LATE-GLACIAL AND HOLOCENE TEPHROSTRATIGRAPHY AND ENVIRONMENT AS RECORDED IN THE LAGUNA SALINAS, SOUTH PERU

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The Laguna Salinas, an undrained basin in the Central Andean Volcanic Zone, lies at 4300 m in elevation on the Western Cordillera (16°22'S, 71°08'W, 4,300 m, Southern Peru: Fig. 1A,B). The Laguna is a saline playa, termed *salar*, which has acted and still acts as a sedimentary trap. The flat floor of the *salar* is occupied by a shallow saline lake 35 km^2 in area, in the western part of the basin 12 km across. The volcano-tectonic basin is open in upper Tertiary lava flows, overlain by volcaniclastic sediments Pleistocene in age. The Laguna Salinas is surrounded by high, extinct stratovolcanoes such as Pichu Pichu to the West and South, which have been heavily glaciated. Front moraines end at about 4500 m in elevation and glacial outwash has formed fans that are overlain by lacustrine and palustrine deposits towards the *salar*. Within 50 km distance from the basin, the Misti, Ubinas, and Huaynaputina stratovolcanoes have been active for the past five centuries (Fig. 1B).

Seven tephras are recorded in this area since the end of the Last Glacial, when glaciers melted away. Two groups of tephras were recognized, the first in two quarries to the West of the Laguna Salinas, the second in two cores drilled in the salar (section sites in Fig. 1C).

To the West, the pyroclastic sequence observed along the Arequipa-Puno road encompasses 4 tephras (from top to base, sections a and b, Fig. 1D): (1) the 10-cm-thick white ash fall T.H., dacitic in composition, from Huaynaputina volcano; (2) a 65-cm-thick, white coarse Plinian pumice-fall, T.P.1, andesitic in composition; (3) a 40-cm-thick pumice and lithic-rich tephra-fall, T.P.2, andesitic in composition; (4) a 135-cm-thick Plinian pumice-fall, T.P.3, dacitic in composition; (5) a 25-cm-thick yellowish lithic-rich pumice-fall, T.P.4, andesitic in composition. A few thin eolian deposits and poorly developped soils in ash are interbedded in these tephra-fall deposits, suggesting that the fallout occured repeatedly, precluding long-lasting episodes of quiescence in the area. Interestingly, this pyroclastic sequence is missing on the formerly glaciated high-plateau to the East and NE.

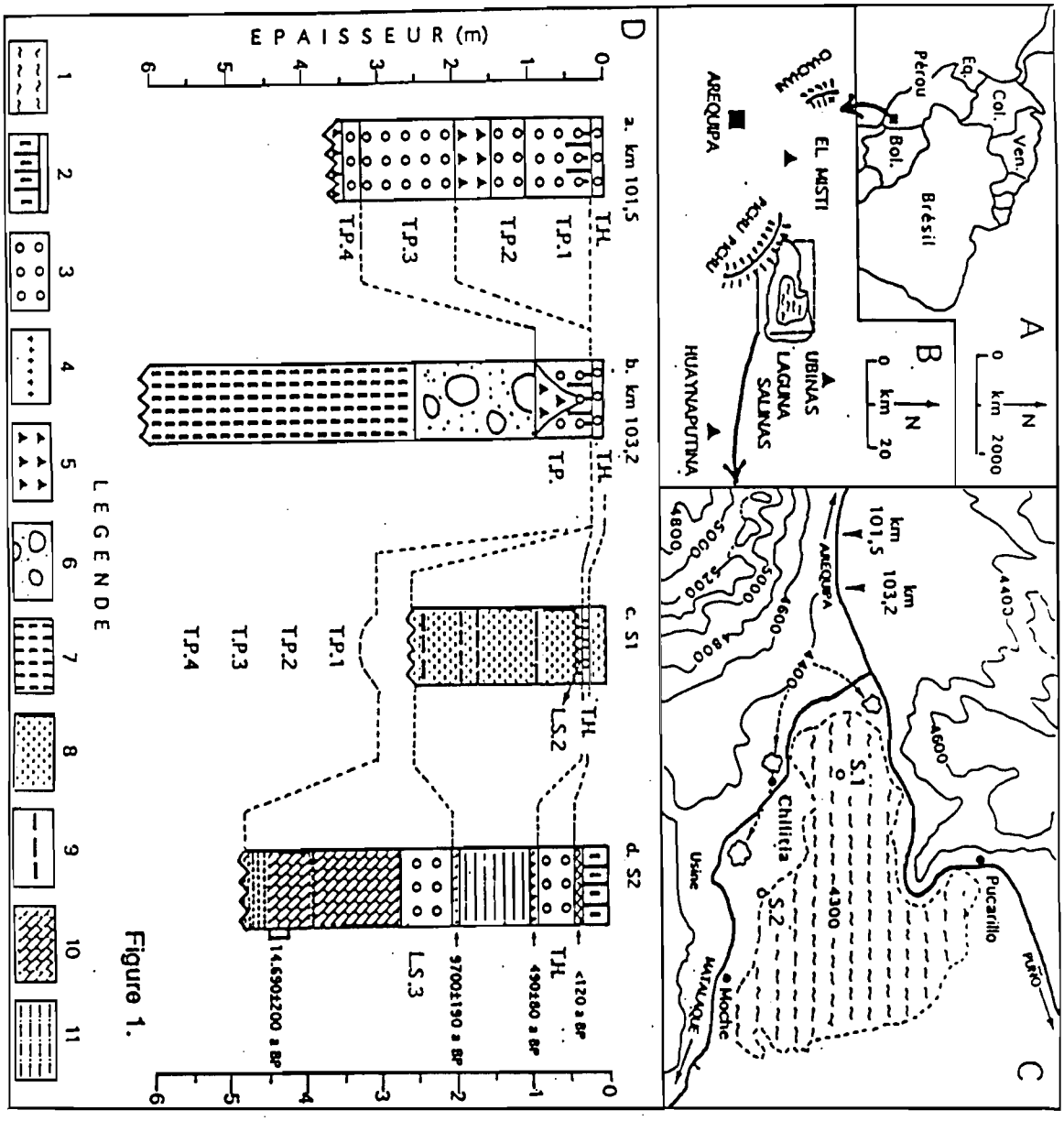

Figure 1.

Location of Laguna Salinas (A and B) and coring sites (C). Description of studied sequences (D): a) road Arequipa-Puno, road-cut at km 101.5; b) road Arequipa-Puno, km 103.2, pit; c) S1, core taken with a "russian corer"; d) S2, core taken with a "russian corer". Abbreviations of tephra beds: T.H., Huaynaputina Tephra; LS.2, Laguna Salinas Tephra 2; LS.3, Laguna Salinas Tephra 3; T.P.1 to 4, pumiceous tephra beds 1 à 4, at km 101.5 (road Arequipa-Puno); T.P., pumiceous tephra at km 103.2 (road Arequipa-Puno).

Two cores were drilled in the southern part of the *salar*, the first in the upper lacustrine deposits (S1, Fig. 1C and section c, Fig. 1D) and the second in the palustrine deposits (S2, Fig. 1C and section d, Fig. 1D). The sequence of the second core S2 corresponds to the last 15,000 years, although the drilling was blocked by an unidentified coarse layer. The 4.7-m-thick S2 core includes 3 tephra-fall layers interspersed in thick peat or gyttja and salt: (1) the 50-cm-thick white ashfall TH from Huaynaputina, dacitic in composition (whose thickness has been exaggerated by runoff); (2) a black, scoriaceous, fine ash layer 5 mm thick, LS2 (section c, Fig. 1D), olivine-bearing andesitic in composition; (3) a 70-cm-thick pumice and ashfall deposit, dacitic in composition.Four ^{14}C datings (section d, Fig. 1D) and tephrostratigraphy in the Misti-Huaynaputina area allow us to correlate and rank the three tephras in a time frame. The dacitic TH tephra belongs to the A.D. 1600 Plinian fallout of Huaynaputina. The black scoriaceous, andesitic ashfall was delivered by El Misti at A.D. 1440-1480, based on the time span and rate of peat sedimentation between TH and LS2, and correlated to historical accounts. The third thick pumice fallout is slightly older than 9700 ± 190 yr B.P., i.e., at the transition between Late Glacial and lower Holocene.

Correlation with the pyroclastic sequence along the Puno road (Fig. 1D) shows that the coarse tephra-fall deposits T.P.1 to T.P.4, missing in the cores, are to be found below the radiocarbon dated peat layer at 14,690 ± 200 yr B.P., i.e., before the Late Glacial period. However, the tephras TP1, TP2, and TP3 are probably placed close to the end of the Last Glacial period when the glaciers melted away, while the tephra TP4 may be contemporaneous with that period. Conversely, the lowermost tephra ≥ 9700 yr B.P. old in the core is missing in the pyroclastic sequence to the West of the Laguna Salinas : it has been either eroded away or removed in eolian deposits and soils.

Polen analysis has been carried out on the second core at 200 to 400 cm in depth (section d, Fig. 1D). Based on ^{14}C datings, this part of the core corresponds to the Late Glacial. The polen record shows that the paleovegetation was uniform: steppe graminae (Poaceae), cushion plants (Caryophyllaceae) and shrub (Asteraceae) prevailed. Such a steppe vegetation point to arid to semi-arid climate in that area throughout the Late Glacial. Evaporation and drought increased or decreased according to temperature fluctuations, a fact that explains the observed changes in the polen record.

We distinguish two phases with distinct environments. The Salinas I phase (Late Glacial) is characterized by a *tolar* vegetation in the *puna* vegetation, i.e. dwarf trees (*Asteraceae*), *Polylepis*, and a few graminae which point to a cold and semi-arid climate (less dry than that prevailing today). The Salinas II phase (transition from Late Glacial to lower Holocene) reflects a drier environment including graminae from desert steppe (*Poaceae*), alike that of the dry altiplano today. The vegetation was poor and the climate very dry. The transition between Salinas I and II occurs close to 280 cm in depth and may represent the Late Glacial-Holocene boundary.

Reference

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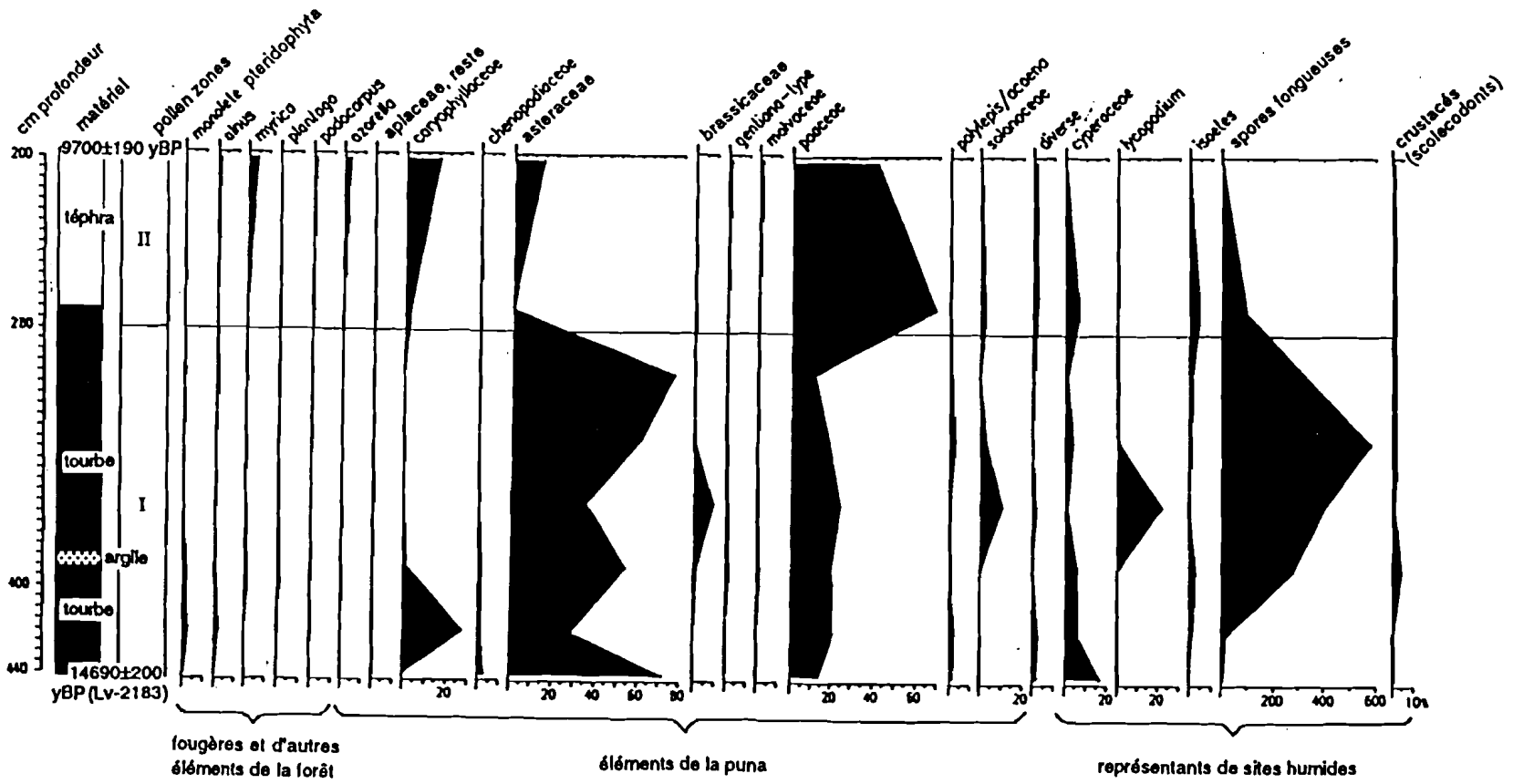
Laguna Salinas
16°24'S/71°9'W, 4300 m
Kurt Graf

Figure 2.



Pollen diagramme of the peat sequence 200 to 440 cm (depth) of core S2.