UNIVERSITY OF CHILE, SANTIAGO DE CHILE
SOCIETY OF ECONOMIC GEOLOGISTS
STUDENT CHAPTER

Field Trip 2016 – 2017

Santiago de Chile, September 2017

CLARIFICATION NOTE

University of Chile, Santiago de Chile SEG Student Chapter clarifies that the initial field application submitted as financial assistance of Steward R. Wallace Fund, Round II, 2015 is different from what is described in this report. The original plan included visits to Minera Los Pelambres (MLP, AMSA), Minera El Soldado (MES, Angloamerican) and División Andina (DA, Codelco). However, it was impossible to get approval for visiting División Andina of Codelco (they request that all the visitors could pass a physical exam to work over 3,000 m above sea level, which costs more than US$100 per person). In addition, the visit to Minera El Soldado was scheduled for November 30, 2016. However, due to contractor workers strike and disturbs in Los Bronces operation during the second half of November, Angloamerican suspended all the visits to their operations in Chile.

Therefore, we made relevant changes to the original plan, due to the shortcomings that arose and restructured our visits. We decided to visit the Cerro Negro stratabound Cu deposit, Los Pelambres and El Teniente porphyry Cu-Mo deposits.

1. INTRODUCTION

The University of Chile, Santiago de Chile SEG Student Chapter is hosted in the Department of Geology of University of Chile. Activities of the student chapter involve field trips, talks and conferences with the aim of learning about the economic geology, for example, conditions for the formation of mineral deposit, tectonic environments, mineralization characteristics and metallurgical processes. Chile being the main producer of Copper in the world has world-class mineral deposits such as porphyry, stratabound and IOCG and as a student chapter, it is important that we visit these ore deposits.

2. FIELD TRIP PARTICIPANTS

The participants who attended the field trips were undergraduate, graduate students and professors of geology of the University of Chile

Table 1. Field trip participants of University of Chile, Santiago de Chile SEG Student Chapter.

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*Not all students attended the three field trips.

3. TRIPS ITINERARY

The itinerary was as follows:

Tabla 2. Trip itinerary of University of Chile, Santiago de Chile SEG Student Chapter.

Date	Deposit	Company Mine	Activities
October 18-19 2016	Los Pelambres Cu-Mo Porphyry	Antofagasta Minerals	Safety talk and introduction to the geology of Los Pelambres deposit; visit to the open pit area and drill-core storage facilities.
May,17 2017	Cerro Negro Stratabound Cu (Ag)	Compañía Minera Cerro Negro	Safety talk and introduction to the geology of Cerro Negro deposit; visit to the open pit area, hydrometallurgical plant and drill-core storage facilities.
June 14, 2017	El Teniente Cu-Mo Porphyry	CODELCO	Safety talk and introduction to the geology of El Teniente deposit; visit to the underground mine area and drill-core storage facilities.

4. TRIP SUMMARIES

The deposits visited are as follows:

4.1. LOS PELAMBRES PORPHYRY Cu-Mo DEPOSIT

Los Pelambres is a mining company of Antofagasta Minerals and is a world-class porphyry Cu-(Mo) type deposit. This deposit occupies the sixth place in the production of Cu in Chile and the seventh place in the world.

Los Pelambres deposit is located in the Andean Cordillera between 3500 – 3600 meters above sea level in commune of Salamanca of Coquimbo Province and its port is located in the Commune of Los Vilos, in the sector of Punta Chungo (see Figure 1).

Figure 1. Location scheme of the mining operation Los Pelambres, 4th Region of Coquimbo.

Los Pelambres *"is related to an Upper Miocene tonalite stock, which was passively emplaced into Upper Jurassic-Middle Cretaceous andesitic volcanic and sedimentary strata which constitute a north-south- trending monocline"* (Sillitoe, 1973).

In these deposits, the Cu-(Mo) sulfides and sulfosalts mineralization are composed of chalcopyrite, bornite, tennantite and molybdenite (mainly) developed in the Pachon Formation (andesitic- volcanic), Los Pelambres Formation (deformed andesite's rock) and Abanico Formation (sedimentary basin). The mineralization occurs in fractures, veins, stockwork and hydrothermal breccia.

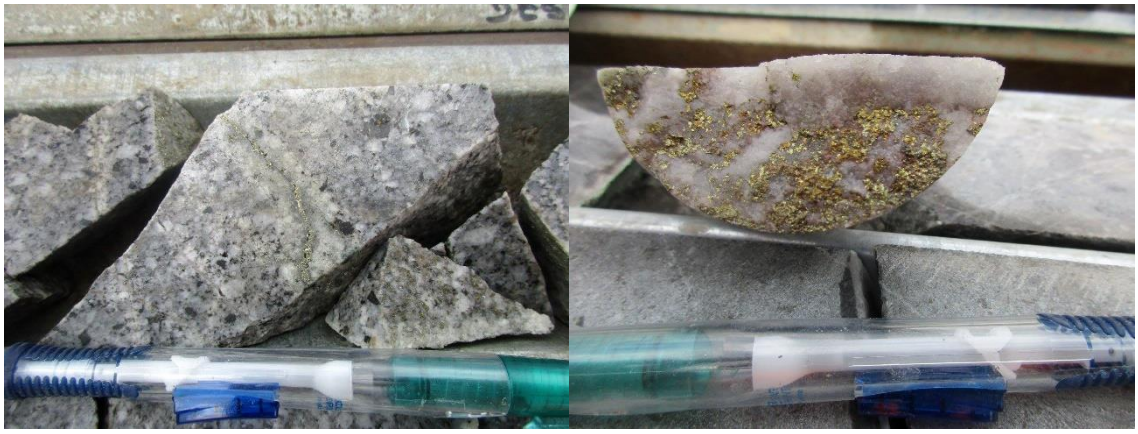

Figura 2. Drilling cores with chalcopyrite mineralization in veins.

In 2013, Los Pelambres reached a production of 405.300 metric tons of fine copper and produced 9,000 tons of molybdenum concentrate as by-product. Copper and molybdenum production is distributed to Asia and Europe from the Punta Chungo port.

Figura 3. Open pit in Los Pelambres porphyry Cu-Mo deposit.

A group of 13 members of the SEG Student Chapter of University of Chile participated in a field trip to Los Pelambres copper mine.

Figure 4. The group of students in the Los Pelambres mine.

4.2. CERRO NEGRO STRATABOUND Cu DEPOSIT

Stratabound copper deposits represent the third most important source of copper in Chile after porphyry and IOCG deposit. These deposits also contain variable amounts of precious metals, including silver, which can be concentrated up to economic levels (Reich et al., 2010). Most importantly, several studies have recognized the association of Cu (Fe) sulfides and sulfosalts with solid bitumen and pyrobitumen within these deposits (Wilson et al., 2003). In addition, stratabound Cu (Ag) deposits are intimately related to active regional faulting (Atacama).

Cerro Negro belongs to these deposits and is located at Coastal Range between 470 – 1050 meters above sea level and ~210 Km northeast Santiago, 5 th Region of Valparaíso. The main bodies are Rajo Media Luna and Chiringo.

Figure 5. Location of Cerro Negro stratabound Cu (Ag) deposit, 5th Region of Valparaíso, Chile.

Figure 6. Media Luna open pit in Cerro Negro stratabound Cu (Ag) deposit.

Cerro Negro is hosted in volcanic rocks of intermediate composition that alternate with sedimentary (sandstones, tuff, shales, calcilutites and laminated mudstones) units. In these

deposits, the Cu(Ag) sulfides mineralization are composed of chalcocite, bornite and chalcopyrite and occurs in fractures, veins or vesicle-filling, and is intimately associated with organic phase.

Figure 7. Left: Chalcocite in tuff rock. Right: Chalcopyrite in calcilutite rock.

Figure 8.Visit to Cerro Negro drill-core storage facilities.

In Cerro Negro, the mineral processing is carried out in a sulfide and oxidized plant after grinding and concentrating the material. Leaching and Electro-winning are the industrial electrolytic process to recover Cu.

Figure 9. Technical visit to the hydrometallurgical plant, leaching and electro-winning stages.

A group of 14 members of the SEG Student Chapter of University of Chile composed the field trip, the students could learn about the geology, mineralization and metallurgical extraction about Cerro Negro stratabound Cu deposit.

Figure 10. The group of students and professors in the Cerro Negro mine.

4.3. EL TENIENTE PORPHYRY Cu DEPOSIT

Porphyry copper deposit represent the most important source of copper in Chile. These deposits are generated mainly in magmatic arc (including back arc) environments subjected to a spectrum of regional-scale stress regimes, apparently ranging from moderately extensional through oblique slip to contractional and are defined as large volume of hydrothermally rock centered on porphyry Cu stocks (Tosdal and Richards, 2001).

El Teniente is one of the divisions of the state-owned company –CODELCO- and is Neogene giant Cu-Mo porphyry deposit (75 Mt Cu) of the Chilean Andes that occurs within an upper Miocene – Pliocene volcanic-plutonic complex (Maksaev et al., 2003). This is located at the Andes Range, 54 km from Rancagua city, southeast of Santiago.

Figure 11. Location of the main mining operation El Teniente porphyry Cu- (Mo), 6th Region of Libertador General Bernardo O'Higgins, Chile.

In addition, El Teniente is the largest underground copper mine in the world and has more than 3000 kms of underground galleries. Among its production units are the ore bodies: Diablo Regimiento Fase IV, Esmeralda, Dacita, Reservas Norte, Pipa Norte, Sur Andes Pipa, Pilar Norte y Teniente 4 Sur.

El Teniente is hosted in volcanic rocks of Farallones Formation that included: (i) El Teniente mafic complex with subvolcanic mafic rocks, (ii) breccia pipe and basaltic porphyry, (iii) tonalite stocks (iv) micro-diorite porphyry, (v) dacitic porphyry and breccias (vi) dacitic porphyry with late magmatic veins (vii) breccia pipe "Braden" (viii) supergene enrichment.

Figure 12. Left: Mining front of the mafic complex El Teniente (gabbro, diabase and basaltic porphyry). Right: The group of students in the underground mine area.

In these deposits, the Cu-(Mo) sulfides mineralization are composed of chalcopyrite, bornite and molybdenite (mainly) and occurs in fractures, veins or stockwork.

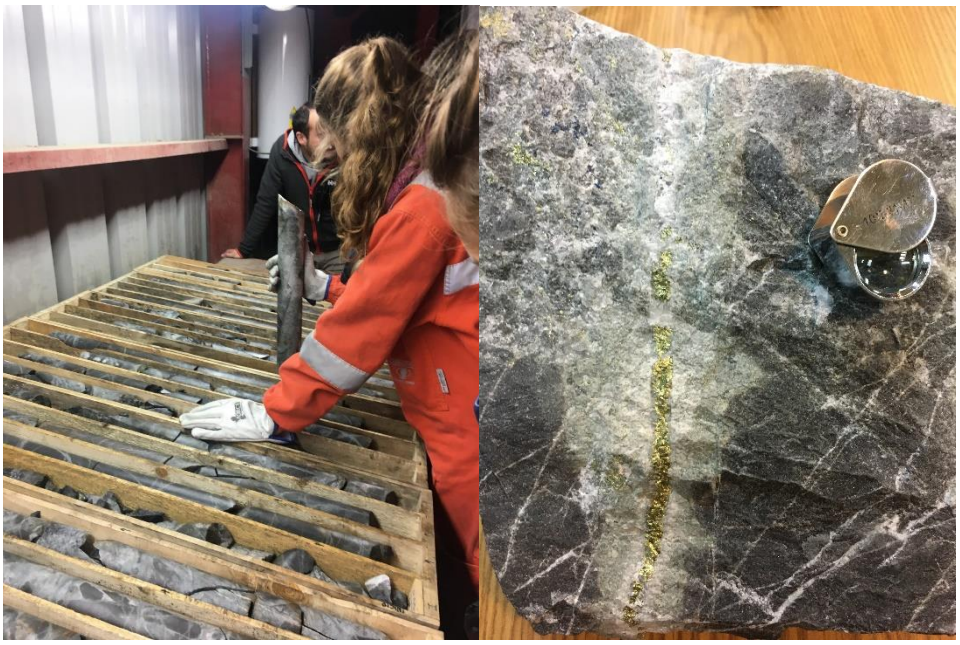

Figure 13. Left: Visit to El Teniente drill-core storage facilities. Right: Chalcopyrite in veins.

The main operations of the Division's industrial complex are the mine, Colón (concentrator) and Caletones (smelter). In 2016, El Teniente reached a production of 193.341 metric tons of fine copper and produces molybdenum and sulfuric acid as by-product.

Figure 14. Mining operation in El Teniente.

A group of 14 members of the SEG Student Chapter of University of Chile participated in a field trip to El Teniente copper mine.

Figure 15. The group of students in the El Teniente mine.

5. FIELD TRIPS EXPENSES

Details	Amount (USD)
Driver	**893,95**
Food	**132,73**
Fuel	**256,65**
Accommodations	**697,34**
Visit URFJ SEG Student Chapter	**80,23**
Total	**2060,9**

SEG Field Trip Support: USD1434.

6. ACKNOWLEDGEMENTS

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7. REFERENCES

Sillitoe, R., 1973. Geology of the Los Pelambres Porphyry Copper Deposit, Chile. Economic Geology, v.68, pp. 1-10.

Reich, M., Chryssoulis, S.L., Deditius, A., Palacios, C., Zuniga, A., Weldt, M., Alvear, M. 2010, "Invisible" silver and gold in supergene digenite. Geochimica et Cosmochimica Acta 74, 6157–6173.

Wilson, N., Zentilli, M., Spiro, B., 2003, A sulfur, carbon, oxygen, and strontium isotope study of the volcanic-hosted El Soldado manto type copper deposit, Chile: The essential role of bacteria and petroleum. Economic Geology Vol.98, pp. 163-174.

Maksaev, V., Munizaga, F., McWilliams, M., Mathur, R., Ruiz, J., Fanning, M., 2003. Implications of Isotope Age Data for the Origin and Evolution of the El Teniente Giant Porphyry Cu-Mo Deposit, Chilean Andes. 10° Congreso Geológico Chileno.

Tosdal, R.M., and Richards, J.P., 2001, Magmatic and structural controls on the development of porphyry Cu±Mo±Au deposits: Society of Economic Geologists, Reviews in Economic Geology, v. 14, p. 157-181.