



Norwegian University of
Science and Technology

MAIN EXCURSION PERU 2012

24th of March – 6th of April



Introduction

From March 24th to April 6th 22 students from the Department of Geology and Mineral Resources Engineering travelled to Peru for the traditional 4th year excursion. The participants on the study trip consisted of various specializations within the field of geology. Associate professors Steinar Løve Ellefmo and Krishna Kanta Panthi travelled together with the students.

The purpose of the trip was to acquire an international perspective in the field of geology and also to gain wider field experience. The academic program for the trip was put together to reflect the areas of interest for all the students from the different study programs and included a visit to an open pit mine Volcan, a visit to the underground mine El Porvenir and the Cheves hydropower project that is being developed by a Norwegian company called SN Power AS. It also included a visit to Atlas Copco's offices in Lima and a visit to the department of mining engineering at the Pontificia Universidad Católica del Perú.

During the course of excursion we gained an important insight of the Peruvian mining and hydropower industry. We also managed to learn about the educational system in Peru by visiting the university in Lima and meeting with some of the Peruvian geology students. All in all it was a very educational and memorable journey.

We wish to extend a special thank to the people who contributed making this trip a wonderful experience. Sune Jonsson and others in Peru & You Travel, Mario Cedrón Lassus, professor at Pontificia Universidad Católica del Perú, and Rune Mordal, the project director at Cheves for their help in planning and organizing the academic part of the trip. Also, a big thank to the many companies who made this trip possible by giving us financial support.

The excursion group

Associate professors and excursion leaders Steinar Løve Ellefmo and Krishna Kanta Panthi.

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Hanne Morsund

Elisabeth Stormyr

Siv Krane Rodahl

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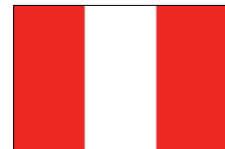
About Peru



Peru is a country in western South America bordering the Pacific Ocean and the countries Ecuador, Colombia, Brazil, Bolivia and Chile. It is the third largest country in South America based on area, and the fourth largest based on population. The country has a varied terrain where rugged Andean mountains cover the central highlands, whereas arid coastal

plains dominate the western regions. Tropical forests that are part of the Amazon basin make up the eastern lowlands. The climate differs from dry and mild in coastal areas, warm and humid in the jungle, to temperate to freezing in the Andes. A wide variety of natural resources can be found throughout the country – copper, silver, gold, petroleum, timber, fish, iron ore, coal, phosphate, potash, hydropower and natural gas.

Ancient Peru was the seat of several prominent Andean civilizations, most notably that of the Incas. The Incas emerged as a powerful state in the 15th century and within the span of a century they grew to form the largest empire in pre-Columbian America. The Inca Empire was centered in Cuzco and extended over a large region from northern Ecuador to central Chile. Their official language was Quechua, which is still considered as one of the official languages in Peru, next to Spanish. The Incas and other Andean societies were based on agriculture and are known for their use of techniques such as irrigation and terracing.



The Spanish arrived in Peru in the 16th century and by the year 1533 the Inca Empire was defeated by the conquistadors, led by Francisco Pizarro. Peru quickly became one of the key sources of Spanish wealth and power in South America because of the numerous deposits of gold and silver in the Andes. The Viceroyalty of Peru, a Spanish colonial administrative district that originally contained most of Spanish-ruled South America, was created in 1542 and governed from the capital of Lima. Peru was under Spanish control until it achieved independence in 1821, and the remaining Spanish forces were defeated in 1824.



Today, Peru is a democratic republic with a multi-party system. The President is the head of the state and government and is elected for five years. The country is divided into 25 regions and the province of Lima. The economic performance has historically been tied to exports with the main export goods being gold, copper, petroleum, zinc, textiles, coffee and fishmeal. Major trade partners include United States, China, Brazil, European Union and Chile. During the latter years the country has experienced stable economic growth.

El Porvenir

On Monday the 26th of March we visited our first site in Peru, El Porvenir. It is a polymetallic mine located outside of Cerro de Pasco, at an elevation of approximately 4100 m.a.s.l. The mine produces a concentrate consisting of a very fine powder of mainly zinc, lead and copper, with additional silver and gold. MILPO, the operator of the mine, is a company with 3350 employees, listed on the stock exchange in Lima, operating five main mines and with several projects under development. They have a long list of prospects both in Peru and Chile, but aim to also grow by acquisitions.



The view from the bus approaching El Porvenir.

The access road to the mine from Cerro de Pasco is quite interesting in itself, winding along the steep mountainside and offering a spectacular view of the valley below. On arrival at El Porvenir we got a briefing about the company and their Health, Safety and Environment policies. After that we were kindly treated to a lunch where several hot and cold dishes were available. Not being entirely accustomed to the altitude, our appetites were reduced, but we enjoyed the meal nevertheless. We then climbed some very steep stairs that, this being at 4100 m.a.s.l., had us gasping for air. After having been outfitted with protection equipment we moved underground, into an auditorium a hundred or so meters into the mine itself. There we received another presentation, this time about the mine, the production methods and the plans for the future.

We took the personnel elevator 1000 m down. In the mine the air quality was good, except for the dust which has to be expected in a working mine, where light and heavy vehicles travel on a roadbed of crushed rock. The temperature was also rather pleasant. We breathed more easily than we did just a few minutes earlier, a kilometer higher. We were in a system of tunnels connecting rooms blasted into the rock. the rooms were used for such things as storage and doing maintenance on machinery. The roof of the mine was covered by mesh reinforcement to guard against loose rock falling. In addition rock bolts were used for general stability. The more permanent parts of the mine had a concrete floor.



Students in the mine.

After the elevator, we traveled by pickup truck through some tunnels and down to a couple of levels on a spiraling ramp. Here, several ore bodies were being exploited by the cut and fill method. At the time of our visit, drilling for blasting was going on on top of 120 m of fill at one face, with another 20 m to go before that particular ore body would be abandoned. At another face, ore was loaded and carried by a loader to a chute leading to a lower level, where it presumably was taken to the 7000 tpd capacity winch for transport to the surface, and then to the 5000 tpd capacity beneficiation plant.

The final stop before departure was a mutual exchange of thanks and the distribution among the visitors of souvenirs in the form of t-shirts, caps, shopping nets and information material about the company and the mine. At the end of our visit we were exhausted, this having been our first day at this high altitude, but we still found the visit interesting, and got some insight into how a mine is run, in particular Health, Environment and Safety work.

Volcan

Tuesday the 27th of February we drove back up in the mountains to visit an open pit mine owned by Volcan Compania Minera S.A.A in the city of Cerro De Pasco. This open pit mine is one of five mining centers in the company.



Cerro de Pasco is a city in central Peru and is the capital of the Pasco region. The population is about 70 000. It is one of the principal regions in the world for polymetallic mineralization (zinc, lead and silver). Cerro de Pasco is situated at 4330 meters above sea level in the Andes,

Cerro de Pasco.

and is one of the highest cities in the world! It became one of the world's richest silver producing areas after silver was discovered there in the early 17th century. Sadly, this is not reflected by the city today.

Because of the high altitude, the whole group of 24 people got a thorough medical check-up before we could enter the mine. Unfortunately, some of us were affected by the altitude, but according to the doctor there was no health risk. After the health check we got a nice presentation in off course Spanish about the mine and company. It was nice to have Spanish speaking friends in our group to translate.



Map view of Cerro de Pasco.

The Cerro de Pasco Mining Unit is comprised of the underground mine, the Raúl Rojas open pit mine, and the open pit and underground mines at El Pilar. We visited the Raúl Rojas open pit mine where silver, copper, zinc and lead are being abstracted. The mine is situated in the middle of the city and as you can see from the picture, the area of the mine is quite limited because of the population around it.

As a result of the limited space they have started underground mining under the Raúl Rojas open pit mine. The second half of 2010 they implemented a plan to increase the profit. The strategy was to focus in strengthening the underground mine operation and increasing silver production. In addition to the silver obtained through underground mining, this increase is supported by two projects: one involving oxides with high silver content and the other involving bulk silver concentration in pyrites. These projects are well-supported by mineral reserves and resources, part of which are in the form of stock piles accumulated on the ground and thus represent a low operating costs. Underground mine operations are supported by abundant reserves and high-quality ore. This has made it possible to improve metallurgical recovery and operating margins.

After the presentation we were driven in busses out to the open pit. The first thought when we stepped out of the busses was the dimension of the mine. It was huge! Also, the sight of the houses that was almost on the edge of the mine was unimaginable. They ensured us that the evacuation system was working properly in case of an earthquake. Since the mine has the special situation with the population living extremely close to the open pit, the safety is therefore very important. In the mine they had installed radar to measure any slope movement and stability. This was an action to increase the safety for the mine workers and also to prevent any issues for the population surrounding the mine.

Since the medical check-up took about 2 hours, which was not included in our schedule, the time spent in the mine was shortened. Back at the main office we were presented with nice gifts made of copper from the mine. They were pleased with our visit and invited us to visit again, to do masters or PhD work or even to apply for a job. As thanks for having us there, the chief geologist and the manager got a gift from us that represented NTNU and Norway. Before returning to Lima we got a big Peruvian lunch in their canteen, we had a long trip ahead of us. On the bus trip to Lima, we saw beautiful nature and amazing structures in the mountains and we had a short stop on a mountain



4818 meters above sea level. This was the first time at such a high altitude for many of us. About two hours before we would arrive in Lima, it was noticed that one of the tires had low air pressure. With no chance to fix this late at night, the remaining time to Lima was almost doubled. It did not help when we were stopped by the local police. Luckily, the police had only good intentions. Five minutes later we were back on the road again. It had been an exciting and long day with lots of impressions for all of us.

Students in front of the open pit mine at Volcan.

Cheves Hydropower Project

On Thursday the 29th of March we visited Cheves Hydropower Project owned by the Norwegian company SN Power AS. The project is under construction and is located on Rio Huaura, about 130 km north of Lima. The project consists of three dams ranging from 10-25 meters, 18 km long tunnel system and 77 km long transmission lines. The powerhouse will be underground. The installed capacity of the project is 148 MW with estimated yearly production of 837 GWh electrical energy. Currently, Peru has a lot of thermal power production and the Cheves project will reduce CO₂ emissions by 394 000 tons each year.

We arrived at the head office a little behind schedule, but Project Director Rune Mordal was flexible. After having nice lunch in their cantina we sat down for an interesting presentation of the project.

Rune talked about the project in general and their experience in working with Peruvian bureaucracy and the challenges concerning local people's interests in the surroundings of the project. We realized that a project like this is not easy to conduct for a company from another country. The bureaucracy can be very slow and the fact that Peru had an election that resulted in a new government, which seems take time understanding each other. The level of confidence that was built between the previous government and the company was now no more useful because new people were now in charge and new bonds had to be made. As a result, it took a long time just to get development license and permissions to start the work. There will always be people who are against projects like this almost no matter where you are and this was no different in Peru. SN Power spends large resources to build bonds and to get a good collaboration with the local people.

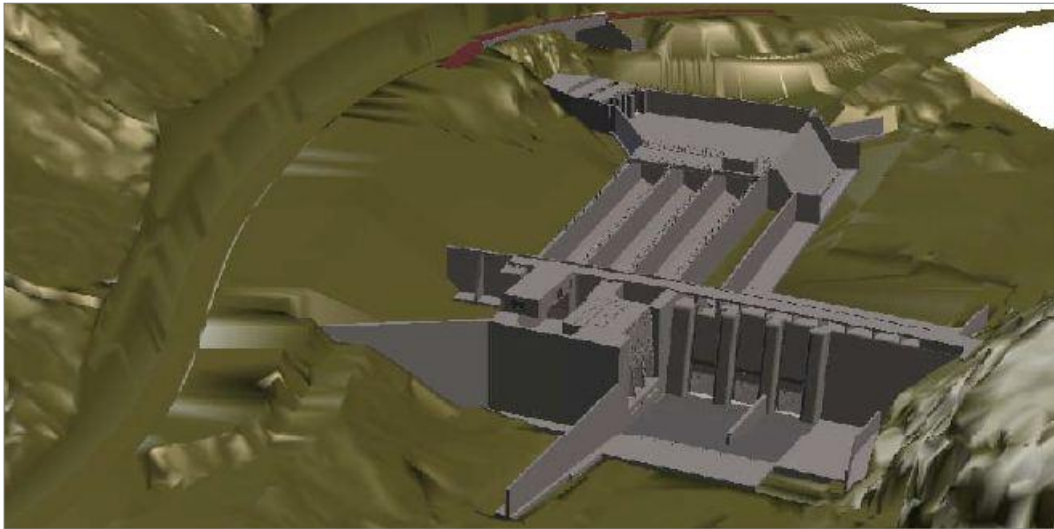


Dam foundations under construction.

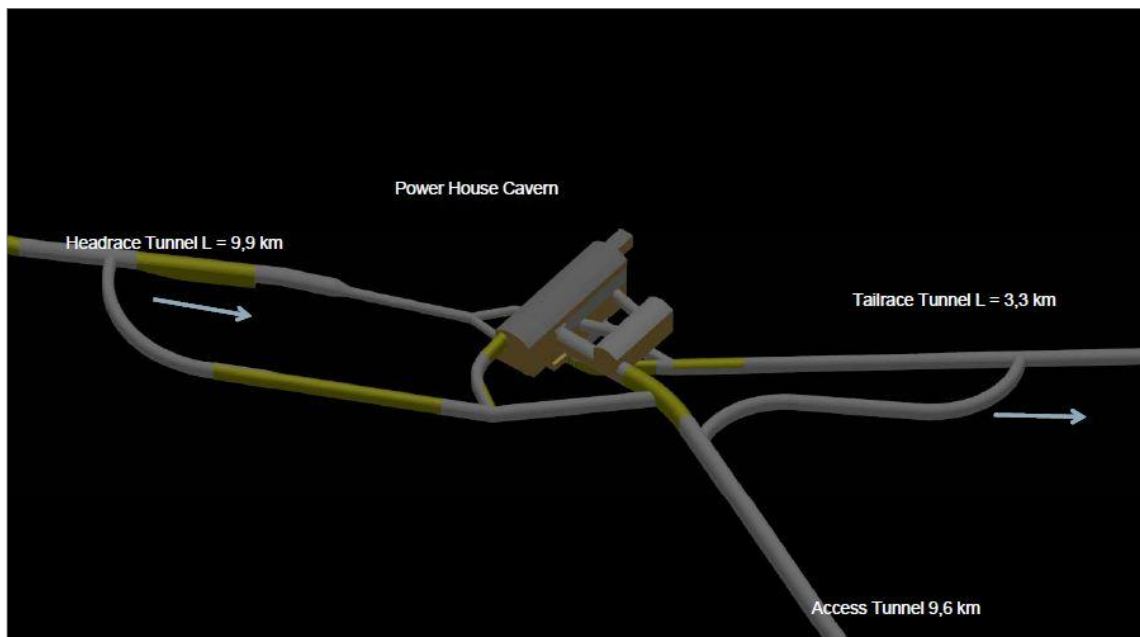
After Rune's presentation we got another presentation from Gunnar Solvang who is the Project Manager working for Norconsult. Norconsult is hired as an engineer on the project. Gunnar talked about the technical challenges related to the construction of both dams and tunnels. The geology, floods, major sediment transport, settlement of sediments underneath the dams, and problems with earthquakes give many challenges that may differ from the common problems in Norway.

After the presentations Rune took us to the project areas to show the construction activities at the dam sites and inside the headrace tunnel. The dams were not finished yet but by referring to models we had seen in pictures it was possible to visualize how the final result would look like. Rune explained that the way concrete construction was done in Peru was different from how it's done in Norway with regards to reinforcement but that the Peruvian way was equally good.

After looking at two of the three dams we went to see inside the tunnels. We were transported inside one of the adit tunnel (lower left corner in the picture below) to look at the working face of the headrace tunnel.



3D model of finished dam.



Power house at Cheves with associated tunnels.

When our tour was finished we went up to a small town called Churin to spend the night there. The road up to Churin was a narrow and steep valley side with lots of loose rocks and overburden soil on the slope. When we asked Rune if there were any problems concerning instability he answered that this was not a major problem as long as it did not rain, and it normally never rained in that area. 30 minutes after, it started to rain. During the ten minutes of driving up to Churin we could see creeks forming and digging into the road making us a little bit anxious if the road would exist the next day. During the night the rain stopped but a quite large landslide blocked the road so we had to wait for the road to be cleared before we could drive back towards Lima. When we were allowed to go

we still had to walk through the spot where the landslide took place, which was an exciting and interesting way to end our visit at Cheves Hydropower Project.



Students leaving Churin, 5 hours behind schedule.

Visit to Atlas Copco and Pontificia Universidad Católica del Perú

After visiting two mines and one hydro power plant it was time to go back to Lima. We arrived the capital city on Thursday evening and took the time to enjoy a nice meal down by the shore. The next day we were going to visit the headquarter of Atlas Copco in Peru, as well as a tour at the Pontificia Universidad Católica del Perú, the University of Professor Mario Cedrón Lassus. As we didn't had to get up as early as we were used to so far, some decided to check out the pubs in Lima, while others decided to call it an early night and get much needed sleep.

We all met outside the hotel the next day at around 0900. Taxis were going to pick us up and take us to Atlas Copco Peruana, the headquarter of Atlas Copco in Peru. The sun was shining intensely from a cloudless sky, and the temperature was close to 30°C. Just to be safe, everyone smeared on a decent amount of sunscreen and we were ready to go.

Atlas Copco is an industrial group with world-leading positions in compressors, construction and mining equipment, power tools and assembly systems. In 2010, the company had 33.000 employees and at the end of the year reaching more than 170 markets. In 2011 the company was ranked at 67 on Forbes' *The World's Most Innovative Companies* list.

At Atlas Copco we were met by General Manager Francisco Menendez Larrea. Before we went inside for the presentation we decided to take a group photo in front of the Atlas

Copco building. Everyone had their T-shirts on displaying all the companies that had sponsored this trip. Thank you all!



Norwegian delegation and Professor Mario Celdrón outside Atlas Copco Peruana S.A.

We then went inside to the lecture room and a presentation of Atlas Copco and their business were given.

During the presentation we were informed about different equipment that Atlas Copco has to offer for the mining industry. It was an impressive selection of different drilling rigs, loaders and haulers, rock drills etc. No wonder the company has the widest product range on the market. During the presentation we also got to learn about Peruvian politics

in regards to the mining industry, and some of the problems and challenges the country has to deal with. It was a lively presentation and the passion and enthusiasm shown by Professor Mario Cedrón Lassus and Francisco Menendez Larrea was clear for all to see. All in all it was a very interesting and informative lecture. At the end of the lecture we all got a little present – a bottle opener (in the shape of an Atlas Copco helmet), a stress ball and some information material about Atlas Copco.



After the presentation we got a tour around the facility and we all got a chance to take a closer look at some of the underground mining equipment

Drilling rig outside Atlas Copco's headquarters.

Atlas Copco has in its portfolio. All the equipment in Peru are built in Ørebro, where some of the students went to visit last year in connection with the course *Mining Engineering*. Independently of whether we had been to Ørebro or not, it was an interesting tour and we got to take a detailed look at the equipment. Some of the students even got a chance to sit in these big machines and test some of the attributes. It was Christmas Eve and New Years Eve all at once...

A great day so far was to become even better as Atlas Copco invited us to a barbeque. Good food and fantastic service set the tone for a relaxing and comfortable afternoon. We also got the chance to test out the fantastic "Helmet bottle opener" as they offered Peru's best beer, Cusqueña. When the meal was ingested and we all had enjoyed our time in the sun, it was time to go our next destination, the Pontificia Universidad Católica del Perú.

Atlas Copco had arranged taxis to take us to the University and the Departamento de Ingenieria de Minas. The mining education at the University is comprised of construction engineering, processing, rock mechanics, geology and mining engineering etc. This can be thought of as more comprehensive than the Norwegian model and covers many fields.

We were met by five of Professor Mario's students at the campus. At first we were given a short presentation of the University. We then had a tour through all of the labs and classrooms. It was very impressive to see all the different equipment they had available for teaching purposes. Among these a drilling simulation lab where the students had to accomplish a complete drilling cycle for mining excavation. In addition to this they had a lab with all the standard rock lab tests, such as the uniaxial test and the triaxial test.



After the tour we all gathered in the main classroom, where Professor Mario gave us some more information about the educational system in Peru. Steinar Ellefmo, professor in Mining Engineering at NTNU, also took the opportunity to inform the Peruvian students about how this works in Trondheim and NTNU. And as Steinar has later told us, maybe there is a chance for the Peruvian mining students to come and visit the mining industry in Sweden and Norway, which of course will include a visit to our university. Hopefully Steinar and Mario will work something out and we will get the chance to welcome them to our university one day.

Downtown Lima.

After the visit to the University, we all went downtown to check out the mineral museum. The *Museum Andrés Del Castillo* presents a large collection of crystals, from micro minerals, cabinet specimens to museum pieces of special quality. It was a varied and beautiful collection of different minerals, all of which had been collected in Peru. After spending about one hour at the museum we went to the Historic Centre of Lima and witnessed one of the many religious parades that take place during Easter. As a heavily Catholic country, Easter in Lima is celebrated over an entire week, known as *Semana Santa* or Holy Week. This is of course a public holiday. Religious ceremonies usually begin on the Friday before Palm Sunday and the following week is filled with daily and evening processions in the city's Historic Center. It was an interesting experience, but as the night came closer it was time to find the nearest restaurant to get something to eat.

All the Norwegian students and all the Peruvian students joined together for a nice meal that would conclude the day. We all gathered around a long table for some Pisco Sour (a South American cocktail) and dinner. Discussions were lively around the table as the students exchanged experiences from their country, both in terms of education, politics and life in general. This brought the day to an end, and everyone was happy to witness and experience some of the Peruvian industry and educational system. A special thanks to the Peruvian students who made us feel very welcome.

Machu Picchu

Machu Picchu is the most famous icon of the Inca world and it is believed that it was built as an estate for the Inca emperor Pachacuti and as a sacred religious site around 600 years ago. The city was abandoned just 100 years after its construction as a belated result of the Spanish conquest. Machu Picchu was first known for the outside world in 1911 and in 1983 it was declared a UNESCO world heritage site. Today it is an important tourist attraction.



Machu Picchu.



Our tour guide at Machu Picchu. Note the weather compared to the picture above.

On Saturday 31 of March we left Lima heading to the town Cuzco which is located in the Andes Mountains south of Lima. After dropping our luggage at a hostel and eating a good lunch we took the train down to the village Aguas Calientes which is the nearest city to Machu Picchu. The next morning we woke up at 5 o'clock and took a bus up to the ruins. Watching the sunrise from Machu Picchu is supposed to be amazing but because of heavy clouds and rain, we could not see it. Because we had a really enthusiastic guide who knew

all there was to know, the visit became a great success. After some hours the clouds cleared and Machu Picchu revealed an amazing view.

When we came back down to Aguas Calientes (Spanish for "hot springs") we had a few hours before the train was going to head back to Cuzco and some of us went for a swim in the hot springs.

Cuzco

The next day the entire group stayed in Cuzco. Cuzco was the site of the capital of the Inca Empire. The Spanish came there in 1533 and today the city has a mix of both Spanish and Inca influence.

After a hectic program the previous days, it was wonderful to have a day off. Some members of the group found the town so relaxing they decided to stay one day longer. During our stay in Cuzco three members of our group was hospitalized with either E-coli or Salmonella. Our initial plan was to continue to the town of Puno the next day. Because some members already had decided to stay one more day the rest of the group left as planned to Puno.

Puno and Lake Titicaca

After spending a few days in Cusco, nine students and the two professors, Steinar and Krishna, travelled to Puno. A guided bus ride, with stops at different cultural monuments, eventually took us to Puno, which is the capital city of the region with the same name. Puno is located on the shore of Lake Titicaca, a lake where we were going to spend the next day. Lake Titicaca is a lake located in the Andes on the border of Peru and Bolivia. At 3811 m above sea level, the lake is on record as the highest navigable lake in the world. By volume of water, it is also the largest lake in South America.

It was known beforehand that Lake Titicaca was the highest navigable lake in the world. What this actually meant no one knew, but hopefully the next day would give us the answer.

We met our guide at the hotel early the next day. A minibus took us down to the boat and Lake Titicaca. As many students were forced to stay behind in Cusco because of illness, there was plenty of space for the rest of us. The roof of the boat was the perfect place to take in the beautiful view of Lake Titicaca. Lake Titicaca is notable for a population of people who live on the Uros, a group of 44 or so artificial islands made of floating reeds. These islands have become a major tourist attraction for Peru, drawing excursions from the city of Puno. Their original purpose was defensive, and they could be moved if a threat arose. Many of the islands contain watchtowers largely constructed of reeds.

The first stop was one of the many Uros located in the lake. Here we met a local family who showed us how the islands were constructed. They also showed us some of the clothing they wore, and finished it all with a nice song. We also had to sing a song for them, and after some discussion we decided to sing Bæ Bæ Lille Lam. It was very well received indeed, and next year some lucky tourists might get the new and improved version presented by the local people.



Norwegian students in traditional outfit.

After visiting the Uros we went to an island called Taquile, 45 km from Puno. About 2200 people live on the island, which is 5.5 by 1.6 km in size. The highest point of the island is 4050 m above sea level and the main village is at 3950 m. The inhabitants are known as *Taquileños*. *Taquileños* are known for their fine handwoven textiles and clothing, which are regarded as among the highest-quality handicrafts in Peru. Knitting is exclusively performed by males, starting at age eight. The women exclusively make yarn and weave. We were given another singing performance by the local men, after which we had a nice

meal specially prepared by the village chef. Soup for starters and omelet or fish as the main course.

After dinner we decided to go down to the boat which was located a short walk from the village. Some took the opportunity to take a swim in Lake Titicaca, while others decided to relax and enjoy the strong sun. While it doesn't get very warm at Lake Titicaca, the altitude makes the sun extremely intense and we all had to take our precautions.

We soon departed for Puno once again, and on the way back we all got the chance to ask the guide the Million Dollar Question – what does it mean that Lake Titicaca is the highest navigable lake in the world? Answer: Lake Titicaca doesn't freeze during winter, which means that it is navigable all year round!

After getting the answer to this puzzling fun fact mystery, we all agreed that a fantastic and relaxing day had come to an end. Despite heavy rain on the way back to Puno, it had been some incredible experiences during the day. This trip also concluded the GEOEX12 excursion, as the next day was the first of a two-day trip back to Norway.

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