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Volcanic and tectonic influence on the Holocene sedimentation of Lake Chungara (Andean Altiplano, N Chile)

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Geological setting

The Chungara lake (18°15'S, 69°10'W, 4520 masl) is located in a small hydrologically-closed sub-basin (273 km^2) in the Lauca Basin (Fig. 1 A). The lake is currently 40 m deep and is surrounded by volcanoes (Parinacota, 6342 m; Quisiquisini, 6063 m; Ajoya, 5293 m and Guallatire, 6063 m) (Fig. 1A). Miocene volcanic rocks compose the substratum of the Quaternary lacustrine deposits. The volcanic activity was very important in the lake Chungara area during late Pleistocene and Holocene (Wörner *et al.*, 1988, 2000, 2002; Clavero *et al.*, 2002). First, the collapse of the Parinacota caldera blocked the paleo-Lauca river causing the isolation of the sub-basin and the formation of Lake Chungara. The activity of post-collapse Parinacota volcano had a strong imprint in the lacustrine sedimentation due to the direct inputs of ashflows to the lake.

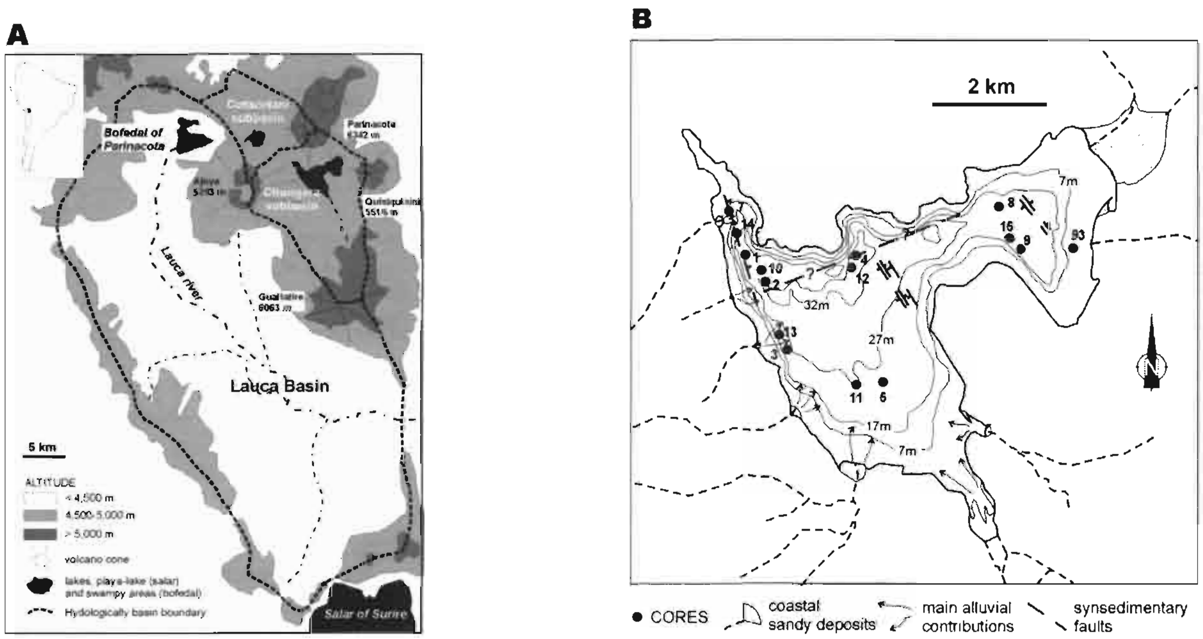

Figure 1. A. Map of the Lauca Basin showing main subbasins and physiographic elements. B. Scheme of the Chungara lake showing bathymetry, location of cores and synsedimentary faults.

Stratigraphy and synsedimentary faults

In November 2002, 15 cores up to 8 m long were recovered in Chungara lake using a Kullemberg system (Fig. 1B). Two main sedimentary lithostratigraphic units have been identified in the lacustrine sequence, (Fig. 2), and their chronology established using AMS 14C and 238U/230Th dates. **Unit 1** (12,899 to 7,000 cal years BP) is composed of laminated diatomites with only a thin volcanoclastic layer intercalated (M1, Fig. 2). Several carbonate-rich laminae appear towards the top of the unit. **Unit 2** (7000 cal yr. BP to the recent time) is composed by massive to banded diatomites with frequent interbedded volcanoclastic layers (M2 to M14 and WAF layers in Fig 2), both fine (ash layers) and coarse grained (lapilli). Subunit 2a is characterized by brown-reddish colour and the occurrence of frequent carbonate layers, whereas Subunit 2b sediments is grey-black in colour because of the presence of abundant volcanic maphic minerals.

Core stratigraphic correlation and seismic profiles (Valero-Garcés *et al.*, 2000) reveal that Unit 1 and the lower part of Unit 2 are affected by normal faults (less than 1 meter of fault vertical displacement). The high relief existing before lake formation and these synsedimentary faults determined the location of the sedimentary depocenter in the north sector of the lake (around coring sites 10 and 12) and, also, the formation of an onlap surface near the base of Unit 2 deposits. Consequently, Unit 2 deposits are onlapping Unit 1 deposits to the south (Fig. 2) and to the east.

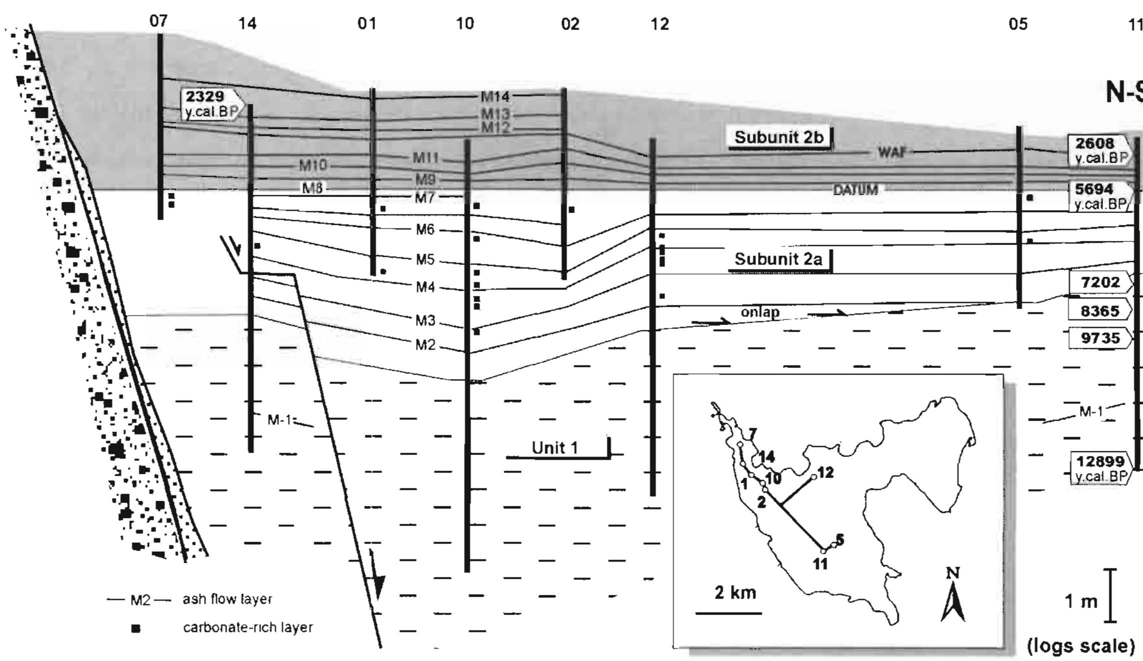

Figure 2. N-S stratigraphic cross section indicating the age of some sediment marker layer dated in cores 11 and 14. Note that the frequency of ashflows is greater in Unit 2. The thickest carbonate layers occur in Subunit 2a.

Compositions of the ashflows and the offshore carbonate deposition

X-ray diffractions (XRD) of bulk sample point to glass as the major component in ash flows. Minor percentages of feldspars, muscovite, pyrite and quartz are also found. Continuous X-ray fluorescence (XRF) analyses on ashflows layers indicate that the composition of ash changes mainly in the Ca contents (Table 1). The presence of Ca-rich ashflows in Subunit 2a (M2 to M8 layers) coincides with the stratigraphic position of the thickest carbonate levels in the lacustrine sequence (Table 1) suggesting a genetic relation. Moreover, other factors such as decreasing lake levels could also contribute to carbonate precipitation.

Unit	*Key layers*	*Ca (mg/kg)*
Subunit 2b	M-11	22.7
Subunit 2b	M-10	11.9
Subunit 2b	M-9	30.2
Subunit 2a	M-8	52.1
Subunit 2a	M-7	43.9
Subunit 2a	M-6	61.1
Subunit 2a	M-5	68.6
Subunit 2a	M-4	158.7
Subunit 2a	M-3	204.5
Subunit 2a	M-2	247.8
Unit 1	M-1	33.2

Table 1. Calcium contents in major ashflow recorded in Chungara lake deposits from XRF analysis.

Conclusions

- The collapse of Parinacota volcano and subsequent Chungara lake basin formation occurred more than 13000 years ago.
- From 13000 years to 7000 years BP the area experienced a "calm" period without major volcanic effusions.
- Around 7000 years ago, a synsedimentary faulting phase occurred. The distribution and orientation of the synsedimentary faults determined the generation of the sedimentary depocenter towards the northeast zone of the lake and the formation of an onlap surface.
- The principal phase of volcanic activity recorded by ashflow events into the lake was from 7000 years BP to the present. The volcanic ashflow deposits in the lake changed its composition from poor to rich –Ca contents around 7000 years BP and again to poor-Ca contents around 5700 years BP.
- The input to the lake of Ca-rich volcanoclastic material from 7000 to 5700 cal years BP could have contributed to carbonate formation in the lake offshore zones .

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