in the craters. Our next stop was located in Bavaria (Germany), where we examined a classical road cut near the town of Marktredwitz, which superbly exposes late-Variscan igneous rocks – redwitzites (porphyritic to equigranular igneous rocks of mafic to intermediate chemical compositions ranging from quartz gabbro to quartz monzonites: *locus typicus*) and their mingling with biotite granites. This igneous suite consists of porphyritic granites with large K-feldspar phenocrysts that mingled and mixed with biotite- and amphibole-rich diorites (redwitzites). They both belong to the older intrusive suite of the Fichtelgebirge and Northern Oberpfalz batholiths, the age of which is 326 to 321 Ma. Interestingly, the younger intrusive suite is highly evolved and bears tin- or uranium mineralization. The ore potential of this batholith has been further promoted by Tertiary weathering leading to economic accumulations of uranium in deeply altered granites or cassiterite in placers. At the Marktredwitz outcrop we

observed magmatic structures of redwitzite, products of magma mixing and mingling as well as textural variability probably related to local fluctuations in water concentration in the magma. Our last stop of the first day was a large quarry near the village of Zinst (Kemnath). The quarry has closed now, but remains accessible. The rock excavated for road construction is nepheline basanite to olivine nephelinite of Tertiary age, with abundant mantle peridotite xenoliths. The volcanism started around 26 to 20 Ma at the intersection of two structures: the Eger line, the extension of the Eger Rift, and structures parallel to the Franconian Line, which is the northwestern border of the Bohemian Massif. Lava flows in this quarry were dated at 25.6 Ma and they split by columnar jointing. Many flows are rich in spinel peridotite xenoliths, providing insight into the nature of the upper mantle beneath central Europe.

We spent our second day in Germany, with the most important stop at the Continental Deep Drilling site (KTB) in Windischeschenbach. The drilling site is located very close to the boundaries of three major tectonic units of the Bohemian Massif – the Saxothuringian and the Moldanubian units intertwined with a small segment of the Bohemian unit. During the main drilling phase (1990–1994), the borehole reached the depth of 9101 meters. This was the maximum depth permitted by the modern drilling technology, limited to operating temperatures of ca. 300 °C. At this site, many technical aspects of drilling methods and geophysical exploration strategies under extreme conditions were developed and tested. We took a guided tour through the exhibitions (geological and mineralogical museum) and the facility, learned about the drilling process, walked up the drilling rig and had the opportunity to see various drilling machinery. Close to Windischeschenbach is situated a small pegmatite mine with old dumps in the forest near Püllersreuth-

Lenkermühle. The pegmatite was mined for feldspar, and in the past beryl, garnet and columbite crystals could have been collected on the site as well as pegmatites with graphic texture. We then moved to the Wölsendorf fluorite district, one of most important fluorite suppliers in the world in post-war times. The district consisted of dozens of underground mines, which excavated fluorite from NW-SE trending fault zones located near the western boundary of the Bohemian Massif and spread over an area of about 120 km<sup>2</sup>. We visited old mine facilities in the Nabburg-Stulln area. The fluorite, barite and quartz veins yielded 130 000 tons fluorite annually during the 1950's. The Freitung fluorite deposit was discovered in 1890 during construction of the local water line and within 60 years it became the largest fluorite mine in the world. The mine was operating until the 1970's, now it is a museum. Hydrothermal fluorite veins, up to several meters thick, were emplaced during Cretaceous brittle tectonic events in the foreland of the Alpine orogeny. When we visited the mining shaft, we noticed the color zoning of the fluorite veins from green to blue and mineral zoning of barite, fluorite and quartz.

During the last part of the excursion we returned to the Czech Republic and continued with several visits of ore occurrences in the south-western part of the Bohemian Massif. The Svržno ore deposit belongs to

the volcanogenic massive sulfides and it hosts Cu–Zn–Fe mineralization. The disseminated ore is present in metamorphosed mafic volcanics (amphibolite) with distinct layers of massive ore that mostly consists of pyrrhotite and pyrite, together with smaller quantities of sphalerite, magnetite, chalcopryrite and galena. Stable isotopes and thermometry combined with the metamorphic history of the area speak for the origin of massive ore by regional metamorphism and deformation of a submarine exhalative deposit. In the next stops, we have examined two zoned and layered mafic-to-intermediate intrusions at Mutěňín and Drahotín, emplaced near the Bohemian-Moldanubian crustal boundary. These intrusions are characterized by a protracted differentiation sequence under relatively reducing conditions. This process has led to extreme iron enrichment in the former (crystallization of ferrodiorites with fayalite olivine), and to the formation of spinel (hercynite) mineralization in the latter (locus typicus). More recently, these intrusions were explored for platinum-group elements. This region is also known for numerous intrusions of silicic rocks associated with Be-rich pegmatites. At the Otov locality near Poběžovice, the beryl-bearing granitic pegmatite was mined for feldspar. Classical pegmatite minerals and samples with micrographic textures can still be found at the gallery entrance or at the mine dumps. We have concluded our

trip by visiting the Pancf locality, situated in the micaschists of the Královský Hvozd unit (the Royal Forest Mts.), which belongs to the medium to high-grade metamorphic units of the Moldanubian and is well known for the occurrence of the crystals of clear blue kyanite. Kyanite is found in quartz-dominated segregations and it provides a beautiful evidence for extensive metamorphic fluid flow through this crustal segment that has led to the formation of these selvages, most probably by hydrolytic leaching. The kyanite crystals are sometimes surrounded by andalusite rims and these are interpreted as a result of subsequent decompression during orogenic exhumation.

This field excursion covered a wide range of geological interests as is necessary for a large number of chapter students from various geological departments at the Charles University. The scientific content focused on linking outcrop observations to broader ore deposit models with an attempt to place them into the context of the Variscan and Alpine orogenies. Furthermore, we hoped to promote understanding of ore-forming processes among the young chapter students. Finally, we would like to thank the staff members at individual sites, at the KTB facility in particular, for excellent tours and encourage the readers to contact the trip organizer (Kateřina Schlögllová) or the scientific guide (David Dolejš) for further information.



Student Chapter Prague visiting KTB in Windischeschenbach: Jan Soumar, Miroslav šulák, Tereza Jandová, Nikol Novotná, Barbora Hanková, Václav Špillar, Jan Loun, Jan Franěk, Jan Bubal, Lukáš Vondrovic, Matylda Heřmanská, Zuzana Šnellerová, Jaroslav Řihošek, Zita Bukovská, Michal Čurda, Hanna Ditterová, Nikola Denisová, Jana Paclíková, Petra Podzimeková, Ondřej Krýza, Luboš Vrtiška, Vít Peřestý, David Dolejš and Kateřina Schlögllová.

# SGA Student Conference "Mineral Resources for the Society"

Jan Soumar & Jakub Truba

*SGA Student Chapter Prague*

The Faculty of Science of the Charles University, Prague, hosted the SGA student conference „Mineral Resources for the Society“ between April 15 and 19, 2011. The conference was organised by the SGA Student Chapter, Prague. Altogether 62 students from 8 countries (Czech Republic 27, Germany 14, Slovakia 9, Finland 5, Poland 3, Turkey 3, Russia 1) attended the conference.

The conference started with an ice breaker party held in the Chlupáč Museum of the Earth and Life History at the Faculty. All participants enjoyed the evening with delicious food, prepared by Chapter students and local beer among the fossils under the supervision of a Carnotaurus dominating the collection.

Two days of lectures followed. We were happy to have such significant key note speakers as Prof. Pär Weihed (lecture - Precambrian VMS and gold with case studies from the Fennoscandian Shield),

Prof. Bernd Lehmann (lecture - Metallogeny of an active continental margin: The Central Andes), Dr. Jiří Zachariáš (lecture - Orogenic gold deposits in the Bohemian Massif: review and case studies) and Dr. Peter Koděra (lecture - Actual problems of metallogeny in Slovakia: Au-porphyry mineralisation at Biely vrch and Kremnica hydrothermal system). The level of students' contributions was mostly high and all presenters did their best to cope with the challenge of – in the case of many – the first scientific presentation in English. After the first day of plenary lectures the participants could join a guided sightseeing walk „Prague by night“ organised by local students. Lobby of the Faculty provided space for poster presentations. At the closing ceremony the best oral (F. Minz – MSc student, T. Dittrich, M. Valkama and J. Plášil – PhD students) and poster presentations (J. Jasberg – MSc, G. Kučerová – PhD student) were awarded with prizes provided by students

of Prague Chapter, 4C minerals s.r.o. and the Czech Geological Survey.

Many students delegates took the opportunity and went on field trips to two interesting geological and historical sites, Příbram and Jáchymov, where mining of silver, lead and uranium ran for centuries and hard labour camps of the communist regime used to be. The field trips and whole conference was ended up in a small brewery near Jáchymov.

From the positive reactions of the participants we can say that the organisers did a good job. Everything ran smoothly and without any complications mainly because of thorough and intensive preparations before the conference. Photogallery, abstracts and field trip guidebooks are available to download at <http://sga.cuni.cz/conference.html>.

Many thanks to all who contributed to this event!



*Participants of the conference.*



President of Prague Chapter –Kateřina Schoglová is giving an interview to local newspaper.



Winners of best presentations and posters. From right to left: Friederike Minz, Thomas Dittrich, Mira Valkama, Jani Jasberg, Jakub Plášil, and Marta Sosnicka.



In the Drkolnov mine, Přebram.



Field trip participant at the Vojna labour camp Plášil, and Marta Sosnicka.



Jáchymov – participants with a barrel full of Behounek radioactive (Rn-rich) spring water.



End of the field trip.

# 6th Annual Workshop and Training Session on ORE DEPOSITS MODELS AND EXPLORATION

October 31-November 4, 2011,  
China University of Geosciences, 29 Xueyuan Road  
Beijing, China, 100083

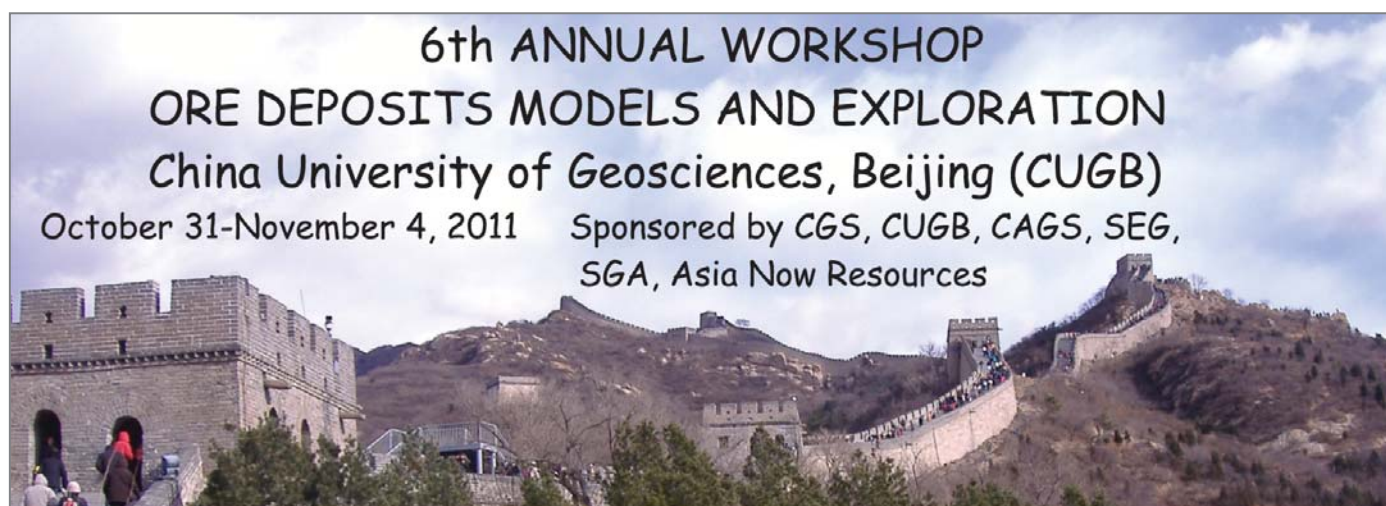
Sponsored by China Geological Survey (CGS), China University of Geosciences, Beijing (CUGB), Institute of Geology of the Chinese Academy of Geological Sciences (CAGS), Society of Geology Applied to Mineral Deposits (SGA), Society of Economic Geologists (SEG) and Asia Now Resources Corporation

#### Course description:

An in-depth examination with lectures and laboratory sessions of a spectrum of ore deposits presented by experts from several countries. The focus is on up-to-date research and industrial applications. Laboratory sessions will involve examination of hand specimens and maps of important ore deposits from around the world.

The course is intended for geoscientists of the China Geological Survey, exploration geologists working in China and students, professors and researchers from research institutes and universities.

The main language of instruction is English with sequential translation into Chinese. Some lectures are in Chinese.



## 6th ANNUAL WORKSHOP ORE DEPOSITS MODELS AND EXPLORATION China University of Geosciences, Beijing (CUGB)

October 31-November 4, 2011    Sponsored by CGS, CUGB, CAGS, SEG,  
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#### Lecture and Laboratory Instructors

Zhaoshan Chang, CODES, James Cook University, Australia – skarns, epithermal

Yanjing Chen, Peking University - metallogeny of North China Platform

David Cooke, CODES, University of Tasmania, Australia – porphyry, epithermal

Jun Deng, China University of Geosciences, Beijing - Tethyan orogeny and Sanjiang area

Richard Goldfarb, US Geological Survey, Denver, USA – gold

Zengqian Hou, Chinese Academy of Geological Sciences - metallogeny of the Tibet Plateau

Ruizhong Hou, Institute of Geochemistry, China Academy of Sciences (CAS)

Dave Leach, formerly US Geological Survey, Denver, USA – Pb & Zn in sediments

Chusi Li, Indiana University, Bloomington, USA – magmatic Ni, Cr, Pt

Jingwen Mao, Chinese Academy of Geological Sciences - Mesozoic metallogeny of eastern China

Steven Scott, University of Toronto, Toronto, Canada – volcanic-hosted massive sulfides

Jingbin Wang, Beijing Institute of Geology and Mineral Resource

Noel White, Consultant, Brisbane, Australia – iron ores; ore models in exploration

Wenjiao Xiao, Institute of Geology and Geophysics, China Academy of Sciences (CAS)

Kaihui Yang, President of Asia Now Resources, Toronto, Canada – exploration in China

For further information, contact Dr. Zengqian Hou <houzengqian@126.com>

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## &gt;&gt;&gt; FORTHCOMING EVENTS &lt;&lt;&lt;

**\* marks a new entry****2011****July 4-9**

Seventh Hutton Symposium on Granites and Related Rocks, Avila, Spain - Contact: <http://www.seventh-hutton.org/meeting/Welcome.html>

**\*July 12-14**

11th Australasian Environmental Isotope Conference and 4th Australasian Hydrogeology Research Conference, Cairns, Australia - Contact: [weblink: http://www.ainse.edu.au](http://www.ainse.edu.au)

**July 20-27**

INQUA — XXVIII Congress of the International Union for Quaternary Research, Bern, Switzerland. [weblink: http://www.inqua.tcd.ie/](http://www.inqua.tcd.ie/)

**\*July 25-29**

The Galápagos as a Laboratory for the Earth Sciences, Puerto Ayora, Galápagos, Ecuador - Contact: [weblink: http://www.agu.org/meetings/chapman/2011/fcall/index.php](http://www.agu.org/meetings/chapman/2011/fcall/index.php)

**\*July 31-August 5**

18th American Conference on Crystal Growth and Epitaxy, Monterey, California, United States - Contact: [weblink: http://www.crystalgrowth.us/acce18/index.php](http://www.crystalgrowth.us/acce18/index.php)

**August 1-5**

ICAM 2011 — 10th International Congress for Applied Mineralogy, Trondheim, Norway - Contact: <http://www.icam2011.org>

**\*August 9-11**

ECROFI XXI, Leoben, Austria - Contact: [weblink: http://ecrofixxi.unileoben.ac.at/Home.html](http://ecrofixxi.unileoben.ac.at/Home.html)

**August 14-19**

Goldschmidt 2011, Prague, Czech Republic - Contact: <http://www.goldschmidt2011.org>

**\*August 20-25**

Twelfth International Workshop on Modeling of Mantle Convection and Lithosphere Dynamics, Groß Dölln, Germany - Contact: [weblink: http://www.gfz-potsdam.de/events/2011/Mantle\\_Lithospheric\\_Dynamics\\_Workshop](http://www.gfz-potsdam.de/events/2011/Mantle_Lithospheric_Dynamics_Workshop)

**\*August 21-23**

Short course 'Sulfur in Magmas and Melts and Its Importance for Natural and Technical Processes', Goslar, Germany - Contact: [weblink: http://msasulfurmelts.org](http://msasulfurmelts.org)

**\*August 22-26**

25th IAGS 2011 — 25th International Applied

Geochemistry Symposium, Rovaniemi, Finland - Contact: <http://www.iags2011.fi>

**\*August 29-September 2**

14th Latin American Geological Congress, Medellín, Colombia - Contact: [weblink: http://www.14clg.com](http://www.14clg.com)

**\*September 2-9**

7th International School of Earth Sciences, Odessa, Ukraine - Contact: [weblink: http://www.ises.su](http://www.ises.su)

**September 4-7**

ECMS 2011 — 7th European Conference on Mineralogy and Spectroscopy, Potsdam, Germany - Contact: <http://www.physchemgeo.com/ECMS/>

**September 5-8**

II International Geology & Mining Forum, Magdan, Russia - Contact: <http://gold-pacific.ru>

**September 6-9**

AIMEX06, Sydney, New South Wales, Australia - Contact: [weblink: http://www.aimex.reedexhibitions.com.au/](http://www.aimex.reedexhibitions.com.au/)

**September 7-9**

Ore Deposits in an Evolving Earth, The Geological Society, Burlington House, London - Contact: <http://www.fermor2011.org.uk>

**\*September 18-22**

International Conference 2011: Uranium Mining and Hydrogeology VI, Freiberg, Germany - Contact: [weblink: http://www.geo.tu-freiberg.de/umh/](http://www.geo.tu-freiberg.de/umh/); c/o TU Bergakademie Freiberg Institute for Geology, Chair Hydrogeology Gustav-Zeuner-Str.12, 09599 Freiberg, Germany; phone: (+49 3731 39 2039)

**September 26-29**

11th SGA Biennial Meeting, Antofagasta, Chile. Contact: Av. Angamos 0610, Antofagasta, Chile, Tel. +56 (55) 355967, Fax +56 (55) 355977; [weblinks: www.e-sga.org](http://www.e-sga.org), [www.ucn.cl](http://www.ucn.cl); e-mail: [edcampos@ucn.cl](mailto:edcampos@ucn.cl)

**\*October 4-8**

9th Silicate Melts Workshop, La Petite Pierre, Alsace, France - Contact: [weblink: http://web.missouri.edu/~whittingtona/9thSMW/index.html](http://web.missouri.edu/~whittingtona/9thSMW/index.html)

**October 9-12**

GEOLOGICAL SOCIETY OF AMERICA: 123rd Annual Meeting, Minneapolis, Minnesota, USA - Contact: 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](mailto:meetings@geosociety.org), <http://www.geosociety.org/meetings/index.htm>

**\*October 31-November 4**

Ore Deposits Models and Exploration workshop, China University of Geosciences, Beijing, China - Contact: Dr. Zengqian Hou, e-mail: [houzengqian@126.com](mailto:houzengqian@126.com) (see page 20)

**\*December 1-3**

GEOINDO2011 — International Conference on Geology, Geotechnology and Mineral Resources of INDOCHINA, Khon Kaen, Thailand - Technical Conference: 1-3 December 2011, Kosa Hotel, Khon Kaen, Thailand; Excursion: 4-8 December 2011, from Khon Kaen to Laung Prabang (World Heritage), Laos PDR - Contact: [weblink: http://home.kku.ac.th/geoindo2011/](http://home.kku.ac.th/geoindo2011/)

**December 5-9**

AGU 2011 Fall Meeting, San Francisco, California, United States. contact: AGU Meetings Department 2000 Florida Avenue, NW Washington DC USA 20009; phone: (202-777-7333); email: [meetinginfo@agu.org](mailto:meetinginfo@agu.org); [weblink: http://www.agu.org/meetings/](http://www.agu.org/meetings/)

**2012****January 7-9**

International conference of the Geology of the Arabian Plate and the Oman Mountains, Muscat, Oman - Contact: <http://www.geoman2012.com>

**June 24-29**

Goldschmidt 2012; Montréal, Canada - Contact: <http://www.goldschmidt2012.org/>

**August 5-10**

34th International Geological Congress, Brisbane, Queensland, Australia. Contact: phone: (+61 62499556); [weblink: http://www.ga.gov.au/igc2012](http://www.ga.gov.au/igc2012)

**\*September 9-13**

1st European Mineralogical Conference, Frankfurt/Main, Germany - Contact: [weblink: http://emc2012.uni-frankfurt.de/](http://emc2012.uni-frankfurt.de/)

**December 10-14**

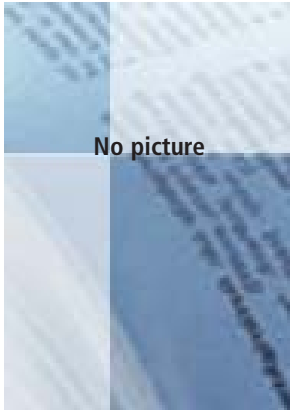
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**2013****December 15-19**

AGU 2013 Fall Meeting, San Francisco, California, United States. Contact: AGU Meetings Department 2000 Florida Avenue, NW Washington DC USA 20009; [weblink: http://www.agu.org/meetings/](http://www.agu.org/meetings/)



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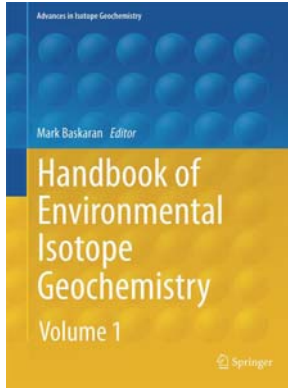
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11<sup>th</sup> SGA Biennial Meeting

# Let's Talk Ore Deposits



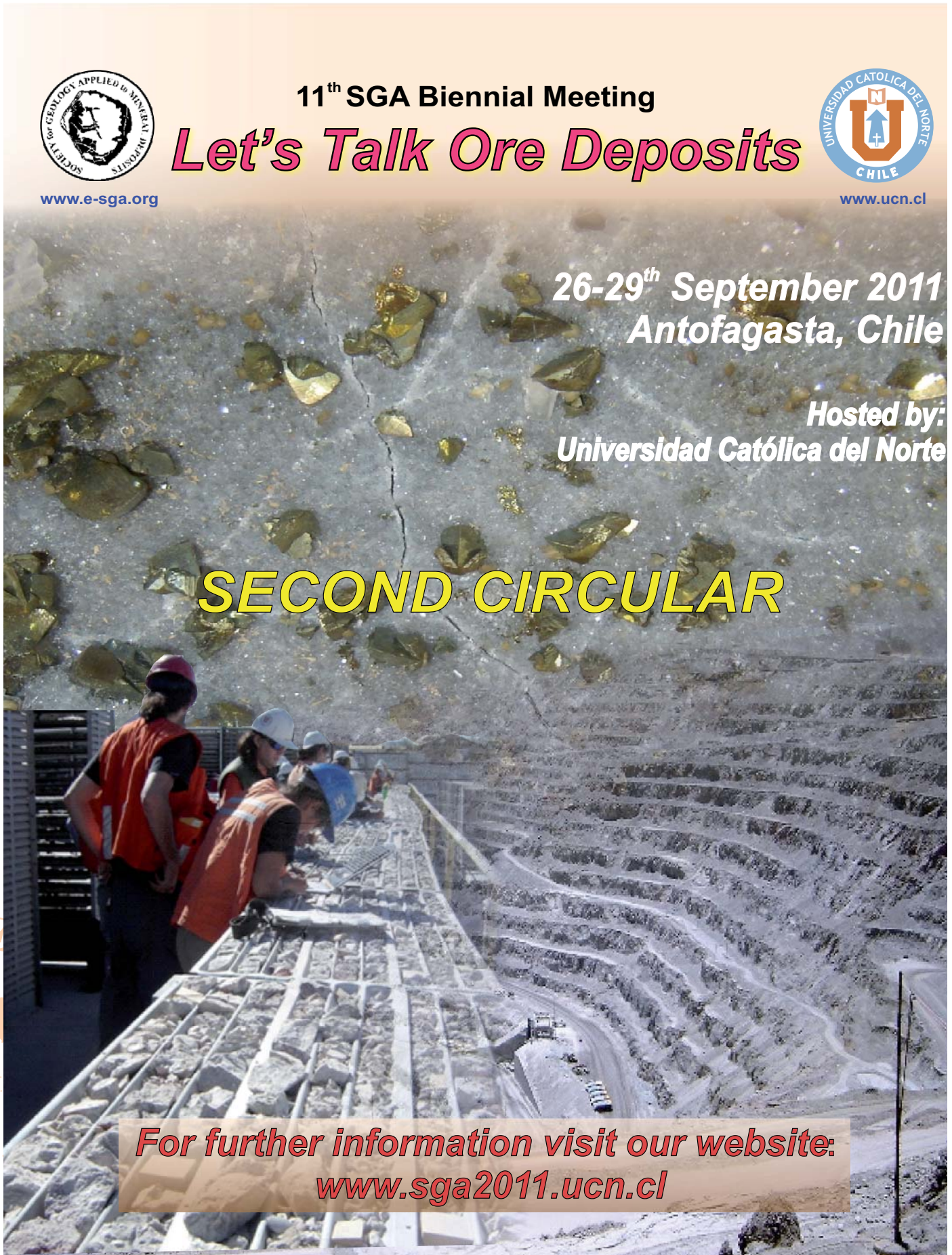
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26-29<sup>th</sup> September 2011  
Antofagasta, Chile

Hosted by:  
Universidad Católica del Norte

## SECOND CIRCULAR

For further information visit our website:  
[www.sga2011.ucn.cl](http://www.sga2011.ucn.cl)





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**Dates and deadlines**

Papers and posters	
Abstract submission opening	January 28, 2011
Abstract submission deadline	March 7, 2011
Confirmation of abstract acceptance	May 1, 2011
Final abstract submission deadline	May 27, 2011
Abstract submission fee deadline	May 27, 2011
Registration	
Open for professionals and students presenting abstract	January 28, 2011
Open for students not submitting Abstract	May 16, 2011
<b>Early registration ends</b>	<b>June 3, 2011</b>
Field trip registration deadline	July, 29, 2011
Support for students submitting abstracts	
Student financial support application opening	January 28, 2011
Student financial support application deadline	March 27, 2011
Student financial support awards	May 15, 2011
<b>SGA2011 MEETING</b>	<b>September 26<sup>th</sup>-29<sup>th</sup>, 2011</b>

**Registration fee**

Early Registration Fee			
SGA Members	Non-SGA Members	SGA Students	Non-SGA Students
US\$ 400	US\$500	US\$100	US\$150
Late Registration Fee			
SGA Members	Non-SGA Members	SGA Students	Non-SGA Students
US\$500	US\$600	US\$150	US\$200

**Registration fee includes:**

- Access to all technical and plenary sessions
- Lunch
- Morning and afternoon refreshments
- Ice breaker party
- All meeting materials including the final program and conference abstract volume in digital format.

**Exhibits**

Limited space is available for exhibits at the conference center. The exhibits will provide outstanding exposure and advertising for companies, universities and government organizations. Please contact [SGA2011@ucn.cl](mailto:SGA2011@ucn.cl) about reservations and details on how your company can benefit from an exhibit.



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### Welcome

The SGA Council and the SGA2011 Local Organizing Committee invites all professionals and students who work in the field of economic geology to participate in the 11th SGA Biennial Meeting, which will be held in the coastal city of Antofagasta, Chile, at the Enjoy Resort and Casino.

Our goal is to promote the exchange of knowledge and experience among geoscientists. The SGA2011 conference represents an exceptional opportunity for the exchange of information and experiences among international lecturers, exploration and research geologists and students in economic geology.

### Venue

The conference will be held at the Enjoy Resort and Casino, located about 500 m south of the Universidad Católica del Norte main campus.



### Organizing Committee

Chairman	Eduardo Campos
Technical Liaison	Fernando Tornos
Treasurer	María Soledad Bembow, David Leach
Students Committee	Andrés Veloso, Anna Vymazalova, Jorge Relvas
Sponsorship	María Soledad Bembow, Eugenio Ferrari, David Leach
Courses	Bernhard Dold, Thomas Bissig, Massimo Chiaradia, Adam Piestrzynski
Field Trips	Shoji Kojima, Bernd Lehmann
Edition and Technical Session	Martin Reich, Fernando Barra, Fernando Tornos, Jan Pašava
Advertising and web page	Rodrigo González, Hartwig Frimmel
Logistics	Hans-Gerhard Wilke, Rodrigo Riquelme





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The main technical program will be held over four days from Monday, September 26 to Thursday, 29 September, 2011, with the following daily structure:

- Monday, 26 and Tuesday, 27 September: Morning plenary sessions, afternoon concurrent technical sessions.
- Wednesday, 28 and Thursday, 29 September: Concurrent technical sessions.

**Plenary sessions Keynote speakers**

- Sergio Rivera (Exploraciones Mineras Sociedad Anónima, filia CODELCO)
- Christoph Heinrich (Institut für Geochemie und Petrologie, ETH Zurich)
- Martin Reich (Departamento de Geología, Universidad de Chile)
- Noel White (Consulting Geologist)
- Richard Sillitoe (Consulting Geologist, London )
- Constantino Mpodozis (Antofagasta Minerals)
- Lluís Fonbote (Département de Minéralogie, Université de Genève)
- Bernd Lehmann (Mineral Resources, Technical University of Clausthal)
- Stuart Bull (CODES, University of Tasmania)
- Sergei Cherkasov (IAGOD, Vernadsky State Geological Museum of Russian Academy of Sciences)
- Fernando Tornos (presidential address)( Instituto Geológico y Minero de España)

**Sessions**

**S1 ORE FORMING PROCESSES**

- S1.1 Large Scale Controls on Ore Genesis
- S1.2 Dating Ore Deposits
- S1.3 Geochemistry of Ore Systems
- S1.4 New Advances in the Study of Mineral Deposits

**S2 STYLES OF MINERALIZATION**

- S2.1 Porphyry Systems and Related Mineralization Styles
- S2.2 IOCG and Magnetite-Apatite Deposits
- S2.3 Orogenic Gold Deposits
- S2.4 Upper Mantle to Weathered Surface: Mineral Deposits in Mafic-Ultramafic Terranes
- S2.5 Epithermal Systems
- S2.6 Sedimentary- and Volcanic-hosted Ore Deposits
- S2.7 The Cherry on Top - Supergene Ore Formation During Climate and Landscape Evolution
- S2.8 Lithium, Salars and Industrial Mineral Deposits

**S3 ORE DEPOSITS IN SOUTH AMERICA**

- S3.1 New Developments in Cordilleran Evolution and Metallogeny
- S3.2 Ore Deposits in South American Shields
- S3.3 New Discoveries in South America

**S4 APPLIED GEOLOGY**

- S4.1 Energy Resources
- S4.2 Geometallurgy
- S4.3 Sustainability in Mining and Related Environmental Issues



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### Field trips

The Central Andes (Chile, Perú and Argentina) are renowned for their abundant and diverse metal resources, and their long history of mining. The region is one of the key metal mining regions in the world and is an important producer of copper, molybdenum, gold, silver, antimony, bismuth, cadmium, lead, lithium, iodine, tin and tungsten. In particular, the Atacama Desert in northern Chile hosts one of the world's largest concentrations of ore deposits.

The area is home to a large community of geologists dedicated to exploration, mining and academic research. The region is regarded as an ideal natural laboratory to study mineralization associated with subducting plate boundaries.

Field trip participants will have opportunities to visit porphyry and manto-type copper, magnetite-apatite IOCG and Au-Ag epithermal deposits, among other styles of mineralization.

### List of Field trips

- FT-1. Porphyry Copper Deposits, Central Chile
- FT-2. Active Volcanoes and Geothermal Fields
- FT-3. Bolivia to Northern Chile: a Metallogenic Transect
- FT-4. IOCG and Magnetite-Apatite Deposits, Copiapo Area
- FT-5. Porphyry Copper Deposits in Northern Argentina
- FT-6. Supergene Copper Deposits, Antofagasta Area
- FT-7. Manto-type Copper Deposits, Antofagasta Area
- FT-8. Copper and Gold Deposits in the Antofagasta Area
- FT-9. Salar Deposits
- FT-10. Chanaral-Maricunga transect: Ore Deposits and Geomorphology
- FT-11. Copper Deposits, Calama Area

Detailed information concerning all field trips such as itinerary, prices, dates and others will be posted on the web page by the end of December.



### Short Courses and Workshops

- C1- Understanding controls on mineralization: applied structural geology to exploration and mining.
- C2- IOCG deposits
- C3- Gold- rich porphyry systems: From petrogenesis to fluid and exploration strategies
- C4- LA-ICPMS techniques and applications
- C5- Integration of field spectroscopy, ASTER and hyperspectral technology for mineral resources exploration
- C6- Sustainability in mining: From the ore, through exploitation, towards final waste management
- C7- Skarn deposits

Those interested in offering additional short courses or workshops, please send an email to: SGA2011@ucn.cl.





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### City of Antofagasta

**ANTOFAGASTA** is located in the Atacama desert, on the Pacific Ocean coast, approximately 1,130 km (702 miles) north of Santiago de Chile. With a population of over 350,000 inhabitants, Antofagasta is the largest city in northern Chile and historically has been the main gate to one of the richest mining regions in South America.

#### TRAVELLING TO ANTOFAGASTA

Antofagasta is easily reached via Santiago de Chile with connecting flights from Europe, America and Australasia. Alternative means include bus or private transportation from nearby major cities.

#### LANGUAGE

The official language of Chile is Spanish; however, the official language for the meeting is English.

#### RESTAURANTS

Antofagasta offers a wide range of dining experiences including local and international restaurants, and a vibrant nightlife.

#### ACCOMMODATION AND HOTELS

Antofagasta offers a wide variety of lodging from luxury hotels to affordable accommodation.

#### TOURISM

Antofagasta is the gateway to the Atacama desert and its fascinating attractions, including the mystic and magical pueblo of San Pedro de Atacama, El Tatio geysers, salars, several national parks, a long coastline, volcanoes and high peaks in the Andes mountains. Bolivia, Argentina and Southern Peru are within easy reach from the city of Antofagasta.

#### For further information visit

[www.welcomechile.com/antofagasta](http://www.welcomechile.com/antofagasta)

[www.municipalidadantofagasta.cl](http://www.municipalidadantofagasta.cl)

[www.turismochile.com](http://www.turismochile.com)

#### CLIMATE

The climate is marine influenced. In September temperatures range between a maximum of 19° C (66° F) to a minimum of 13° C (55° F). Rain is almost unheard of, representing less than 4 mm -0.16 in- per year.

#### PASSPORT AND VISAS

A passport is required for travel to Chile. Participants are advised to check with their local travel agencies or the nearest Chilean Embassy or Consulate for information concerning visas. Citizens from the USA, Canada, Mexico and Australia do not need a visa, but a reciprocity fee, payable in US Dollars cash on arrival, will be charged per tourist.

For further information concerning visa please go to [www.extranjeria.gov.cl](http://www.extranjeria.gov.cl)

#### CURRENCY

The unit of currency in Chile is the peso (\$). Very few commercial locations accept other currencies (i.e. U.S. Dollars). Several currency exchange bureaus are located in downtown Antofagasta and at the Enjoy Resort and Casino.

#### BANKS

Banks are open Monday to Friday from 9 am to 2 pm. ATMs are widely distributed throughout the city.

#### CREDIT CARDS

Major credit cards are accepted in most local businesses.

