

## PALEOENVIRONMENT EVOLUTION IN THE BOLIVIAN ANDES DURING THE UPPER PLEISTOCENE

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### INTRODUCCION

The Bolivian Altiplano (3650-3900 masl), is situated en the heart of the Andes (66-71° long. West, 14-22° lat. South), between Eastern and Western branches, which surpass the 6000 masl (figure 1)

Nowdays, the lacustrine extensions (Titicaca, Poopó, Coipasa and Uyuni) are the result of the pluviometric gradient, very stepped, from the Norhteast (Eastern Cordillere, Lake Titicaca basin) to the Southeast of the Altiplano (Western Cordillera, Uyuni salines basin); the yearly precipitation change from 800 mm to 200 mm, while the estimate evaporation would vary from near 1500 mm per year in the North to near 2000 mm at the South (Roche et al., 1992; Grsjean, 1994). These climatic gradients are consequences of the latitude displacement of the Interropical Convergence Zone.

### METHODS AND RESULTS

We had analized several kinds of registers, aiming to reconstruction the paleoenvironment scenarios; the registers were from big geomorphologic units of the Altiplano: the Titicaca lake, the southern basins and the chain valleys.

In the Titicaca lake, the sedimentological study of the TD1 sample of 5.4 meters long (figure 1), and the radiocarbonic date give us two kinds of information, related to the temperature and the high of the water level at the time when the sediment was settled. The lower part of the sample (540-200 cm) characterize lower lacustrine levels. The mean atmospheric temperature, rebuilt from the palinologic data, is 3.5°C to 4°C lower to the actual temperature; and has a period of deep freezing (-6°C) between 20 000 and 19 000 years BP. There is an important hiatus at 200 cm of the sediment, which correspond to near 18 000 to 15 000years BP. This hiatus is synonymous of a very hard drought. From 200 to 155 cm (15 000 to 18 000 years BP). Neither the palinologic data nor the lower sediment index permit us to be precise at mark the maximun level reached by the lake in that time, nor limit its radiometric age, which is around  $13\ 180 \pm 130$  years BP. Aparently, this has happened simultaneously with the so called Tauca phase (Servant & Fontes, 1978). The temperatures are lower than today (-2°C). The existence of gypsum indicates the dryness of the Huifaimarca lake at the end of this period (Wirmann & Oliveira Almeida, 1987). from 155 to 10 cm, the paleodepths are rebuilt from a tranference function of ostracodes/bathymetry values (figure 2) Mourguiart et al., 1992). from 10 to 0 cm, the absense of ostracodes cannot allow to rebuilt quantitatively the evolution of the lake levels.

The deposits distributed along the perimeters of the main basins in the South (Poopó, Coipasa and Uyuni) are completely different. They show essentially as carbonated sediments, clayly or limely. In the figure 3 appear the rates age/high. The ages were fixed by dating of organism and carbonated deposits (molluscs, vegetal bioherms and microcrystalline crust). The Tauca phase extended from 14 000 to 10 500 years BP. While during this humid phase, there were hydric balance with oscilations of great magnitude.

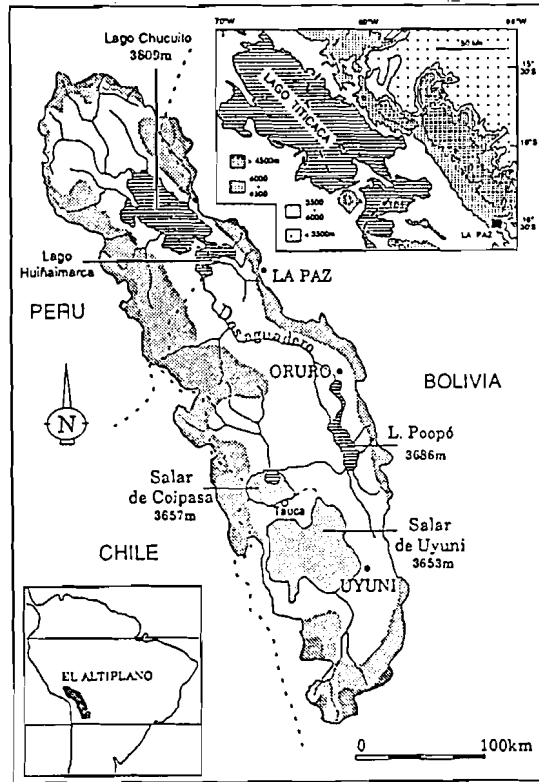


Figure 1: The Altiplano. Location of the cordilleras, lakes, and salines. The site of sampling TD1 is marked in the Huinamarca lake.

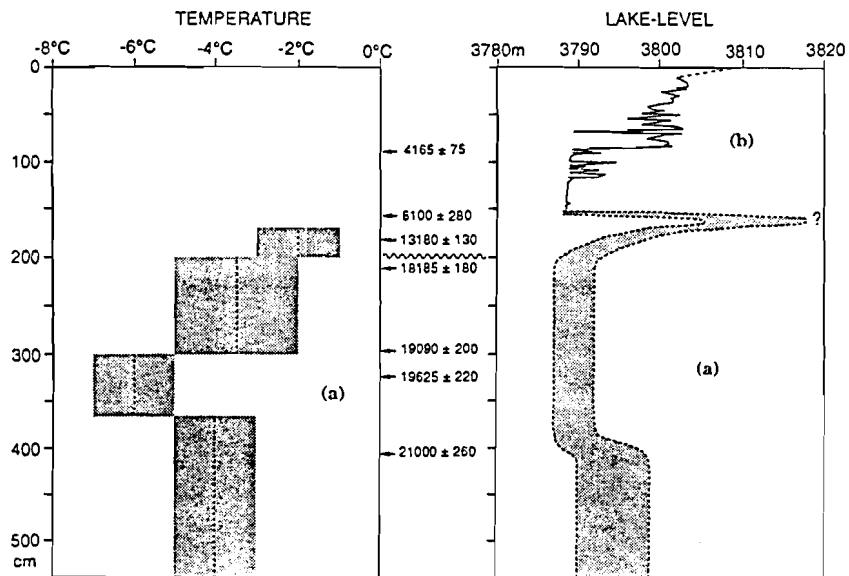


Figure 2. The reconstruction of the paleoclimatology and paleohydrology of the Huinamarca lake (sonde TD1). The shaded are the rebuilt from data analysis of the palinomorfe (Ybert, 1992). The continuous line in graph at right represents the results from the transference function ostracodes/water depth (Mourguiart et al., 1992).

The traces of forewent glaciations and diverse kind of flowings that happen in the time were identified by radiocarbon dating. We find five groups of moraines (figure 4). they are called: M1a, chronologically situated after 23 000 years BP; M1b, which is after 14 300 years BP and is considered as the last maximum glacier in the Bolivian Andes; M2, with unknown precise chronological position; M3, dated to be before 10 500 and 10 000 years BP, seems to be synchronous with the Younger Dryas; M4, which correspond to the Little Ice Age, period of the centuries XVI to XIX (Thompson et al., 1986).

## CONCLUSIONS

The paleoenvironment evolution of the Bolivian Altiplano from approximately 30 000 years BP, is fairly complex. Anyway it can be described as follows:

- From 25 000 to 18 000 Years BP, progressive dryness of the Titicaca lake. It would correspond to the final phase of the Minchin lake. An advance of the M1a glacier around 19 000 years BP.
- From 18 000 to 14 500 years BP, there is no information neither at the North nor the South of the Altiplano. The climate phase was dry.
- From 14 500 to 10 500 years BP, is the lake Tauca phase, with an advance of the glaciers (moraines M1b, M2, M3).
- From 10 500 to 8000 years BP a new dryness of the Titicaca lake and a quick recession of the glaciers.
- From 8000 to 3900 years BP, a little improvement in the water balances of the Titicaca lake.
- From 3900 years BP to ? a notorious rise of the lake levels, but with dry phases, short but important.
- From ? to nowadays, the Little Ice Age (moraine M4) and the actual period are characterized by a complex evolution of the lakes and glaciers.

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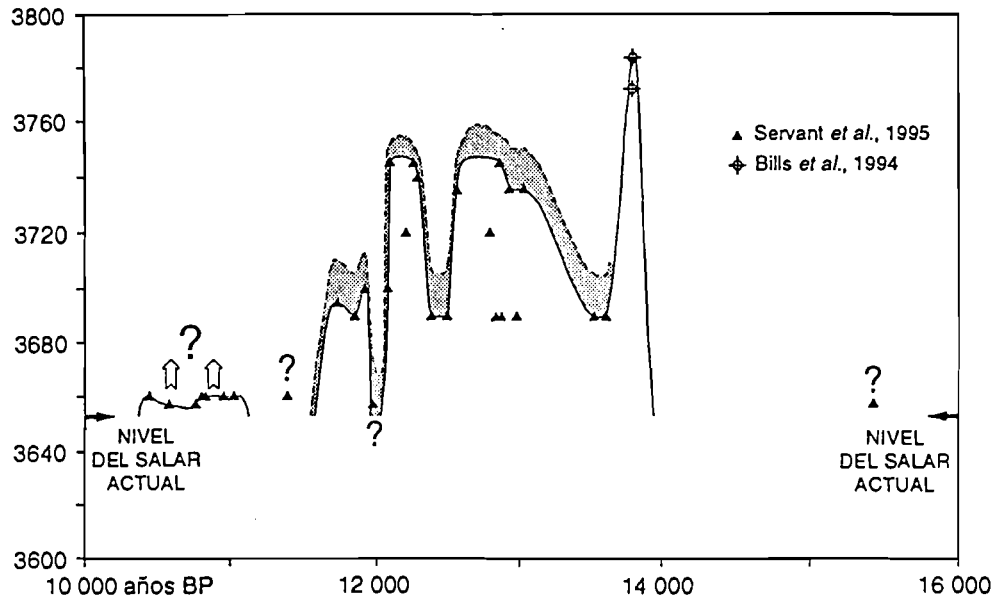


Figure 3. Projected dates from the salines zones versus the high of the sampling site. The wide line correspond to a minimum level of the lake; the two dating on the narrow line correspond to a shore line. The question marks point out isolated dates to be confirmed.

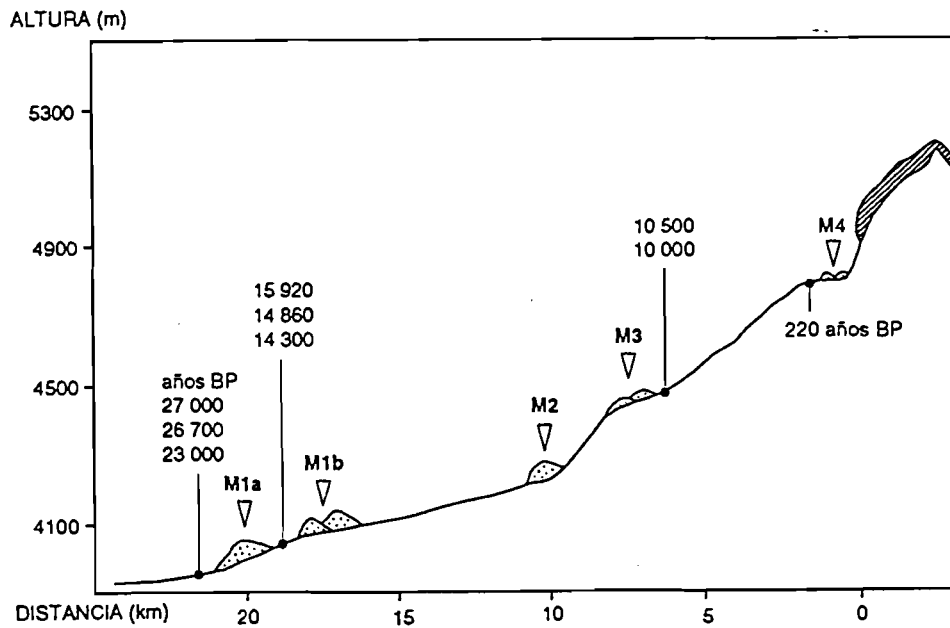


Figure 4. Draw showing the location of the moraines relative to the today's glacier front and the estimate age. The distances are given only in an indicative mode.