Guidebook

Society of Economic Geologists Foundation, Inc.
Student-Dedicated Field Trip Course –
IOCG and Copper-Silver Districts of
Northern Chile

May 14 - 21, 2011

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Geologic map for Central and Northern Chile (Modified from Andrew Alden 2001)

- Sedimentary Rocks:
  - Quaternary
  - Tertiary
  - Cretaceous
  - Jurassic-Cretaceous
  - Jurassic
  - Triassic
  - Carboniferous-Permian
  - Paleozoic
  - Precambrian-Paleozoic

- Igneous and Metamorphic Rocks:
  - Quaternary volcanics
  - Cretaceous-Tertiary volcanics
  - Mesozoic volcanics
  - Mesozoic-Cenozoic intrusives
  - Paleozoic-Mesozoic intrusives
  - Other Units:
    - Water
    - Glacial Ice
    - Unmapped Area
Welcome to the Society of Economic Geologists Foundation, Inc. Field Trip Course – IOCG and Copper-Silver Districts of Northern Chile, May 14 to 21, 2011. This field trip course is the eighth in Society of Economic Geologists Foundations Series that was established as a response to a student petition at the 2005 SEG Conference held in Keystone, Colorado, to provide support for field trips to important mining districts.

The course starts in Antofagasta. An organizational and safety meeting for all participants will take place at 7:00 pm on Saturday the 14th at the Hotel Tatio. The next morning you will pack up and we will depart from your hotel at 7 AM to visit Mina Julia. Roberto Aguilera Rojas will be our driver all week. Sunday evening we will stay in Taltal, a picturesque town on the beach. Tuesday we depart early again (7 AM) to visit the Altamira District and return to Taltal. Take only what you need for the day. On Tuesday we visit the Manto Verde deposit and head for Copiapó, which will serve as our base of operation for the rest of the trip. On Wednesday through Friday we will visit deposits in the Copiapó area. The field trip course ends on Friday evening with participants departing on Saturday.

Entrance to the mine sites usually follows a specific protocol; please be patient. At the mines we will receive safety training and a geological/engineering presentation. Do not take any pictures of the presentations unless and until we clear this point with company personnel. We will ask, but in general, participants can take pictures and collect samples on company property. Participants are responsible for their own samples (be aware of weight limits if you plan to take samples back with you).

We will have VERY LIMITED . . . REPEAT: VERY LIMITED . . . . . space for luggage, so you should bring clothing and field gear ONLY IN DUFFLE BAGS - NO HARD-SIDED LUGGAGE. See you in Antofagasta.
Acknowledgements

This field trip is generously supported through the Society of Economic Geologist Foundation through the SEGF Student Field Trip Fund. We also wish to thank the companies that provided access to their operations in Chile and the many company representatives that gave generously of their time to make this trip a success. Special thanks are due to Borden Putnam, Brian Hoal, John Thoms Vicky Sternicki, Joshua M. Coder, Raúl Venegas Carvajal, Florea Sgar, Cindy Gonzáles Salazar, Jose Cardenas, Roylester R Guerra Dubó, Constantin Isache, Ioan Filip, Nicolae Pop, and Roberto Aguilera Rojas.

The Society of Economic Geologists Foundation

Luz
Franke
Mina Julia
Mina Carola
Las Pintadas
AngloAmerican
QuadraFNX Mining Ltd.
S.C. Minera Atacama Kozán
Erich U. Petersen
William X. Chávez, Jr.

Cover: IOCG ore, Altamira District
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Society of Economic Geologists Foundation, Inc.
“IOCG” and Copper – Silver Districts of Northern Chile Reprise
14 – 21 March, 2011

Leaders:  Dr. William X. Chávez, Jr.  Dr. Erich U. Petersen
New México School of Mines  University of Utah
Socorro, New México, U.S.A. 87801  Salt Lake City, Utah
exchavez@nmt.edu  erich.petersen@utah.edu

Date  Itinerary  Overnight
14 May  7:00 PM: Assemble at Hotel Tatio, Antofagasta  Antofagasta
Saturday  Safety and Logistics Meeting for all participants.
 Lodging:
 Students: Hotel Costa Marfil
hotelcostamarfil@yahoo.es (Sra. Erika Corrales Poblete) – or Danitza
Teléfono: 56-55-225569 (oficina) ó 283590 (oficina) ó 269-361 (público)
 Professionals: Hotel Tatio
Avenida Grecia #1000
Telephone: (56-55)-419-111
<consultastatio@123.cl>
Contact: Luis Castillo or Alejandro
15 May  7:00AM – Depart for Mina Julia Cu-Au vein system  Taltal
Sunday  Discuss “ IOCG” styles and classification and ages in northern Chile.
 Lodging:
 Students: Residencial Paraná
Contact: Sr. LLamil Jalil Nara Negrete (dueño): 56-55-613-604
Also: Sra. Rosita
 Professionals: Hostería Taltal: 56-55-611-173 or FAX: -625
Contact: Nury Cortes/Tanya; Marseilla Cabaña
<lorens.caseres34@gmail.com>
16 May  7:00AM – Depart for Altamira District and Franke andesite-hosted Cu-Ag system;  Taltal
Monday  discuss copper systems hosted by volcanic rocks; redox settings.
 Lodging:
 Students: Residencial Plaza:
Calle O’Higgins No. 670
Telephone: 56-52-212671
Contact: Maria Cortés Rojas
 Professionals: Hotel La Casona
Calle O’Higgins No. 150
56-52-217-278 or 277
Contact: Pamela <reservas@lacasonahotel.cl
17 May  6:00AM – Depart for Manto Verde breccia-hosted copper-(gold) systems.  Copiapó
Tuesday  ‘IOCG’ systems discussion; What are “IOCG” systems? Atacama Fault Zone
 Lodging:
 Students: Residencial Plaza:
Calle O’Higgins No. 670
Telephone: 56-52-212671
Contact: Maria Cortés Rojas
 Professionals: Hotel La Casona
Calle O’Higgins No. 150
56-52-217-278 or 277
Contact: Pamela <reservas@lacasonahotel.cl
18 May  7:30AM – Visit Las Pintadas Cu-(Fe, Au) system; compare with skarn systems  Copiapó
Wednesday and to other Punta del Cobre District ore deposits
19 May  7:30AM – Visit Atacama Kozán Cu-(Fe, Au) (as cp-py-po) ore deposit;  Copaipó
Thursday: compare this system to distinct Cu-(Au) ores of the Copiapó District.

20 May

Friday: 7:30AM - Visit Mina Carola structurally-controlled Cu-Fe-Au deposit; Copiapó

Friday: ?vein system or “IOCG”? or what?

Evening: Final dinner as SEGF Field Course participants.

21 May

Saturday: End of Course – Participants Return on their own schedules

PARTICIPANT CHECKLIST AND NOTES:

♦ Participants must arrive at the Hotel Tatio in Antofagasta by 7:00PM on the 14th of May for a logistics and safety meeting.

♦ All participants MUST – REPEAT…MUST - bring hardhat, STEEL-TOE boots, reflective vest, gloves, eye protection (not sunglasses for underground visit). DO NOT plan to obtain these items during the course, as there is no time to do so!

♦ Participants must provide proof of insurance coverage valid in Chile PRIOR to participation in the course. Please bring your insurance card ID with you.

♦ All participants must sign a liability waiver form that will be provided by SEGF prior to participation in the course.

♦ Participants from the U.S. will be required to pay a one-time Reciprocity Fee (around US$140) as part of the immigration entrance process into Chile; this is done in the Immigration area prior to entering the lines that lead to the immigration checkpoints.

♦ Participants will need to check on Chilean visa requirements well in advance of their travel to Chile; for some nationalities, the visa may be obtained on the flight to Chile.

♦ All participants will need to submit their passport information (name, country of issue) to SEGF so that this information may be passed along to the mining companies as a part of our mine entrance procedures.

♦ The weather in northern Chile during May is generally balmy and cool; with especially cool nights. Please bring layers of clothing for warm days and cool evenings.

♦ Participants must bring along long pants and long-sleeve shirts for the mine visits.

♦ Sunscreen, lip balm, sunglasses, and a hat or cap are strongly recommended.

Some additional information from your field trip leaders to assist with your arrival into Santiago, bus ticket transfers/purchase to travel from Santiago to Antofagasta and travels while in Chile.

♦ Remember to check on your visa requirements WELL IN ADVANCE of your travel to Chile.
Remember, some countries' residents are charged a "Reciprocity Fee" upon entering Chile - one must pay this fee **BEFORE** passing through Immigration (sharp left at the foot of the stairs before entering the lines to the Immigration stations).

Students would benefit greatly from the purchase of a tourbook/guidebook (with maps) of some sort (Lonely Planet, Fodor's etc.) prior to this course, so that they can know at least some of the customs and general travel information prior to their arrival in Santiago.

It is highly recommended that students buy their bus tickets immediately upon arrival in Santiago.

The way to do this is:

1. Arrive SCL, collect baggage, go to kiosks in lower level arrival exit area; buy transfer bus ticket (usually on a company called TurBus, but several companies will have easy, inexpensive transport to Santiago downtown). DO NOT TAKE A TAXI UNLESS YOU BOOK THROUGH ONE OF THE AGENTS INSIDE THE AIRPORT – DO NOT TAKE AN OFFER OF A TAXI FROM ANY OF THE INDIVIDUALS WHO OFFER SUCH OUTSIDE OF BAGGAGE CLAIM. IF YOU INSIST ON TAKING A CAB, BOOK (AND PAY) FOR ONE AT THE KIOSKS OUTSIDE OF BAGGAGE CLAIM.

2. Get off the bus at the last stop, at the Estación Central Metro Station.

3. The Bus Station is a few blocks away (check with your tourbook), so ask the transfer bus driver or refer to a tourbook for directions on how to get to the Bus Station.

4. Upon arrival at the Bus Station, check for bus departures for Antofagasta, and purchase a ticket on a "Semi-Cama" style sleeper bus; these are inexpensive, comfortable, and reliable. Be sure to note the departure time, as buses keep to a strict departure timetable.

5. Students will arrive at the Bus Station in Antofagasta, and then can easily walk (approximately 2 blocks, uphill) to the Costa Marfil Hosteria, where they will staying the first night. Please note that it is not necessary to take a taxi (you will be charged about 2000 pesos for a five-minute walk). The Safety and Logistics Meeting is at the Hotel Tatio at 7:00 PM, and is a taxi ride from the Costa Marfil.

You may change money at the airport in Santiago, either as you enter the Baggage Claim area or upon leaving the Customs area. You will need Chilean money (**do not** count on using a credit card!) for your personal expenses, including some meals, so **change money prior to your arrival in Antofagasta – there will be no time to do so during the field course**.

Students are staying at the Costa Marfil hostería in Antofagasta (see address, above) – when you arrive, a room will have been assigned to you, so please use that room for your stay in Antofagasta (one night).
Because we will be staying in hostels, please bring a towel, the usual toiletries, and a facecloth for your use; please pack lightly (easier to travel, too, with less baggage and weight). Laundry is available at the hostels where we will be staying.

Las Pintadas, Garnet with calcite.
# Minerals Occurring in IOCG Deposits of Chile

## (Supergene and Hypogene)

### Copper (Fe, As) sulfates
- **Antlerite** \( \text{Cu}_3\text{SO}_4(\text{OH})_4 \)
- **Atacamite** \( \text{Cu}_2\text{Cl}(\text{OH})_3 \)
- **Bonattite** \( \text{Cu}_3\text{SO}_4(\text{OH})_6 \)
- **Brochanite** \( \text{Cu}_4\text{SO}_4(\text{OH})_6 \)
- **Chalcocite** \( \text{Cu}_4\text{SO}_4(\text{OH})_6 \)
- **Posnjakite** \( \text{Cu}_4\text{SO}_4(\text{OH})_6 \)
- **Wroewolfeite** \( \text{Cu}_3\text{SO}_4(\text{OH})_6 \)
- **Malachite** \( \text{Cu}_2(\text{CO}_3)(\text{OH})_2 \)
- **Azurite** \( \text{Cu}_3(\text{CO}_3)(\text{OH})_2 \)
- **Dioptase** \( \text{Cu}_2\text{SiO}_2(\text{OH})_2 \)

**Chalcosiderite** (compare to turquoise) \( \text{CuFe}_6(\text{PO}_4)_4(\text{OH})_8 \)

### Chalcothyrite (mineraloid)
\( \text{Cu}(\text{Fe},\text{Mn})\text{O}_x\text{Si}_y\text{O}_z\text{H}_w \), with copper content varying from ~20-40 wt % Cu

### Cu sulfides & oxides
- **Bornite** \( \text{Cu}_5\text{FeS}_4 \)
- **Chalcopyrite** \( \text{CuFeS}_2 \)
- **Chalcocite** \( \text{Cu}_2\text{S} \)
- **Covellite** \( \text{Cu}_x\text{S} \)
- **Cuprite** \( \text{Cu}_2\text{O} \)
- **Tenorite** \( \text{CuO} \)
- **Paramelanconite** \( \text{Cu}_2\text{O}_3 \)
**Silicates**

- Alkali feldspar ........................................ (K,Na)AlSi3O8
- Plagioclase ............................................ (Na,Ca)xAl12Si12O30
- Chlorite .................................................. (Mg,Fe)3(Al,Si)4O10(OH)2*(Mg,Fe)3(OH)6
- Epidote .................................................. Ca2(Al,Fe)3(SiO4)2(OH)
- Biotite .................................................... KFe3AlSi3O10(OH)2
- Muscovite (sericite) ............................... KAl3Si3O10(OH)2
- Kaolinite .................................................. Al2Si2O3(OH)4

**Other minerals**

- Alunite .................................................. KAl3(SO4)2(OH)6
- Dumortierite ............................................ Al7(BO3)(SiO4)3O3
- Tourmaline ............................................... (Na,Ca)(Li,Mg,Al)(Al,Fe,Mn)6(BO3)3
  (Si6O18)(OH)4

Magnetite after hematite Pucobre Mine
(1) Typically *trondhjemite* if biotite is only mafic mineral and makes up less than 10% of rock.

(3) The kind of alkali feldspar should be specified if possible; e.g., *microcline granite*.

(2) With less than 5% mafic minerals, the rock is *anorthosite*. With more than 40% mafic minerals, it is typically *gabbro*. Rocks with 5-40% mafic minerals are either *diorite* or *leucogabbro*, and require determination of the plagioclase, the limiting composition being *An_{50}*. 

(4) The feldspathoid should be specified in each rock name; e.g., *nepheline syenite*. 
Fig. 7.5 Commonly employed methods of representing noninterfering, multicomponent equilibria. The same type of line is used to indicate each sort of reaction in each figure, but it is impractical to plot the full set of lines on each diagram. All of these diagrams are calculated for 250°C and an H₂O pressure of 40 bars. Abbreviations: py = pyrite; gn = galena; ang = anglesite; ccp = chalcopyrite; bn = bornite; mag = magnetite. The stability field for ferrous sulfate would appear in (a), but has not been included; it would be off the diagrams at low pH in (b) and (c).

Fig. 5.5 Schematic stability relations in the system K₂O-Na₂O-Al₂O₃-SiO₂-H₂O-HCl at 400°C and 1 kb. Pyrophyllite is metastable. (a) Triangular mole fraction diagram, showing solid assemblages with quartz present. (b) Similar plot of molar Na₂O/Al₂O₃ vs. K₂O/Al₂O₃. (c) Stability of phases as a function of aNa₂O vs aK₂O. (d) Stability of phases as a function of log aNa⁺/aH⁺ vs log aK⁺/aH⁺. See text for discussion of the paths of solution composition during reaction of solution A with a mixture of feldspars. (e) Stability as a function of µNa₂O vs µK₂O. Figures based on data in Helgeson (1974), Meyer and Hemley (1967), and Montoya and Hemley (1974).
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At the end of the trip, and as soon as possible, please send a brief e-mail to Borden Putnam with a copy to Brian Hoal and John Thoms describing your experience on the trip and acknowledging the support of the Society of Economic Geologists. This is very important, as the feedback received by SEG is critical for the planning of future field course trips. You will also find that maintaining contact in this manner will greatly benefit your career whatever course it may follow. Your note may be in your native language.
log $a_{Fe^{2+}}/a_{H^+}$

Chlorite

Biotite

Orthoclase

Muscovite

Bornite

Cpy

Pyrite

Magnetite

log $a_{Cu^{+}}/a_{H^+}$

log $a_{K^+}/a_{H^+}$