NTNU
Norwegian University of Science and Technology

Geology excursion Chile 2011

The report provides a summary of the exciting excursion done by 4th year students from the Department of Geology and Mineral Resources Engineering.

9-23 April 2011

Introduction

12 students in the 4th year from the Department of Geology and Mineral Resources Engineering on NTNU were on a geology excursion to Chile from the 8.-23. of April. Travelling companions also included our excursion planner from Sweco, Werner Stefanussen, his wife Glenny Foslie and Bjørn Nilsen, professor in engineering geology at NTNU.

The trip to Chile was intended to give us insight and inspire us in how to become a better employee, how to use our geological expertise in the best way and also to give valuable input from the daily life in Chile to extend our understanding of other communities. This was tried achieved by a combination of high valued field trips and visits to representative offices.

Among the things we experienced was a trip to the Norwegian embassy and the University Of Chile, both of great value to increase our understanding for Chile and to learn more about the relationship between Chile and Norway. A branch of the Norwegian companies, SN Power and Norconsult, greeted us with wonderful presentations of their work in Chile. It gave us an insight into difficulties in being a foreign company and also an introduction to the social class differences. Hidro Aysen's hydropower project showed us a new dimension in hydropower projects, but also a genuine picture of the fight between public opinion in preservering wildlife (Patagonia) and a society increasing need for more electricity. Field trips to La Confluencia hydropower plant (SN Power and Pacific Hydro) and Andina mine, a huge copper mine in the Andes Mountains, showed the importance of sustainable contracts and also interesting differences in use of HSE.

Finally we would like to give a big thank you to Werner Stefanussen who solely on his own arranged this excursion for us, thus making it possible for us to visit Chile and the different locations described in this report.

The Excursion group

Mari Lie Arntsen

Aina Natterøy

Åsmund Ryningen

Solveig Løtveit

Ingrid Vik

Asgeir Samstad Gylland

Marianne K. Rødseth

Alexander K. Andrianopoulos

Audun Sletten

Asta Krattebøl

Jeanette Kvalvågnes

Anne Mari Farstad

Gleny Foslie

Werner Stefanussen

Bjørn Nilsen

About Chile

The long and narrow country along the south west coast of Latin America has always been a dominating country on the continent. The North of Chile was first ruled by the powerful Inca tribe in the central part and the Mapuche tribe in the south, before European colonisation. Ferdinand Magellan was the first European to discover Chile as he sailed through the Strait of Magellan in 1520. The Spanish first came to Chile in search for gold and silver, as these precious minerals where found elsewhere on the continent. However they did not find the extensive gold and silver they sought, so they recognised the agricultural potential of Chile's central valley and the middle part of Chile became part of the Spanish empire.

Chile:

Capital	Santiago
Language	Spanish
Government	Republic
President	Sebastian Pinera
Area	756 950km^2
Population	17 224 200
Density	22/km^2
GDP	$ 257 884bill
GDP/capita	$ 15 002
Currency	Peso(CLP)

The Spanish crown abolished slavery already in 1683 and the Spanish colonists did not bring African slaves as colonists did in North America. However many natives where forced into what was more or less slavery by the Spanish. Because the colony was cut off by the desert in the North, the Andes in the east, the coast in the west and the remaining Mapuche tripe in the south, it became a centralised and homogeneous colony. Later immigration to Chile, came mostly from Spain (predominantly Andalucian, Castillian and Basque), Germany, Italy, Ireland, France, Britain, Switzerland and Croatia.

As the Spanish empire weakened in the 1800's, Chile was proclaimed an independent nation on the 12th of February 1818. Chile grew to become a powerful nation, increasing their territory by defeating the Mapuche tripe in the south and winning the war of the pacific against Bolivia and Peru in 1879. Chile expanded its territory northward with almost one third, cutting off Bolivia's coastline and acquiring valuable nitrate deposits. At this time Nitrate was the most important mineral for mining in Chile, until the Norwegian scientist Birkeland developed a method for using Nitrogen from air instead of Nitrate, to produce fertiliser. Bolivia's lost coastline have lead to rather tensed relationship between the countries ever since. Today Bolivia is dependent on a railway through Chile, to get to the sea.

Chile and Norway – visit to the embassy

Both counties being long, narrow and mountainous, Chile and Norway have a lot in common. Norwegians, who travel to the famous region Patagonia in south Chile, say that it's like being in western Norway. Fjords, glaciers, mountains and the green vegetation make it very similar. It is also said that the far southern end of Chile, is very similar to northern Norway, with its cold climate and sparse vegetation. The only difference is the extremely sparse population in southern Chile, making the nature even more untouched than in Norway.

The Norwegian embassy in Santiago has four employees from the foreign affair office and six local staff, working for the political and economical relationship between the two counties. During our visit to the ambassador's house, the ambassador himself, Mr. Bjørndal gave us a brilliant talk of Chile and the relation to Norway. During the past years, the Norwegian embassy in Santiago, have been more or less dealing with trade and business relations. Their work is to assist Norwegian companies, getting to know the Chilean way of business. These business relations go way back, as Norwegians ships have been sailing around Cape Horn since 1840. Including shipping related business, Norwegians are involved in the Chilean aquaculture, hydropower, infrastructure and tunnelling.

The Norwegian ambassador in Santiago, Mr. Martin T. Bjørndal, and his colleague Kristian Røed, was eager to share their knowledge about the county and it's relation to Norway. The conversation soon tracked into the history of Pinochet and his regime which ruled Chile from the coup in 1973 until 1990. Many Chileans in opposition to Pinochet feared what the regime would do them. Some of them jumped over the fence, into the Norwegian ambassador's house, seeking asylum in Norway. During the 17 years of Pinochet, 7000 Chileans immigrated to Norway. Some of these came back after 1990, but most of them still live in Norway today. After the regime, during the mid 90's, the Norwegian embassy worked with improving Human rights in Chile in the after math of the dictatorship.

Augosto Pinochet

Today roughly 300 Norwegians live in Chile, most of them in Santiago, but also some in the south part where the aquaculture farms are located. As mentioned, business is the main reason for Norwegian settlement, and the embassy believes that the potential for more business contracts is high for Norwegian contractors and aquaculture companies. There are also large Norwegian investments in Chile through the government pension fund. When these investments where at its highest in the beginning of this century, Norway was the fifth largest foreign investor in Chile. Other business relations mentioned by the ambassador were Norwegian wood's factory and a large delivery of weapons from Kongsberg group. Chile recently bought the Norwegian advanced surface to air missile system (NASAMS) for the defence of Chilean air space.

At the Norwegian ambassador's residence

Social life in Chile

Through our two weeks stay in Chile, we did not only pick up the essence of Chilean industry. Social life and the differences to Norway is something that caught everybody's curiosity. None of us had been in Chile before, and nobody had found the time reading themselves up before travelling, as we had our hands full with NTNU reports and hand-ins before we left Trondheim.

The first thing that struck us, as we arrived the morning of 16th April, was the big city feeling, driving into a smog covered Santiago, with huge Sky Scrapers and fancy avenues. We stayed in a business neighbourhood called El Bosque, where everybody wore smart suits, running to reach office hour or lunch at one of the street restaurants. We soon discovered, the formality of Chileans, especially those working in the offices of Santiago. The people we met where very polite, but relatively shy compared to other Latin American people. The embassy secretary Kristian Røed, could confirm this when we asked him about social life in Chile. The Chileans where in fact recognised as the most introverted people of South America, according to him. He told us that he often travelled on weekend holidays to Buenos Aires or Brazil, where he felt a more typical Latin American atmosphere. However, both he and the ambassador enjoyed Santiago and the politeness amongst people very much.

During our conversation with the ambassador and his secretary, we could not avoid to talk about Pinochet. They told us that this was still a sensitive issue amongst Chileans. When Christian democrat Patricio Aylwin received majority of votes against Pinochet in 1990, it was only by 56%, against 44% who still voted for Pinochet's regime. This splitting of the population can still be recognised today, as nearly half of the population supported Pinochet and the other half totally disagrees with what Pinochet stood for. The fact that Pinochet's regime was quite harsh, killing 3000 people and torturing up to 30 000 according to various reports, makes the situation even harder. Those of the population that supported Pinochet, often have the opinion that refugees of the regime, such as the 7000 people who came to Norway, were traitors. With this in mind, we were recommended not to bring up this issue, or talk about Chileans in Norway, in case the person we spoke to was a Pinochet supportive.

Class society

Chile is one of the most developed countries in Latin America, but there is a huge difference between rich and poor. The country has a liberal economy and far less governmental influence than in Norway. Industry and business is heavily dominated by private sector, attracting a lot of big international companies with their stable and liberal tax regime. Most Chileans believe in having a strong family, taking care of each other and securing oneself when it comes to health insurance and so on. The Norwegians we talked to, working in Santiago, had their children in private international school and paid large sums for private clinics if in need for health care. Having housekeepers cleaning their home as well made the life in Santiago quite luxurious.

Mining study in Chile

The first Monday after our arrival, we visited the university in Santiago where we were going to meet some students and two professors at the department of mining. When we first got there not everything was in order, as only some of the students were present. After some quick exchanges concerning the situation it came to knowledge that both of the professors had forgotten about the visit. Luckily, by the aid of mobile telephones they soon arrived and the presentation could begin. In the meantime we talked with the students and got to know a bit about how life as a student in Chile was. The presentation session was split into two, as we first learned a bit about the structure of the studying programme for hoe to become a mining engineer and then a little bit about how big the mining industry was in Chile.

Audun of our class then presented Norway, focusing on the mining industry and history. Finally, Bjørn Nilsen presented NTNU as an institution and taught the Chilenians about how the studying programme worked at our university. After some quick mingling at the end we reached an agreement to meet some of the students for dinner and beer at a local pub not far

away from our hotel the very same evening. Last but not least two Bergmannkrus were handed out, one to the students and one to the chief coordinating professor of the study.


Presentations at the universtity

Mining engineering study with a business perspective

What struck us, as the main difference between mining study at NTNU and the University of Santiago, was the strong business perspective. Students studying a five year program in mining engineering spent much of their time learning about mineral economics, management and mine planning. It was clear to us that this department educates a lot of future leaders for the mining industry. We had the impression that engineering geology and tunnelling, which is the most popular specialisation at IGB, NTNU, was not emphasised in their study. However, they seemed quite concerned about rock stability in mines, especially after the San Jose accident, where 33 miners were trapped for 17 days in the collapsed mine. The University had a modern rock mechanics lab, doing a lot of numerical analysis for Chilean mines.

When asking the Chilean mining students about their job opportunities, they seemed very optimistic about the future. They had many options, and could choose between working shift in the mining operations, working for technology and equipment suppliers or office work for the large companies in Santiago. It was clear, that not everybody wanted to work far up North in the mines, even though this was the best paid option. They seemed more interested in research and business, wanting to work in Santiago, close to family and friends.

Chilean copper mining – A visit to Andina

The absolute peak of our excursion programme was to see a huge copper mine, far up in the Andes. We had all been looking forward to the trip with enthusiasm, but also fear for altitude sickness, as the mine lies 4200m above sea level. The Andina Mine, not far from the city of Los Andes was our goal for the fourth day. After some two hours of drive we reached the office of Codelco, the national copper mining company of Chile, operating Andina. After safety briefing and equipment hand-out, we were set to go with a special shuttle bus for mine workers. As the mine is only one hour drive away from the city Los Andes, workers are transported up and down every day for work. The exception is when roads are closed due to heavily snow fall, and workers have to live in the barracks close to the mine.

Arriving at the top no one had ever seen a mine deposit at such a great scale with those kinds of huge dimensions. Haulage trucks carrying 330 tonnes of load in their trailers dominated the landscape, accompanied by a giant excavator capable of lifting 100 tonnes of rock mass in its loader. Incredibly enough, no one suffered from altitude sickness.

Andina copper mine

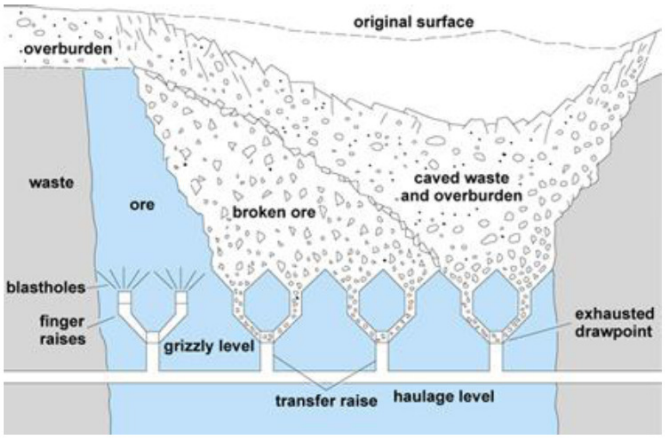
The mining operation in Andina, is divided in an underground block caving operation which was the first operation to start in 1970, and the newer open pit operation at Sur-Sur where the largest production is today. We only got to visit the open pit and the milling plant, located in huge underground caverns, because of the harsh weather conditions during winter. The mining company served us a nice lunch in the workers canteen inside the caverns, eating proper heavy diet miner's food with desert.

Andina copper mine:

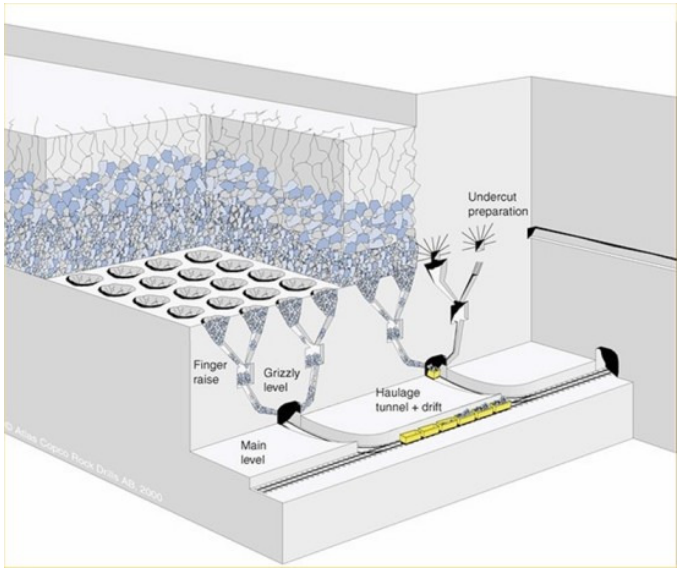
Operated by	Codelco
Production start	1970
Exavation	Open pit and UG block caving
Ore grade:	0,78% Cu and minor amounts of Mo
Mineralization	Mineralized Breccia of the Los Bronces-Rio Blanco complex
Annual production	209 727 metric tonnes Cu concentrate
Milling capacity	92 000 tonnes per day
Employment	5000 incl. contractors

Efficient underground mining – block caving

Copper deposits in Chile are of such a large scale and low grade, that mining operations must be cost efficient, handling many tonnes per day with large equipment. The most straight forward mining method for such deposits is open pit, because it allows the use of large equipment and parallel production from several muck piles. However, there is a limit in depth of open pit, where the cost for handling waste rock, becomes too big compared to the income from valuable ore. Waste rock/ore ratio increase by depth as pit must also increase laterally.



Cross section of block caving method



For large deep, low grade deposits, a highly cost efficient method have been developed called block caving. The mining department at the University of Santiago, spoke very enthusiastic about this method and their research to implement this method into several mining prospects. The method is based on fragmentation and caving of the overlying ore, all the way up to the

surface, as seen on the picture. If successfully blasted, the overlying will simply collapse and fragment into blocks that are eventually pushed through draw bells for haulage. The investments for such a method is huge and the development of all the draw bells, haulage drifts and infrastructure can take 10 years according to the mining professors we spoke to. However, when developed, excavation cost can be as low as for open pit caving. They spoke of excavation costs per tonne between 5 and 10 US$.

In Andina we drove past a huge dump in the ground, explained by our guide, to be the caving of overlying rock mass above the block caving operation 800m below the surface! When looking at rock stability, the main interest for most of us students from IGB, block caving involves many challenges. Firstly, one has to assure that the ore rock will fragment, so it should be relatively weak, with high join density. Preferably one seeks joint systems in at least three directions. If the rock does not fragment properly, big boulders can block the draw bells. Despite this, the method is amongst the safer, because workers never stay in the excavated area, but in underlying haulage drifts that can be secured to avoid stability problems. There was also a whole system of access tunnels and tunnels for concentrate and waste conveyor belt transportation. Werner Stefanussen, our excursion organiser from Sweco, had done some work previously on one of these access tunnels, assisting the Chileans with his expertise from Norwegian tunnelling engineering. The geology at Andina consists of mineralised breccias, cutting through the host rock Andesite. It also includes some tuff in certain areas.

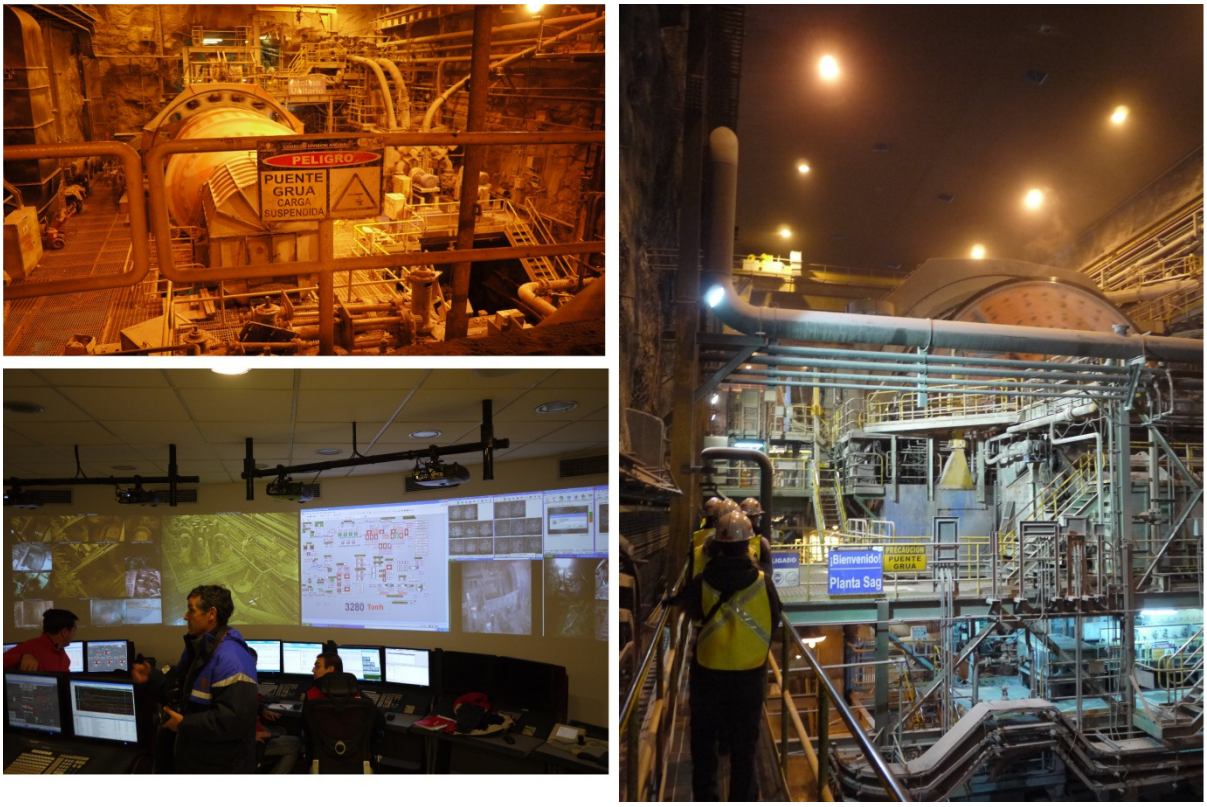
Codelco – Chiles's adequate to Statoil?

South America is a continent of resources, where Chile is the world leading Copper producer, holding 38% of world production. It was very clear to us during our stay in Chile, how important copper is to the nation's income and wealth. The national copper company Codelco (*Corporación Nacional del Cobre de Chile)* is the biggest producer in Chile and the world, holding 11% of world production, producing 1,66 million tonnes of copper concentrate in 2007. The company clearly secures the interests of the nation in copper values, making it comparable to our own partly government owned Statoil, which secure Norway's interests in our oil fields.

The history of Codelco started with the nationalisation of copper industry, first by the creation of the Copper office in 1955, which later became the Copper cooperation of Chile in 1966. The government bought several big mines during the 50's and 60's ending up with a complete nationalisation of all Chilean mines as Socialist Salvador Allende was elected president in 1970. Nationalisation of industry was one of Allende's main goals, buying out all the international copper companies with a relatively low compensation. The American companies operating Chuquicamatra, El Salvador and El Teniente, did not receive any compensation at all, making immediate reactions from the U.S. department of state. The creation of *Corporación Nacional del Cobre de Chile*, as it's known as today, was formalised by Augusto Pinochet in 1976. The national overtaking of the copper mines was of course far different from the establishment of Statoil, which gradually secured more and more interest in oil fields as the oil industry in Norway grew. Still, the idea that a country's resources should benefit the country, not ending up in foreign hands, is the same in Chile as in Norway.

During Pinochet's junta regime, the big copper mines, remained under governmental control, but Pinochet realised the need for economic liberalisation and gradually opened up for foreign industry in the 80's. The 1980 constitution stated that new mineral deposits were open to private investments. Also healthcare and education was opened for private investments in an attempt to improve the falling economy of Chile.

Today Codelco is the biggest copper producer due to the nationalisation of mines in the 60's and 70's, but BHB Billiton, Vale, Anglo American and other international companies are also very dominant. The revenue from Codelco and the mining tax paid by the private companies makes up the Chilean Copper fund, similar to the Pension fund in Norway. This secures Chile's economy for the future, making mining more sustainable for the nation. The copper fund was a key contributor for getting through the financial crisis. The industry where not badly affected by the crisis either, because investments have such a long horizon. Chileans know how to cope with changing copper prices, and the investments done in Andina during the financial crisis are now paying off as copper prices are higher than ever before.



The Milling plant at Andina, inside a huge Cavern

Hydropower in Chile

Being a country of mountains, lakes and rivers, Chile is ideal for hydropower development. There is a huge energy potential in rivers running down from the Andes, all along Chile's long country strip. Norwegian hydropower specialists are involved in many of these projects, with our knowledge from the Norwegian hydro power plant building era of past century. It was therefore a natural choice for us to look at some of the hydropower activities, during our excursion in Chile.

Visit to La Confluencia hydropower plant

Students at the La Confluencia dam

Our excursion organiser Werner Stefanussen had set up a trip for us on Tuesday 11th of April to one of the projects he had been working on previously. It was a hydropower dam construction site, La Confluencia, built by SN Power and Pacific Hydro, in the Tinguiririca valley some three hours south of Santiago. The area is perhaps best known for where the survivors of a plane crash in the Andes Mountains descended down to civilisation again, after having spent months in the mountains. Arriving in the valley of this historic event, we were met by a big construction site with all facilities for accommodation, canteen and security.

Joining us from Norconsult and working with this project was Øyvind Engelstad, a Norwegian who had worked in Chile for some years. Arriving at the construction site we ate lunch first, due to the delay in the schedule. A quick presentation about this dam project then followed, showing the size of the project with tunnels, dams and power station.

We then split into two groups, and after having been properly equipped, entered the hydropower tunnel. Driving all the way into the tunnel face we got to see what kind of securing means that was used on the rock mass and compared it to what was usually done in Norway.

The tunnel itself was flooded with a great abundance of water along the tunnel floor, mainly due to poor pumping systems. We were told by Øyvind that the entrepreneur used a strict rock classification system to determine safety measures. This resulting in low flexibility and perhaps too comprehensive securing measures. This lead to extra expenditures and time consumed.

La Confluencia Hydropower plant:

Owned by	SN Powers 50% and Pacific Hydro 50%
Location	Tinguririca valley
Installed capacity	158 MW
Type	Run-of-river
Av. annual output	672 GWh
Gross head	344 m
Design flow	52.5 m3/s
Euqipment	Vertical Francis turbines, surface powerhouse, two generating units
Construction start	Est. Q1 2007
Commercial operation	ASAP
Capaital cost	Est. 379 MUSD
Power Purchase agreement:	Chilectra, 375 GWh/yr
Financing:	208 MUSD, IFC loan
Greenhouse gas saving	Est. 402 000 tonnes

Leaving the tunnel, we took a stop at the dam itself and discussed a bit the structure of the power station and, once again, compared it to the Norwegian variant. Lastly, as thanks for having hosted us, showing us around despite our delay, the chief working manager received a Bergmannskrus. During the drive on our way back we stopped for dinner at a restaurant near Santiago, recommended by Øyvind.





Inside the tunnel at La Confluencia

Hidro Aysen's fight against public opinion in Patagonia

Another hydro electric power project we learned about, was Hidro Aysen's, not yet started powerplants in Patagonia. We visited the newly started hydro power development company in their Santiago office, to hear more about their plans for the future.

The well English speaking engineer, started to tell us about the lack of energy in Chile, which some dared to call an energy crisis. Energy situation in Chile during the past years have been changing to the worse and the country is almost totally dependent on import of fossil fuels. Chile has also had some more or less bad negotiations with neighbouring contries when it comes to gas. Their gas import agreement with Argentina from 1996 was cut in 2005 as Argentina needed the gas for its own demands. Bolivia, which could have supplied Chile with gas, doesn't have any diplomatic relations to Chile, due to their lost coastline in the war of the pacific. Bolivia even specified in a gas sales agreement with Argentina, that not a single drop of gas must be sold to Chile from Argentina. Chile has tried to deal with this problem by establishing two LNG terminals to receive gas from elsewhere, but capacity is too low, and supply unstable. Therefore, Chile bases its energy need on coal and oil, used in polluting coal and diesel power plants.

Demonstrations against Hidro Aysens dam in Baker river, Patagonia 13th of march 2011

With this in mind, Hidro Aysen wishes to develop several big Hydro Power plants in Patagonia, south Chile, where there are lots of rivers and lakes, providing a stable energy

flow. The only setback for the project is environmental concerns, because of Patagonia's international status as an area of beautiful untouched nature. The company representative then told us about all the measures Hidro Aysen would impement, to reduce environmental consequences as much as possible. They were willing to reduce the dam size and build everything hidden into tunnels and caverns, to preserve the natural landscape. However, public opinion in Chile, and the rest of the world, was still very negative to every industrial influence in the area. Many people feared that tourism would suffer, partly because fish could disappear from the rivers.

The problem he presented about hydro power in Patagonia reminded us of the same issues debated in Norway, when damming up the Alta river.

Visit to SN Power

The same afternoon we went to the offices of SN Power where Bjarne Austrheim, a hydropower engineer, received us and held a presentation about the activities of the company worldwide, especially in Chile. In addition to telling us about what he was doing on his job, he also provided us with information about how life was as a father of a family when living abroad, about all the challenges and joys he experienced. A questioning session then followed. After having received a Bergmannskrus, Bjarne then took us to an Argentinian style restaurant and, on behalf of SN Power, bought us a most exclusive (and big) dinner.

Presentation by Bjarne at SN Power

Dinner with Bjarne

Visit to Norconsult`s office

A revisit with Øyvind Engelstad occurred the final day, but this time, at his Norconsult office in Santiago. He held a lecture for us about the history, the projects and activities of Norconsult in Chile, and also provided us more detailed information about how it was working with people of a different nationality and culture. He more than recommended that we apply for working abroad, despite the possible hardships one might encounter. Naturally, he was worthy of a Bergmannskrus after having hosted us both Tuesday at La Confluencia and this day, at his job.

At the Norconsult office

Horseback riding

The following afternoon and evening we then enjoyed horseback riding, thanks to one of Werner's contacts in Chile. The trip consisted of us riding together as a group, many of us for the first time in our life, to a location at the top of a hill where a table covered with refreshments and a barbeque awaited us. A nice and pleasant dinner later, we sat around the table enjoying the evening and Santiago by night in the distant sight. As a gift to Werner for all his work and efforts he had accomplished for arranging this excursion for us, we gave him a gift card a spa in Trondheim for him and his spouse. Our professor, Bjørn Nilsen, was also rewarded with an exercising t-shirt for his work as travelling with us as a representative of NTNU this whole trip.

The beautiful evening came to an end and at last we descended down from the hill and went back to the hotel. The following day, Bjørn, Werner and Glenny travelled back to Norway while the rest of us went on a one-week vacation to La Serena, a coastal town north of Santiago.

We wish to make a special thanks to the Sponsors that made this excursion possible:


Elkem


VIKØrsta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