THE CHUNGARÁ LAKE BASIN: A RECORD OF ENVIRONMENTAL CHANGE IN THE TROPICAL ANDES

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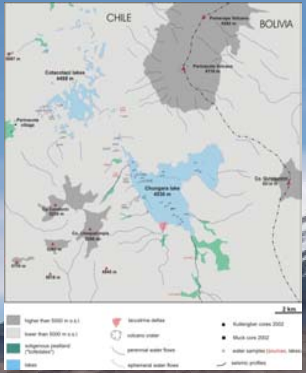
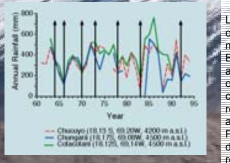


Location of water samples and sediment cores in the Chungará region. For a closer view, see the map to the right.

THE LAKE

Lago Chungará (18° 15' S, 69° 10' W, 4520 m a.s.l.) is located at the northeastern edge of the Lauca Basin. Its origin is related to the emplacement of the Parinacota volcano debris avalanche that blocked the Chungará River. The age of this episode is controversial, ranging from late Pleistocene (ca. 18 ka) to early Holocene (8 Ka). Previous studies carried out in several short cores together with the seismic survey showed the potential of Chungará Lake sedimentary sequence as a high-resolution archive of environmental and climate change in the tropical Andes. New Kullenberg cores along several transects in the lake were recovered last November to find out climate change and the relationships between human communities and environmental changes in the past. Some of the regional controversies are being investigated with the on-going multidisciplinary study.

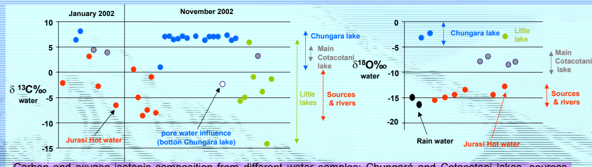


Annual rainfall in the Chungará region. The arrows indicate strong El Niño years, and they are correlated with reduced precipitation.

THE MODERN CLIMATE

Lago Chungará is dominated by tropical summer moisture that comes from the Amazon Basin, as a consequence of the southward migration of the subtropical jet stream and the establishment of the Bolivian high. Average annual rainfall in the Chungará region is about 350 mm/y while potential evaporation has been estimated at over 4750 mm/y.At present-day, three phenomena dominate climate variations on interannual to decadal timescales in the region: the ENSO phenomenon on interannual scale (3-6 years) and ENSO-like variations over the Pacific basin (what is called the Pacific Decadal Oscillation) and the North Atlantic Oscillation on a decadal scales. Particularly, in the Chungará region, precipitation is reduced during moderate to intense El Niño years (see graph in the left).

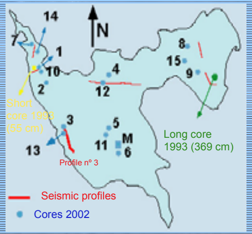
THE 2002 EXPEDITION



Carbon and oxygen isotopic composition from different water samples: Chungará and Cotacotani lakes, sources and rivers, and precipitation. Both Chungará and Cotacotani isotopic signatures are well characterized, with more positive values in Chungará waters: $\delta^{13}C$ between 5 and 10 and $\delta^{18}O$ between 0 and –5.

HYDROLOGY AND HYDROCHEMISTRY

Lago Chungará has a maximum water depth of 40 m, a surface area of 21.5 km^2, and a volume of about 385 million m^3. The main inflows are the Chungará River (300 to 500 ls^{-1}) and several springs on the western margin. There is no surface outlet. The Chungará lake is polymictic, oligotrophic, contains 1.2 g l^{-1} TDS, and the water chemistry is alkaline (pH ranges between 7 and 10) and of (Na$^+$)-(Mg^{2+})-(HCO_3)–(SO_4^{2-}) type. Lake water temperatures in spring (early November) range between 12ºC (surface) and 6ºC (bottom); electric conductivity showed little changes with depth (~1450 mS). Oxic conditions reach the bottom of the lake. Both Chungará and Cotacotani lake waters show large $\delta^{18}O$ isotope enrichment, due to evaporative processes, and heavy $\delta^{13}C$ values.



In November 2002 an international expedition, including Spanish, Chilean and US- institutions, retrieved fifteen Kullenberg cores along several transects in the lake. The longest ones (up to 8 meters) reached the basal seismic unit and recovered the whole post-Parinacota volcano collapse sequence. Basal sediments are coarse and contain gravels and sands. Preliminary core catcher studies showed a variety of sedimentary facies. in the lake. In addition, correlation among distant cores is posible by means of the magnetic susceptibility and provides the opportunity to study the sedimentary evolution in a basin-wide scale.

Coring expedition

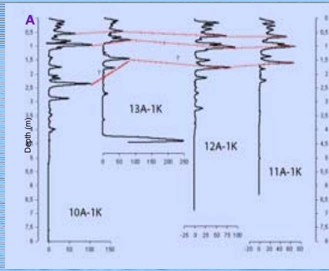
Unloading the platform (left) and setting the tower (right).

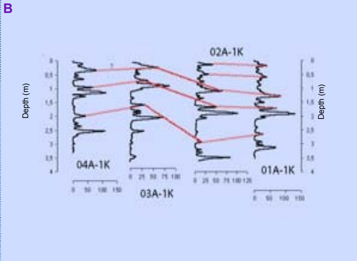
Seismic survey of Chungará Lake

Seismic profile recorded at 1/16 s sweep, 1-7 Khz, 1/2 s shot interval and 100 lines/in

Seismic profile obtained along the western edge of the lake. The reflector C and the erosive surface to the right indicate a lower lake level stage. The on-lap geometry of the C/B sediment package represents increasing lake levels.

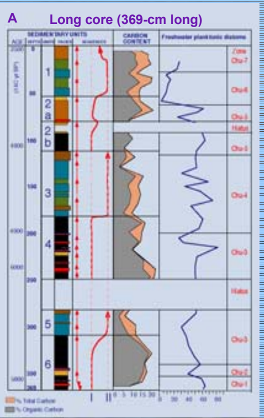
Magnetic Susceptibility



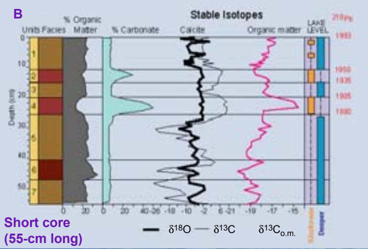


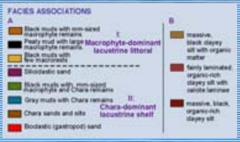
Magnetic susceptibility results (A and B figures) show several sequences reflecting changes in the depositional sub environments. A preliminar correlation is shown by red dotted lines.

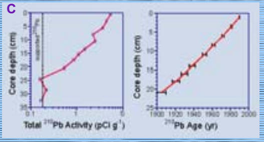
THE RESPONSE OF THE LAKE TO CENTENNIAL AND DECADAL CLIMATE FLUCTUATIONS



Photography of the 55-cm long core from the western basin of the Chungará Lake.







Sedimentary facies, geochemical and micropaleontological results and interpretation from (A) a 3.6 m long core recovered from the eastern basin and (B) a 55 cm long core recovered from the western basin. ^{14}C and ^{210}Pb chronologies are indicated. (C) Total ^{210}Pb activity profile and depth-age relationship for the Chungará Lake.

The sedimentary sequences identified in the 3.7 m long core showed the alternation of lake sub environments (lacustrine shelf, macrophyte-dominated littoral, and peat bog) thus recording century-to-millennial scale limnological and hydrological changes in the lake during the last 4000 years. Abundance of freshwater planktonic diatoms also points to these rapid climate fluctuations. In addition, sedimentary facies analyses and stable isotope geochemistry of a ^{210}Pb-dated core show large paleohydrological changes during the last 500 years: a main period of lower lake levels and increased water salinities between A.D. 1880 and 1950 with a higher lake level fluctuation in the early 20th century (A.D. 1905-1935). The short arid periods inferred from the sharp positive oxygen isotope excursions could be related to droughts of decadal recurrence and intense El Niño years during the second half of this century. These results indicate that the Chungará sediments are an exceptional record of the environmental and climate change in the tropical Andes.

SOME PALEOCLIMATIC QUESTIONS, IMPLICATIONS…. AND FUTURE WORK

Recent studies have highlighted the role played by the tropics in global climatic variability at different timescales, from interannual or decadal with phenomena like El Niño, to centennial and millennial. However, still little is known about the mechanisms and processes that controlled climate fluctuations in the Chilean Altiplano during the last millennia. Previous studies carried out in Chungará have demonstrated that the sediment sequence contains an excellent record of past climatic and environmental changes in the Central Chilean Altiplano. The on-going multidisciplinary study of the new and longer cores will bring new data and hypotheses to study the mechanisms of climate variability and is expected to help solving some of the paleoclimatic questions, and also the origin and evolution of the Lake Chungará Basin:

- Was the Chungará River dammed 18 ka or 8 ka ago?. What was the impact on the lacustrine sedimentation of the Parinacota and Pomerape volcanic activity?
- Do wet periods in the Altiplano correspond with high latitude North Atlantic millennial-scale cold events?. Are there any LIA features comparable to any of those intervals?
- What was the nature of the mid Holocene crisis in the Altiplano?. What is the response of the Altiplano environment to El Niño variability during the Holocene?. What was the response of the Aymara communities to the water availability?.