

IMPERIAL COLLEGE LONDON SOCIETY OF ECONOMIC GEOLOGISTS STUDENT
CHAPTER

Mineral Deposits of Central & Southern Peru

1st - 12th September 2019

Field Report

Written by George Nicholas and Jay Ward



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Preface

This year's field trip to the Central and Southern Peruvian Andes built on the success of the 2018 trip to Namibia and was organised by George Nicholas, Jay Ward, Dan Keogh, Tom Matthews and Jonny Coad of Imperial College London SEG Student chapter. The trip ran from the 1st to 12th of September and was attended by 11 students, 1 academic and 3 professional geologists.

We visited 9 sites across a variety of operations to provide attendees with an overview of the whole mining process; including: open-pit mines, underground mines, smelters, processing plants, SXEW plants and even geochemical laboratories.

Itinerary

01/09/19	Arrival in Lima
02/09/19	Symposium at the Geological Society of Peru
03/09/19	Cerro Lindo Cu-Zn-Pb VMS
04/09/19	Pisco Sn Smelter
05/09/19	Rio Seco Mn Processing Plant
06/09/19	Uchucchacua Ag-Mn-Pb-Zn Skarn
07/09/19	Rest Day in Lima and Flight to Arequipa
08/09/19	Rest Day in Arequipa
09/09/19	Cerro Verde Cu-Mo Porphyry
10/09/19	Cuajone Cu-Mo Porphyry
11/09/19	Toquepala Cu-Mo Porphyry
12/09/19	Pucamarca Au-Ag Epitherma

Sponsors

We are very grateful to our sponsors for providing funding to allow this trip to go ahead. The success of this field trip would have been impossible without their support.

- Institute of Materials, Minerals and Mining (IOM³)
- Old Centralians' Trust
- The Minerals Engineering Society (MES)
- MinSouth
- Geological Society of Perú
- MDSG
- SEG Stuart Wallace Fund
- Mineco
- CRU Group
- CD Capital
- AMinpro Metallurgical Services

Delegate List

Industry:

Dragana Stojanović
Jaime Sepúlveda
Sneha Desai

Mineco
CRU Group
CD Capital

Project Geologist
Base Metals Analyst
Geological Analyst

Guide/Interpreter:

Diego Mesa

Imperial College London

PhD Research Student

Students:

George Nicholas
James Stringer
Jay Ward
Daniel Lindsay
Maximillian Ralston
Samuel Casement
Daniel Keogh
Jonathan Coad
Emily Brugge
Tom Matthews
Martin Fuentes

Imperial College London
Camborne School of Mines
Natural History Museum
Natural History Museum
Pontificia Uni. Católica del Perú

4th Year MSci Geology
4th Year MSci Geology
4th Year MSci Geology
3rd Year BSc Geophysics
Minerals Processing MSc
PhD Research Student
PhD Research Student
MSc Mining Resources



The fieldtrip group and some Aminpro representatives in Lima

2nd September: Joint-PUCP SEG Symposium

The Geological Society of Peru (Sociedad Geologica del Perú) hosted our annual symposium, jointly organised and chaired by Jay Ward (Imperial SEG Chapter) and Raquel Chang (PUCP-UNSAAC SEG Chapter). The Symposium included talks from professors, researchers and students from Imperial College London, Natural History Museum (London) and PUCP.



Full Auditorium at the Geological Society of Peru for the joint Symposium.

Symposium Outline

Session 1: Mining operations – From exploration to processing

Dragana Stojanović	Mineco	Exploration Project Celebici
Jaime Sepúlveda	CRU Group	Copper Market Outlook
Diego Mesa	Imperial College London	Challenges in Minerals Processing

Session 2: Geochemical insights into ore systems

Tom Matthews	Natural History Museum	Titanite in Porphyry Systems
Emily Brugge	Natural History Museum	Apatite in Porphyry Systems

Session 3: Peruvian geology and mineral deposits

Miguel Cardozo	PUCP	Peruvian Mining and Mineral Endowment
Jean Vallance	PUCP	Critical Elements in the Central Andes
Lisard Torró	PUCP	Au-bearing Pyrite at Shahuindo, Peru
Silvia Rosas	PUCP	Organic-rich Facies in Eocene Red-Beds

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3rd September: Cerro Lindo Cu-Zn-Pb VMS

We started off our first field day with a long, early morning drive south of Lima, arriving at the primary security gate for Nexa Resource's Cerro Lindo VMS deposit for about 10 AM. An unfortunate breakdown of communication between the mine site geologists and security contractors meant we had to leap through a fair few bureaucratic hurdles to get our insurance documents confirmed. Following this, an unexpected 2-hour drive up into the mountains to arrive at the actual mine site then meant that we didn't arrive on site until around 2 pm. Though this meant our visit was cut a little short, this is part and parcel of operating a mine in remote areas and I think the whole group was left impressed at the ambition to build this large an operation in such inaccessible terrain.

Cerro Lindo is a polymetallic resource with primary income derived from its Cu & Zn content. The group were given an in-depth and knowledgeable introduction to the deposit and regional geology; also learning about interesting processes such the remobilisation of toxic elements (e.g As or Bi) which are usually associated with VMS deposits by metamorphic fluids, and how this has resulted in a cleaner ore body relative to others within the deposit class.



A view of the tailings storage facility

One half of our group were then taken to the original discovery location of the deposit whilst the second were given then chance to inspect the drill core. Here we picked up useful tips on finding mineralisation using texture mapping (e.g. monomict vs polymict) – whereby mineralisation is generally found only in breccia not conglomerate, because the structure more easily allows fluids to percolate through.

Pure pyrite in drill core



The original discovery location of the deposit



4th September: Pisco Sn Smelter

A short morning drive brought us from our accommodation in Pisco to the Funsur smelter. Once again, we had a few paperwork issues but the staff at the smelter were fantastic and really went out of their way to get the necessary insurances sorted in order to make our visit happen.

The smelter is one of the biggest of its kind in the world and solely processes tin from the San Rafael mine, also owned by Minsur. The concentrate is shipped overland by daily truck convoys.

We were given an introductory lecture from Alexis, the H&S manager, who talked us through the novel and pioneering technology employed by the smelter such as a Top-Submerging Lance – of which there are less than 25 in the world. Alexis provided detail on the smelting process far beyond what we have received in our lectures which resulted in an enriching expansion to the student's knowledge of the mining industry beyond the purely academic, geological understanding which tends to be covered in lectures.

We were then treated to a tour of the smelting operation and took in the huge stockpile warehouse before inspecting the furnace – where we saw the lances being repaired – and then watching a live pour of molten metal, a first for many of the group who had not visited a smelting operation before.



A view of the smelter from the carpark (no phones inside!)



The group pose for a photo in front of the finished product of tin ingots.

5th September: A minerals processing grand tour

Plenge Metallurgical Laboratory



In the morning we stopped off at Plenge Laboratories, a mineral processing consultancy, where Angélica guided us around and explained the whole Metallurgical process in great detail along with some fantastic demonstrations of the froth flotation process. Despite most of the group having taken a minerals processing module at university, seeing a scale small close-up operation was a first for many. It was also interesting to see their geochemical equipment and miniature processing plant, featuring a mini SAG. A worthwhile visit!



Río Seco Mn Processing Plant



After a brief drive to the north of Lima we arrived at the Río Seco Mn processing plant. The plant ingeniously turns unwanted Mn-rich impurities in Uchucchacua's concentrate into a valuable by-product, avoiding concentrate penalties as a result. We were given a fantastic introductory talk by Richard Villagary, the Head of Process, before being taken on an in-depth tour of the operation. The efficiency, cleanliness and smooth operation of the plant impressed all of us and the facility really set a gold standard for the other facilities we would visit throughout the rest of the fieldtrip.

Images of (A) Daniel Lindsay looking across the facility; (B) our group being walked through the facility's process; and (C) trip attendees with the Río Seco team.



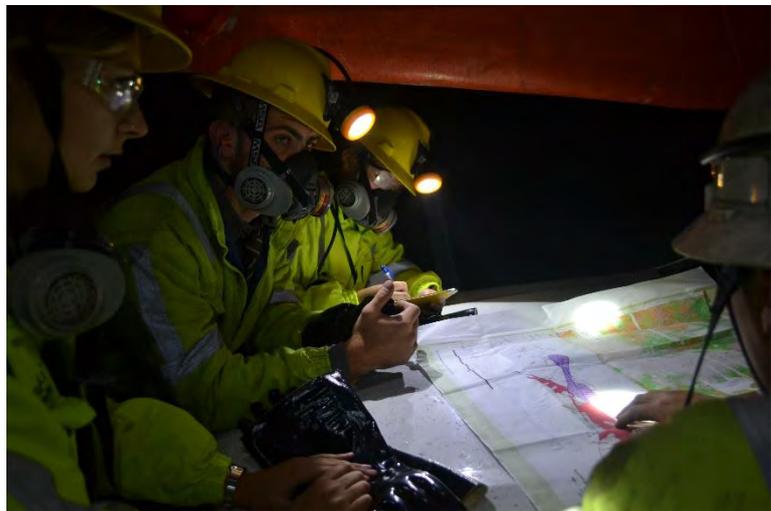
6th September: Uchucchacua Ag-Mn-Pb-Zn Skarn

A tough day but well worthwhile! After an especially early (4.30 AM) wakeup to avoid road closures and a windy drive up to 4500 m.a.s.l. (through stunning scenery) we arrived at Uchucchacua, feeling somewhat worse for wear and certainly noticing the lack of oxygen. Welcomed by our hosts we took breakfast, completed our medicals, those who needed it enjoyed a dose of oxygen and then we headed off to inspect some rocks.

We were split into two, with the first group heading immediately underground and the second receiving a lecture on the regional geology and four-stage paragenesis of the Uchucchacua deposit, before inspecting rocks and drill core from different mineralisation zones and then learning how the Buenaventura geologists had built their resource model. A varied and novel way to gain a good understanding of the operation.

The trip underground was fascinating &, again, represented a first for many of the student members of the group. We observed mineralisation hosted in the tunnel walls and machinery conducting daily operation. Of course, some time was spent hunting for samples!

Finally, both groups received a tour of the processing plant. This was especially interesting given we already had an understanding of how the Mn-rich concentrate was being treated further down the valley. A much older and more 'traditional' operation than Río Seco the plant certainly gave us an appreciation of how investments in new technology can result in higher levels of efficiency.



Emily, George and the Ralston receive an introduction to underground mapping.



Half the group pose for a photo with Uchucchacua's flotation cells

7 & 8th September: Rest weekend (Lima & Arequipa)

After a hectic week of early starts and long bus journeys, including an 8-hour monster back from Uchucchua, the group finally got the chance to relax and recuperate. This gave us the chance to take a bit of time to appreciate Peruvian culture (and cuisine...) and importantly make our way to Arequipa in order to begin the second leg of the field trip!



9th September: Cerro Verde Cu-Mo Porphyry



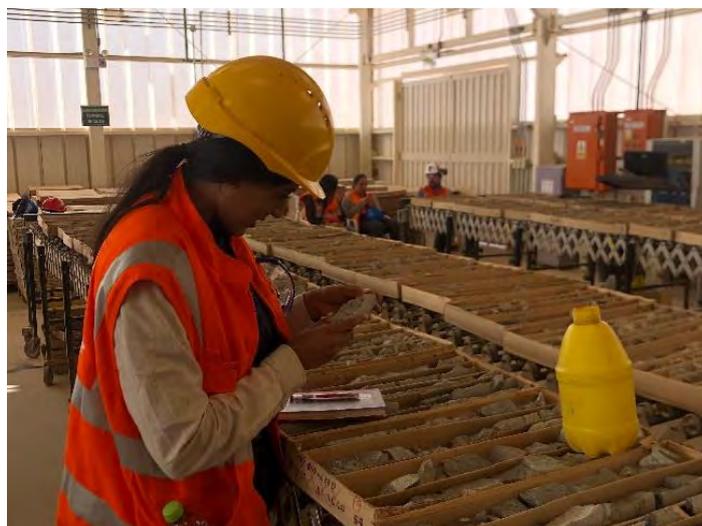
Ready to get stuck back into the field trip proper we were collected by a Freeport minibus from our hostel in Arequipa for a short drive to the Cerro Verde mine. Consisting of three separate deposits: Cerro Verde, Santa Rosa (both porphyrys) and Cerro Negro (tourmaline breccia) with current life-of-mine running to 2040 we were all impressed by the detailed exploration work which had gone into defining three such large ore bodies. Defining such a large resource required Freeport to drill exploration holes up to 2 km deep – and there is still significant exploration potential!

A massive deposit deserves a truly massive processing facility. Although we were unable to tour the processing plant the entire group was astonished by the sheer scale when we looked from a nearby viewpoint. Currently processing 360,000 tpd the facility is the world's largest copper processing plant. What can't be seen in the photo is, just to the left,



The group outside Cerro Verde's Concentrator II

two exploding volcanoes – making this possibly the most picturesque processing plant I have ever visited.



Sneha Desai analysing mineralisation in the core

We were then allowed to inspect some of the core in the coreshed with Freeport geologists on hand to point out interesting textures and mineralisation features to us. Aside from the usual culprits of pyrite, chalcopyrite etc., we were able to pick out some seriously cool and colourful minerals. Unfortunately pictures were not allowed inside so you will have to take our word for it!

10th September: Cuajone Cu-Mo Porphyry

The first of the two Southern Copper mines that we visited, the group enjoyed an excellent tour of Cuajone.

Oscar Concha gave us a very informative general presentation covering the long history of the operation (during which time they have been able to drill 44,898,218 m of core), the whole suite of 51 lithologies at the deposit and the various deposit models which Southern Copper have built e.g. alteration, hardness and specific gravity.

We then headed for our first tour of an operating open pit of the trip. From the first of five viewpoints we were able to observe preparatory blast drilling in action and saw a wide range of mine vehicles in operation.



A dust suppressor, earth mover and dump truck all operate in tandem, just behind the phot a drill rig was also in operation.

The tour then continued on to 4 more viewpoints, each progressively deeper inside the pit and highlighting a different style of mineralisation for the deposit. At each location the Southern Peru geologists would point out the key lithologies and mineralisation types giving us the opportunity to take samples and develop a well-rounded understanding of the deposit's geology.

Following the visit, Southern Peru kindly treated us to lunch in their canteen before we headed on to our overnight stop in Moquegua. Filling the free afternoon, on the recommendation of our bus driver Don Elias, with a tour of a local Pisco vineyard.



Max Ralston, Jonny Coad and Daniel Lindsay inspecting samples in the open pit.



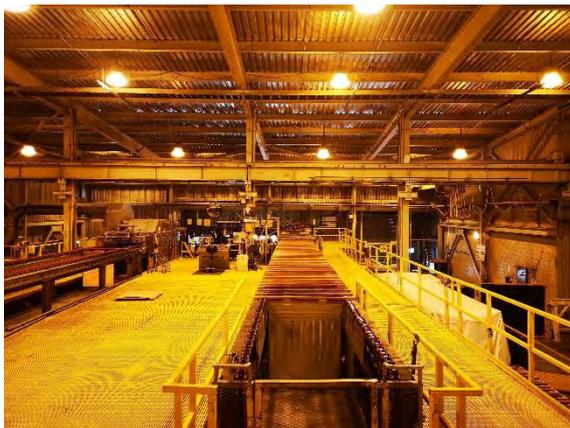
The group inside the open pit

11th September: Toquepala Cu-Mo Porphyry

Once again route issues, meant we arrived slightly behind schedule for our visit. This time the road was too narrow and dangerous rather than closed and we had to take a longer lowland route – though, of course, safety first!

Our tour began at the Toquepala SXEW plant with a very thorough presentation (and a great set of demonstrations) illustrating exactly how the process works. This was followed with a walk to the operating room for an overview of the plant – certainly a quieter and more pleasant place to be than the crushing and flotation plants we had toured earlier in the fieldtrip.

A view of forming copper cathodes from the control room



^ Toquepala team demonstrating to our group the reactions involved in the SXEW operation.

We were then able to tour Toquepala's Concentrator I – a plant which has been in operation since. With a 60,000 tpd capacity it is certainly dwarfed by the operation we saw at Cerro Verde but this only served, yet again, to highlight the positive impact new technology can have – especially in reducing the considerable footprint of mine sites.

Unfortunately, due to our delayed arrival we were unable to view the open pit or coreshed so, after a delicious lunch in the workers canteen, we departed for our long drive to our overnight stop in the border town of Tacna.



Our tour of the processing plant – very different from the four huge SAG mills utilised at Cerro Verde.

The road south to Tacna

12th September: Pucamarca Au-Ag Epithermal



A colossal day to round off the field trip. Following another early (4 AM) start so - we could get the necessary documents from a Tacna checkpoint in time to avoid temporary road closures - we took a roughly 4 hour drive to the mine, arriving there at 9AM, after a 4300m climb in elevation.

The highest mine of the trip at 4700 m.a.s.l. we necessarily had to spend some time passing the requisite medical checks – with variable performance across the group. Eddy Zapana gave us a great introduction to the geology and geochemistry of Pucamarca highlighting the relatively low grade and very fine nature of the gold (just 4 – 10 μm).

We were then bussed around the various pits in operation, some being mined and some under development. Though always disappointing not to find visible gold it is amazing how a mine can be sustained both at high altitude and in such a remote location – a logistical triumph and great example of the advances in mining technology.

After a spot of light lunch we were able to look through some of Pucamarca's core – a treat for the geological purists amongst the group before heading back to the meeting room to learn more about the processing aspect of the mine. We also had the chance to hear about the sustainable practices of the operation, Minsur have impressively managed to control their water supply tightly enough so they are not abstracting any water from basins which are utilised by the local community.



Safe to say, there is significantly more oxygen in London



Martin Fuentes and the rest of the group observing the open-pit from a viewpoint.



Following the visit, we bade goodbye to our final hosts, returned to Tacna for the final group meal and then began the monster drive back to Arequipa where we would end our trip after a great 12 days.

SEG trip attendees pose for a photo alongside our Minsur hosts.