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Lake-level fluctuations from Uyuni-Coipasa basin, Bolivia between 21 and 8 ^{14}C kyr B.P.: Diatom and Shoreline evidences

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In the present arid area of high elevation (~3800 m a.s.l.), stretching from 15°S to 23°S and 66°W to 71°W between the eastern and the western Cordillera of Central Andes, lacustrine deposits outcropping on the margin of large endoreic basins, extensive developments of carbonate algal bioherms and stromatolites delineate variable extension of Pleistocene paleolakes.

A piston-core, collected in the southern part of the Salar of Coipasa, shows a 5 m-thick continuous diatom organic-rich sequence. This record is constrained by seven AMS ^{14}C dates on organic matter, which located the lacustrine sediments between 21 and 17.5 ^{14}C kyr B.P. A high-resolution diatom study provides evidence that, during this period, the Coipasa basin was filled by a shallow body of water, submitted to lake-level fluctuations. Diatom/salinity and diatom/ionic composition transfer functions indicate that the lake was saline, dominated by Na-Cl throughout all the period.

The post-glacial hydrological changes are reconstructed from several outcrops and shorelines on the margin of the Uyuni-Coipasa basin (Servant et al., 1995; Rouchy et al., 1996; Sylvestre et al., 1996; Sylvestre et al., 1999). Paleolake-levels are estimated by the altitude of the lacustrine deposits above the present bottom of the salar of Uyuni (3653 m) and confirmed by the modification of the fossil diatom assemblages. The fossil diatoms are studied in four selected outcrops located on the margin of the basin (Sylvestre et al., 1996; Sylvestre et al., 1999). Past salinity and ionic composition are inferred using transfer functions (Sylvestre et al., in press). The lake-level chronology is based on 44 radiocarbon dates performed on inorganic carbonates (Servant et al., 1995; Sylvestre et al., 1999). The validity of the radiocarbon ages is cross-checked by comparison with 6 U/Th ages measured by TIMS (Causse et al., 1995; Sylvestre et al., 1999).

Our ^{14}C chronology shows the beginning of a lacustrine transgression at ca 16 ^{14}C kyr B.P. in the Uyuni-Coipasa basin. After 16 ^{14}C kyr B.P., the level rapidly rose, interrupted by a period of stabilisation between ca 14.5 and 13 ^{14}C kyr B.P. Finely laminated sediments located on the margin of the basin contain successively a dominance of littoral epiphytic and tychoplanktonic diatoms indicating shallow water conditions with episodic freshwater inputs. At ca 13 ^{14}C kyr B.P., the lake-level rose abruptly reaching its

hydrological optimum with a depth of about 100 m above the present salar. A sudden drop of the lake level (Ticaña event) is recorded at about 4 m above the present salar by fluvial sands between ca <12 and >9.5 ^{14}C kyr B.P. Between ca 9.5 and 8.5 ^{14}C kyr B.P., a slight oscillation of the lake-level (Coipasa event) is represented by a calcareous crust widely developed around the basin at about 7 m above the present salar.

The diatom study in the core CO2 suggests that the southern part of Lake Coipasa was substantially more humid than today between 21 and 17.5 ^{14}C kyr B.P., while during the same period, Lake Titicaca underwent a low level indicating that it could not overflowed into Lake Coipasa (Wirmann et al., 1992; Ybert et al., 1992). As this dry phase was not registered in Lake Coipasa, we suggest that this lake was supplied by winter precipitation originated from the Pacific (Sylvestre et al., 1998). But recently, data from the deep basin of Lake Titicaca show that the lake-level was higher during this time interval (S. Fritz, comm. pers.), and arise the question: do precipitations reflecting the Atlantic and Amazonia sources play an important role on the Bolivian Altiplano during the Last Glacial Maximum? This hypothesis has to be discussed taking into account others available paleoclimatic data from the lowlands of tropical South America, where it is demonstrated that during the Last Glacial Maximum, the conditions were drier than today (Farrera et al., 1999). Global climate simulations show a positive P-E on the Altiplano, but the mechanisms invoked suppose a strong cooling, reducing evaporative demand more than any increase in precipitations (Pinot et al., 1999). According to the synoptic meterological situations generating winter precipitations (cold front or "cut offs" originating from northward incursions of the west wind zone), recent data from a marine core from the Chilean coast shows a northward locations of the Westerlies during the LGM (Lamy et al., 1999). This paleoclimatic hypothesis is also in agreement with a coupled ocean-atmosphere model which indicates weaker summer precipitation and stronger winter precipitation in the southern tropical zones (Ganopolski et al., 1998). However, this paleoclimatic hypothesis do not exclude an advection of water vapour originated from the tropical sources, probably implying a low-stand in northern Bolivian Andes (e.g. Lake Titicaca), but without sustaining nor explaining the forcing mechanism generating more humid conditions in the southern Bolivian Andes.

It has been demonstrated that the lacustrine Tauca phase [16 -12 ^{14}C kyr B.P.] and the lacustrine Coipasa event [9.5-8.5^{14}C kyr B.P.] are related not only to regional forcing mechanisms, but also to large-scale climatic changes in the southern tropical zone of the South America (Sylvestre et al., 1999). A comparison with the hydrological changes from the southern tropics of South Hemisphere, with the major climatic events from tropical oceans (marine records) and with the high latitudes records (ice cores), shows that the hydrological changes which occur at ca 16 ^{14}C kyr B.P. in the southern Bolivian Altiplano, are concomitant with the post-glacial wetting/warming which started early in the southern tropics (e.g. 16-15/14 ^{14}C kyr B.P.). This event is also concomitant with a steep temperature increase in south-eastern Atlantic and in Antarctica. At around 13.2-12.4 ^{14}C kyr B.P., a major increase in moisture is observed in the southern tropics; this roughly matched the major warming event as recorded in North Atlantic region at the onset the Bölling-Allerod. These observations suggest a north-south forcing climatic gradient between the high and low latitudes during the late-glacial times: before 15 ^{14}C kyr B.P., the southern tropics of South America are in response to the southern high latitudes

climatic changes; after 15 ^{14}C kyr B.P., the climate to the southern tropics appear to be mainly linked with northern high latitude climates and with the North Atlantic region, suggesting forcing mechanisms controlled by the deep thermohaline oceanic circulation.

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