Field Trip Report – Chile, May 2005

The University of British Columbia

Society of Economic Geologists
Student Chapter

The barren Atacama Desert of northern Chile was a contrast to the damp Vancouver spring for the participants of the 2005 University of British Columbia SEG student chapter field trip. And with 4500 km of driving through northern Chile in two weeks, we had plenty of time to appreciate the many differences. The trip, from April 27-May 12, was organised in order to develop a familiarity with the world-class porphyry and epithermal deposits of northern Chile and to gain an appreciation for the geologic evolution of a continental magmatic arc. Seventeen individuals participated throughout the entire trip, including six industry members and eleven students and employees from the university. For the first few days we were joined by two additional industry representatives, and on some mine tours we were also joined by geology students from the Universidad Católica del Norte in Antofagasta. The itinerary included six ore deposit tours, including El Teniente, La Candelaria, El Guanaco, La Escondida, Spence, and El Peñón, as well as tours to the Concha y Toro winery outside Santiago and the world's highest geothermal geyser field at El Tatio. And there were, of course, plenty of additional opportunities to sample the Chilean culture and nightlife along the way.

After a day in Santiago touring the city and recovering from our flight, our first stop was CODELCO's El Teniente Cu-Mo porphyry deposit, the world's largest underground mine, 80 km south of Santiago. The day of our visit happened to coincide with the mine's 100th anniversary, commemorated with a visit by the Chilean President. Nevertheless, at least 50 years of mine life remain and the potential for even higher grade ore exists at >2 km depth! Our guide for the day was Rene Padilla, who provided us with a level plan and recent publications before taking us underground. We walked an underground cross-section of the deposit from the low-grade, late stage Braden breccia pipe (0.2-0.5% Cu), through the patchy mineralization in the surrounding breccias (0.5-1% Cu) and later into quartz/sericite-altered, anhydrite-bearing, bornite-rich dacite porphyry and breccia (1-1.5% Cu). The traverse ended in the quartz stock work-veined andesite host rock that contains some 80% of the El Teniente ore (>1% Cu). The tour concluded with a visit to a superb crystal cave that contains

giant, totem pole-sized gypsum crystals discovered during mining, followed by a pleasant underground lunch.

After pushing north to Copiapo, our next mine tour was at the Phelps Dodge and Sumitomo Corporation -owned La Candelaria iron oxide Cu-Au (IOCG) deposit 26 km south of Copiapo. The tour began with an overview presentation of the geology and mine history. Candelaria, discovered in 1987 and currently with ten years of mine life remaining, is the largest deposit in the Punta del Cobre IOCG district with resources of about 600 Mt at 0.9 % Cu, 0.2 g/t Au and 4.5 g/t Ag. Our guide, Raúl Nuñez, described how the deposit was inferred to have formed between 116 Ma and 110 Ma in a graben structure, and outlined the host stratigraphic sequence that consists of a lower andesite unit overlain by tuff, ash tuff and an albite-altered tuff. These units are overlain by a diopside-scapolite+/-amphibole-altered upper andesite units and capped by garnet skarnified carbonates at the top of the sequence. Cu-Au-Ag mineralization is mainly found in the lower andesite unit and the porous lower tuff layer (grading ~1% Cu) and the overlying ash tuff layer (grading ~2% Cu), although isolated pockets of mineralization are also found in the upper andesite and overlying sedimentary units. After the presentation we were taken to the upper levels of the open-pit to see the pyroxene-scapolite skarn in the upper andesite units, and to view the stratigraphic sequence visible in the opposite pit wall. Finally we toured and sampled the ore stockpile that is characterised by chalcopyrite-rich biotite/magnetite-altered lower andesite.

We continued our northward journey, settling in at a great ocean-front hotel in Antofagasta for a few days. On our first day in this region, we drove 220 km southeast of Antofagasta to visit the 120-year old El Guanaco high sulfidation Au-Cu-Ag epithermal mining district. No mining is currently taking place there, but the mine was recently acquired by a partnership between GCH and Golden Rose with the intention of recommencing operations in addition to conducting further exploration. There is little published information on the El Guanaco deposit, so the tour, led by Miguel Guerrero, was particularly insightful. The deposit's high grades are associated with some incredible anecdotal stories: some 20 kg of gold were extracted from 20 bags of ore in 1886, the equivalent of 45 kg/t! Perhaps these stories were validated by the fact that this was the only mine we visited where we could find visible gold in the pit. Two mineralising events have been identified at El Guanaco, an earlier hypogene/magmatic phase at >250 metres depth where higher Cu-Au mineralization occurred (enargite-luzonite-pyrite) and a later shallow supergene/oxidizing event associated with high gold grades. The upper zone contains 0.2-0.3 g/t Au but up to 20-30 g/t Au can occur in limited areas.

The following day we journeyed 150 km southeast of Antofagasta to visit the BHP Billiton/Rio Tinto La Escondida porphyry Cu(-Mo) deposit at an elevation of 3150 m. The orebody is mainly hosted in andesite to rhyolite porphyry where mineralization is primarily associated with phyllic alteration, the main hydrothermal stage, and is one of several ore bodies found in dilation zones near the intersections of north-trending and northwest-trending lineaments. The duration of the magmatic and hydrothermal mineralising system was from 38-34 Ma and the average grade of the deposit is 1.3% Cu. We were given a very detailed presentation of the deposit and its development followed by a well organised tour by Sergio Valenzuela and Walter Veliz; first to the open pit viewpoint and then to the core yard, capped by a lunch in their large, brightly-coloured cafeteria. The open pit was the largest we saw on our trip, currently measuring 3200 m north-south, 2400 m east-west, and 600 m deep. There are expansion plans that involve pumping desalinated seawater from Antofagasta and expanding the pit to 4520 m north-south, 2362 m east-west and 855 m deep. Given the large size, it was surprising to many of us that the open pit is only targeting the supergene-enriched chalcocite-chalcopyrite mineralization (up to 4% Cu) and that the primary underlying bornite mineralization (up to 1.2% Cu) has not yet been fully assessed. The complex overprinting of hypogene porphyry mineral assemblages by hypogene acid-sulfate mineral assemblages and finally supergene enrichment gave us a good lesson in the confluence of factors that can be required to produce truly world-class ore deposits.

Our next visit was to BHP Billiton's Spence porphyry Cu(-Mo) deposit's project office in Calama where Christian Feddersen gave us a run down of the project and took us through the core shed. Spence was discovered in 1996 and is still under development; production is due to commence in December 2006. The deposit extends under the Antofagasta-Calama highway 65 km southwest of Calama but is completely buried by Quaternary gravel. The 57-58 Ma deposit is part of a north-trending porphyry copper belt. Locally, the mineralization is related to north-northeast-trending structures, although west-northwest-trending structures are also present in the deposit area. Spence appears to have many similarities to the La Escondida deposit; however, the wall rocks surrounding the Spence deposit are marine and continental sedimentary rocks (mainly sandstone and siltstone) with some inter-layered volcanic rocks, rather than the arc volcanic wall rocks typical of some other porphyry deposits in northern Chile. Outcropping sedimentary rocks near the deposit resisted any propylitic alteration, thereby reducing the size of the hydrothermal footprint. This highlighted the importance of innovative exploration strategies required in covered areas. The Spence deposit again showed us the importance of supergene enrichment in generating a viable ore body and the drill core showed excellent examples of the effects of repeated oxidisation and leaching events associated with fluctuations in the water table, including the development of exotic copper and atacamite mineralization in the younger gravels above the deposit.

The sightseeing highlight of the trip was our visit to the El Tatio geyser field near the Bolivian border north of San Pedro de Atacama. After a very early (4 AM!) start from San Pedro and a particularly rough 95-kilometre drive under the stars, we made it up to a very chilly El Tatio geothermal field at 4320 metres (the highest point of the trip) in time to catch the sunrise on a beautiful clear day. Many of us had seen geysers before, but the size of El Tatio field and the spectacular landscape of desert and snow-capped volcanoes surrounding the geysers were truly unique. The tour then returned to San Pedro de Atacama through more of this amazing altiplano landscape. We saw the steaming Volcán Putana (5890 m), llamas and vicuñas, and visited the small 'pueblito' of Atacamena de Machuca before following the sharply incised Rio Grande valley back to San Pedro. After some furious shopping at the local market we were on the road again back to Antofagasta, completing an elevation drop of 4320 m over the course of six hours.

Our final mine tour was Meridian Gold's El Peñón high grade Au-Ag epithermal vein deposit, discovered in 1992, 160 km southeast of Antofagasta. The deposit consists of six main en echelon veins averaging 10-12 g/t Au, including the bonanza Quebrada Colorada vein with grades of 5-50 g/t Au and an average of 300 g/t Ag. The veins strike north-south, are vertical to steeply-dipping and trend up to 4 km long. The mineralised veins cut flow-banded and tuffaceous rhyolite, underlain by dacitic to rhyolitic rocks. Argon-argon isotopic ages on adularia suggest a mineralization age of 52-53 Ma. Currently, 2 million ounces of Au and 50 million ounces of Ag remain in the reserve category, providing another 7 years of mine life. Our guide, Greg Struble, took us on an underground tour and a visit into the Cerro Martillo open pit before providing a tasty lunch and showing us some specimens, maps and cross-sections. Supergene oxidation extends to great depths throughout the deposit, so it was often difficult to identify primary minerals and textures; however, bladed quartz after calcite was evident in numerous samples, a feature typical of many low-sulfidation epithermal deposits. As a bonus, El Peñón was the only mine visit that included a tour of the processing plant.

The tour group in Chile learnt a great deal about the continental magmatic arc environment, porphyry copper deposits, iron-oxide copper-gold deposits and epithermal precious metal deposits. The importance of supergene enrichment was clearly demonstrated at many of the deposits and by visiting so many mines in such a short time, we had the opportunity to appreciate the similarities and differences between the various deposit types and subtleties within the framework of specific mineralization styles. Northern Chile provided a spectacular outdoor geologic laboratory enriched by the people involved with the tour and by the gracious and hospitable citizens of Chile.

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