

Main Excursion Chile 2008

Main excursion to Chile by 4. grade students in technical geology, environment- and recycling technology and geological sciences

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NTNU INSTITUTE OF GEOLOGY AND ROCK MECHANICS

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Preface

Late February 2008, eight 4th year students from the Institute of Geology and Rock Mechanics traveled to Chile. With us we had the Head of Institute, Professor Terje Malvik, and Werner Stefanussen from Sweco. We had planned several trips to different construction sites and mines, as well as some social events. All of these trips turned out to be a great experience, which we learned a lot from. Werner Stefanussen had worked several times in Chile and is fluent in Spanish, thus helping us understanding Chile far better than we could've done on our own. Therefore we wish to express our sincere gratitude for his participation.

Monday February 25th - Ministerio de Obras Públicas (MOP) and the Royal Norwegian Embassy in Santiago

On Monday 25th of February we visited the ministry of Public Roads in Santiago. We were greeted by two senior employees who took us to a meeting room in their Headquarters in downtown Santiago. Firstly, they gave us a general presentation of Chile, which we found very useful. After that they gave a more detailed presentation of the road system in Chile, and how Chile pioneered in government-private financed road-construction. A venture that Norway has copied, and that has turned out to be quite useful. The presentation was very interesting and despite our hosts limited English they answered our questions very good and with enthusiasm.

After the presentation we were taken by cars to the San Cristobal tunnel-project. It is a project designed to reduce the traffic congestions that evolve around the San Cristobal Mountain. Two parallel tubes, each containing two motor-lanes will reduced the travel time around San Cristobal dramatically, and also reduce the congestions that occur. There we were given another presentation as to the technical specifics of the tunnel project. We got a comprehensive presentation of the geological mapping and the rock mechanics involved in the project. Our guide presented all of this with great enthusiasm and was glad to answer all of our questions. After that we were taken to the tunnel itself where we were shown around. It was a very interesting experience.



Later that day we visited The Royal Norwegian Embassy in Santiago. We were greeted by First Secretary Ole Reidar Bergum who gave us a presentation of Norwegian activities and investments in Chile. After that we had a lengthy discussion regarding Chilean politics, history and potential. We were handed brochures that the Embassy had made to promote Norwegian interests in Chile. One of the brochures was a guide to establishing a business in Chile. We were very thankful for the

interesting discussion which we felt gave us a deeper insight into Chile from a Norwegian perspective.

Tuesday February 26th - Andina Copper Mine

Andina is located 80 km north of Santiago in the Andes Mountains. It is one of Chile's largest copper mines with a production of 240 000 ton copper concentrate per year. The mine is owned by Codelco; a Chilean state-company.

At Andina; copper is produced in both open pit mine and in underground excavation. We had a guided tour on both production areas. To get to the top of the open pit mine, the bus took us up to an altitude of 4200 m above sea level. In the beautiful weather we had a spectacular view of the Andes Mountains with South America highest mountain Aconcagua (6962 m) in the background. After the open pit mine we went to the underground production area. We were guided through the accessible areas of the grizzly- and the main level. Some parts of the mine were worked by remote controlled machinery which we could only observe from the control room. The production area underground also contained the processing plant in two large caverns. In here the ore is crushed to a size of 200 μm and led through a flotation process separating copper and molybdenum from the waste rock. The capacity of the processing plant is more than 70 000 ton per day.



The block caving method

A common method for extracting metals in underground mines is by block caving. The method allows ore to collapse due to its own weight in a controlled fashion. The collapsed ore is then transported by gravity to a series of tunnels below the collapsed area where further fragmentation and transportation takes place.

Block caving occurs in segments or blocks in all three directions; shown on the sketch below. A series of haulage tunnels are constructed under the ore to be mined. Along each tunnel, in a checkerboard pattern, raises connect the haulage tunnels with another series of crosscuts. In the crosscuts, scrapers or LHD's transport the ore back to the main haulage level. The ore falls down finger raises intersecting the cross drifts below. The ore continues to fall under gravity from the bottom of the block as it is pulled from the raises. As broken ore is removed, the capping or non-mineral bearing rock above the ore will gradually descend until broken fragments of it start coming from the draw points, indicating all of the ore has been withdrawn. No pillars are therefore left to support the mine after excavation, and the production grade is thus very high.

The block caving method is employed in massive ore bodies which is located too far under ground to allow the use of an open pit mine; for example underneath an existing open mine pit. Above block caved mines there is typically large scale settling of the surface, due to the removal of ore and waste rock from the mine workings.

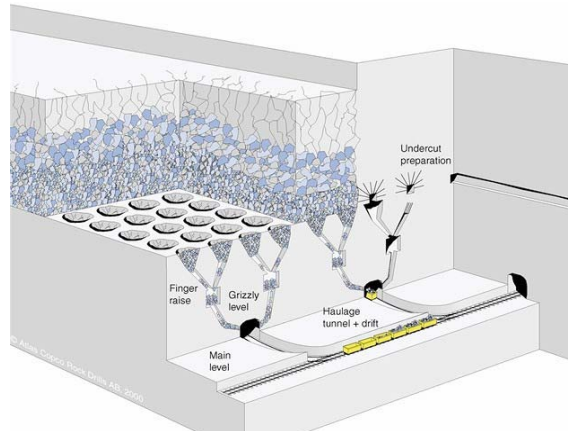


Diagram of block caving – photo courtesy of Atlas Copco

Wednesday February 27th 2008 – Norconsult

In the afternoon on the 27th of February, the group was invited to the headquarters of Norconsult Andina S.A. in Santiago. Two employees welcomed us and presented the activity of the company. The company was established in 2007 and is owned by Norconsult along with an engineering office in Chile named Errázuriz y Asociados Ingenieros S.A. (EAI). Before opening the office in Santiago, Norconsult had been working on projects in Chile for over two decades with EAI as their associates. Along with projects in Chile the company has also had projects in Peru. Norconsult Andina S.A. provides engineering consultancy by blending international experts and local consultants from Chile. The main focus is set on project design and supervision in relation to hydropower projects along with other underground projects. The largest projects Norconsult has been involved in are the hydropower projects Alfafal, 50 km east of Santiago and Ralco in south Chile, where severe tunnel excavation problems in the headrace tunnel were solved. Recent years Norconsult Andina S.A. has also provided engineering consultancy to companies in the mining industry with the world largest mining company in the world, Codelco as their most important customer.

Thursday February 28th 2008 – La Higuera

Situated at the Rio Tinguiririca, Region VI, the La Higuera hydro electrical power plant is undergoing its development, we visited the area during an one-day trip where we saw the main aspect of the project. Structurally the project consists of two intake-dams at about 1100 masl, these are connected to each other by tunnel work, which also is placed through sediment deposits.

These two dams, the Azufre and Tinguiririca, fed by glacial water, are further connected with a 15 km long tunnel in the mountainside that is of volcanic origin. The quality of the local bedrock have proven to be an ordeal, but compared generally to the region it has normal aspects, as e.g. rock strata of low grade etc. From an environmental standpoint this tunnel work have been one of the main aspects that the project have got the green light, since most of the plant is out of sight, other than the dams, penstock and the powerhouse.

At 728 masl the powerhouse is situated, this gives the project a gross height of 372 m and with a designed flow rates of $50 \text{ m}^3/\text{sec}$ this yield to a 155 MW capacity.

This project is a joint venture between Pacific Hydro and Norwegian company Statkraft Norfund Power Invest (SNPI), giving the project a fusion of competence ranging from that of Chilean, to Australian and Norwegian. This seems to be one of the reasons that untraditional choices, from a Norwegian standpoint, have been taken, as example that the whole plant has not been placed into the mountain (Penstock and powerhouse).



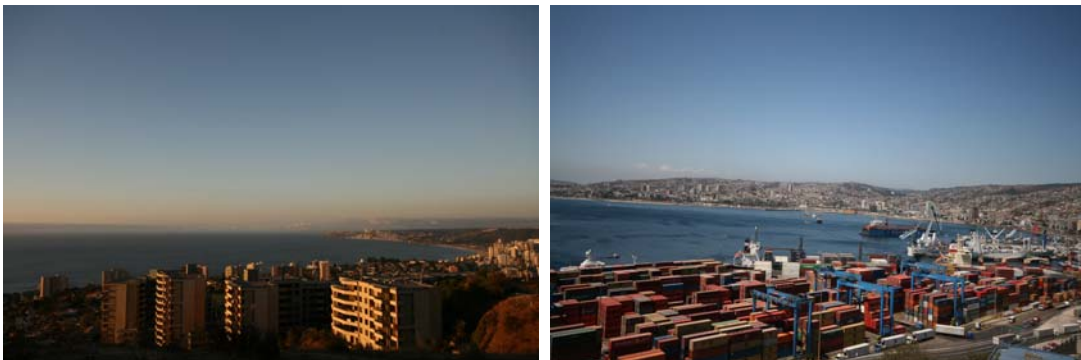
(schematic view of the plant area: www.pacifichydro.com.au)

Friday February 29th - Casablanca, Valparaiso and Viña del Mar

The valley of Casablanca is located some kilometers west of Santiago. A friendly taxi driver brought us to visit the Veramonte vineyard. After some language challenges, we got a guided tour around the beautiful vineyard. We got some information about the types of grapes, the production, the climate in the area etc. and a look inside where some of the barrels were kept. We also got to try three different wines, and for some of us this was a tasteful breakfast.



After the vineyard, we went to Valparaiso. This is a unique city by the sea with steep labyrinthine roads. In 2003, the city was declared a Unesco World Heritage site, and in the same year the National Congress named it 'Chile's Cultural Capital'. Valparaíso is an important center for maritime trading. Our taxi driver brought us to different viewpoints where we could take some photos and enjoy the nice sight.



After a couple of hours we drove to the neighboring town Viña del Mar. Here we had a short stop at the casino before we went to the beach to splash around in the Pacific. It was a chilling experience and a lot of waves. After the swimming activities we all got hungry and our taxi driver took us to a restaurant where we could enjoy a nice dinner before returning to Santiago.

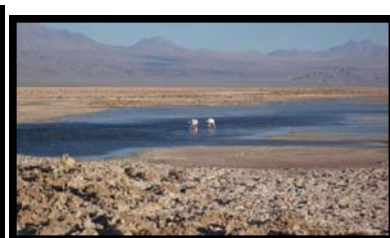
Saturday March 1st – Horseback riding

It was difficult to say no to the opportunity to go horseback riding in the mountains east of Santiago. At the start of the tour it was already clear that this tour would be interesting whereas none of the Chilean cowboys spoke a word in English. After an hour of galloping in the wilderness, we came to a hill with a marvelous vista over the city and a decked table awaited us. While grilled meat was prepared, the group enjoyed the view and the tasteful Pisco sour. After a good meal, a coffee was prepared in a Cola bottle over an open fire with a beautiful sunset. That was a perfect ending for a perfect night. For most of us, this tour was something to remember.



Wednesday March 3rd - Salar de Atacama by the Laguna Chaxa

62 km from San Pedro de Atacama and 2300 meters above sea level is the Laguna Chaxa located. On the surface of Salar de Atacama you can observe salt crusts generated by the accumulation of crystals produced by the evaporation of the underground saline waters. In this area you can also find muddy lagoons that are not very deep, one of these is the beautiful Chaxa Lagoon where you can find Flamingoes and other types of birds. This is the most easily accessible flamingo breeding site. Three of the five known species (James, Chilean and Andean) can be spotted at this salt lake. After sunset we drove back to San Pedro de Atacama.



Tuesday March 4th - El Tatio geysers

El Tatio is the world's highest geyser field at 4320 meters above sea level. It is located 95 km north of San Pedro de Atacama. To reach the geysers before sunrise we had to leave the hotel at 4.30 in the morning. This is the best time to see the steaming geysers in their beautiful surroundings of old volcanoes. It was freezing cold before the sunrise and everybody was wishing that the geysers would spread their heat more efficiently. Walking around was like walking in a gigantic steam bath with hundreds of geysers making bubbling, spurting and hissing sounds, almost like a field of boiling kettles. In 1960, CORFO started a project to use this geothermic energy to generate electricity, but the results did not guarantee financial profit. The only thing left from this is the camp that remains intact and receives the visit of scientist as well as tourists. Not everybody was feeling all right in the high altitude. When the morning winds started to disperse the steam we drove to another geyser field. At this place it was possible to enjoy a large thermal pool and see some bigger geysers. On the way back to San Pedro de Atacama we stopped in the beautiful high plateau village of Machuca located at an altitude of more than 4,000 meters. We had a little walk in the village and tasted grilled lama-meat. During the ride our guide learned us about the plant and animal life.



Wednesday March 5th - Visit to Chuqicamata Cobber Mine

On the 5th of March we went to visit Chuqicamata, a cobber mine just outside of Calama. We had an appointment with a translator in case of language problems. When the translator, Alonso, arrived at our hotel we took off.

Chuqicamata is part of the Codelco Norte division. The Chuqicamata mining complex is located 1650 km north of Santiago and 2870 meters above sea level. The mining complex includes two open pit mines "Chuqicamata" and "Mina Sur". The open pit of Chuqicamata started in 1910 and is still going strong.

When we arrived at the mine, we all became impressed by the size! Nearly everybody had seen pictures of it in forehand on the internet. But to see it in real life was something else. After a short review of the process and the different plants we had to put on some safety gear before we could go out to see the open pit mine and the BIG trucks! Our guide took us in to the mine by a buss, this was the first time we could see how big it really was. In the sunny weather we all lined up for a group photo.



The guide told that they produced more then 600 000 tons of rock mass everyday! Incredible!

After the visit to the open pit we went underground, away from the burning sun, and in to the exploration tunnels. We became surprised that they had so much exploration tunnels. The guide showed us the underground office and how the tunnels were excavated to locate how the ore deposit was oriented in the ground. Down in the tunnels it was incredibly hot and we all were feeling a little bit sweaty.

Sadly we had not so much time to see mine because we had to catch our flight back to Santiago. After a short stop in Calama for some food we all said good bye to the translator, Alonso. And we started our journey to Antofagasta and then back to Santiago.

Friday March 7th 2008 – Universidad de Chile and Go Cart

Universidad de Chile is located in the centre of Santiago. It's one of the oldest and most prestigious universities in South-America, being established in 1843. The university currently has about 30.000 students.

During our visit we were only at the university's mining department. When arriving at the department a professor welcomed us. First he gave us a brief lecture, including a summary of Chile's copper mining history and some environmental issues associated to copper mining.

Later we were guided around at the department. First we were introduced to a couple of student projects dealing with computer simulation of ore deposits. Later we were showed equipment used to test various rock properties. It was both old outdated instruments which were not in use, and newer ones still being used.

Although our tour to El Tentiente was cancelled, that day was used for other usefull and pleasant activity. After an exciting day at a science museum and a marvelous sightseeing in a taxi around north-east Santiago, our driving skills where tested on a go-cart racecourse. In spite of many difficulties finding the suitable equipment for the scandinavian sized racers and completing around 40 rounds, the boys had to swallow their pride and admit their loss to one of the female racers. There have been many discussion regarding the results, but it has been scientifically proven that young male drivers are more likely to be distracted while driving.

Income and expenditure

Expenditure

Plane tickets	67 088	NOK
Plane ticket Werner	13 970	NOK
Domestic plane tickets	16 734	NOK
Hotel in Santiago	24 796	NOK
Hotels in Northern Chile	8 154	NOK
Mini bus	5 592	NOK
Car rental	6 272	NOK
Lunch and dinner	22 676	NOK
Sightseeing and taxi	3 180	NOK
Banking expenses	337	NOK
Other (interpreter, petrol, etc)	6 028	NOK
Total expenditure	174 828	NOK

Income

Company support	165 000	NOK
Self-finance	9 828	NOK
Total income	174 828	NOK

Thanks to the following companies and institutions for their economical support:



Norsk Bergmekanikkgruppe (NBG)

Norwegian Group for Rock Mechanics

