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An Arid Event at the Younger Dryas Time Window in the NE Tibet - Qinghai Plateau: Evidence from Qinghai Lake

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ABSTRACT. A multi-proxy approach was applied to the study of two sediment cores extracted from two subbasins centers of the large closed-basin Qinghai Lake. Results suggest that before the abrupt onset of a warm and wetter climatic regime of the early-Holocene, an arid event occurred around 10,700–10,000 ^{14}C years BP. A decrease in catchment inflow due probably to a reduction of rainfall marked the beginning of the arid period. Enhanced summer evaporation may also be responsible for the formation of a nearly desiccated carbonate playa in the entire lake. The arid event at Qinghai Lake is interpreted as a Younger Dryas equivalent although a return to cold conditions is not evident. Abrupt changes in hydro-climatic conditions across the late glacial-to-Holocene transition in Qinghai Lake may reflect oscillations in monsoon moist to the NE Tibet-Qinghai Plateau.

KEY WORDS: Qinghai Lake, Tibet-Qinghai Plateau, sediment cores, Younger Dryas arid event, carbonate stratigraphy.

Introduction

Younger Dryas (YD) climatic reversal, originally recognized about century ago in paleoclimatic records from northwest Europe, is for now still a subject of scientific interest, including its causes and geographic distribution. To have better understanding on the subject may help us to improve our knowledge on how various components of the biosphere, atmosphere, ocean, and cryosphere interact on short time scales. In the past decade, investigations on paleoclimatic records in China relevant to this scientific issue have been carried out. The investigated proxy records include those from lake sediment cores (Kelts et al., 1989; Lister et al., 1991; Gasse et al., 1991; Gasse and van Campo, 1994; Yu and Kelts, 2000), ice cores (Thompson et al., 1989; Thompson et al., 1997), loess and paleosol sections (An et al., 1991; Zhou et al., 1993), as well as marine cores (Kudrass et al., 1991). A consistent explanation on the climate conditions at the YD time window from these studies is however elusive. This paper presents results from investigation on two sediment cores from subbasin centres in Qinghai Lake to examine paleoclimatic conditions at the YD time window on the NE Tibet-Qinghai Plateau.

Qinghai Lake lies on the northeast corner of Tibet-Qinghai Plateau at an elevation of 3193.7 m a.s.l. It has a size of about 4600 km^2 and a maximum depth of 26.5 m, the largest water body now in China. The lake today is at the outer margin of the

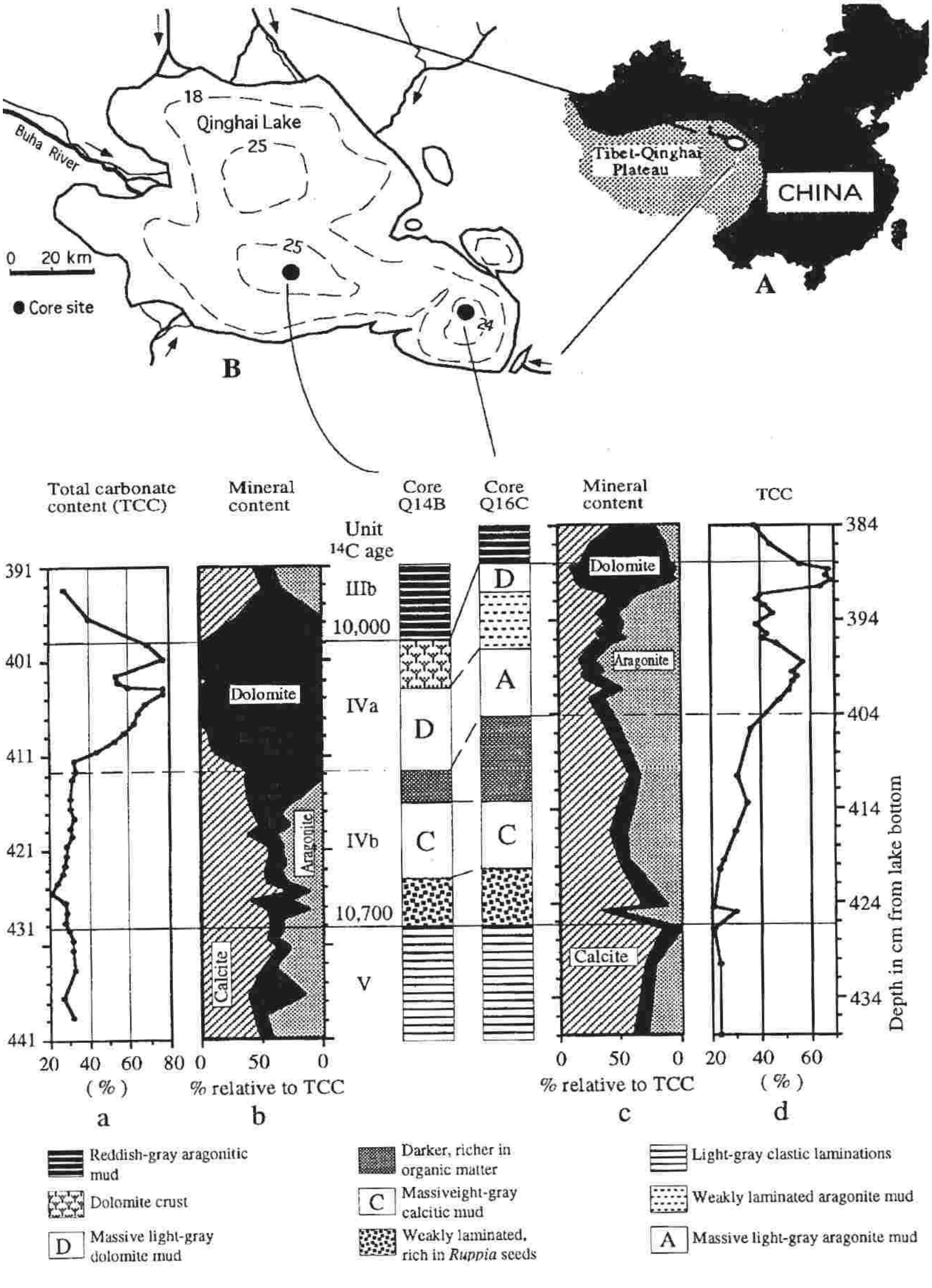

Fig. 1. (A) Location of Qinghai Lake on the Tibet-Qinghai Plateau of China, (B) bathymetry of Qinghai Lake with coring sites, (C) correlation of lithology and carbonate mineral records between core Q14B and core Q16C for the sediments deposited around 10,700–10,000 ^{14}C years BP.

Asian summer-monsoon influence. Changes in monsoon circulation feature in the past could change precipitation to evaporation balance of the large closed-basin lake, resulting in lake-level fluctuations and variations in water chemistry.

Methods

Sediment cores were extracted from the central subbasins of Qinghai Lake (Fig. 1) using a Kullenberg corer and stored in cold room at 4 °C. Core sections were split and photographed fresh. Lithological units are based on sediment colour, structures and texture, smear-slides, XRD mineralogy. Total inorganic carbon (TIC) contents of the sediments were determined by coulometer measurements. XRD analyses defined relative contribution of three carbonate minerals. Total carbonate contents (TCC) were calculated from TIC contents and relative contents of three carbonate minerals. Seeds were picked and used for AMS radiocarbon dating. Organic debris from rooted aquatic plant *Ruppia* was used in conjunction with sedimentological evidence as a lake-level indicator.

Results and discussion

^{14}C dated multiple stratigraphic records from the transitional sequence of the Late Glacial Holocene in cores Q14B and Q16C (Yu and Kelts, 2000) indicate that before the onset of a warm and wetter Early Holocene, an arid interval between ~ 10,700 and 10,000 years BP (uncalibrated ^{14}C ages, extrapolated from four AMS ^{14}C dates of macrofossil seeds), occurred in Qinghai Lake. Fig. 1C shows a high-resolution correlation of lithology and carbonate mineral records between cores Q14B and Q16C. At the base of Unit IV, a layer rich in seeds and debris from *Ruppia* plants, which occurred in both southern and eastern subbasins, followed an abrupt cessation of clastic laminations. The layer was fairly well laminated in Q16C and weekly laminated in Q14B. The *Ruppia* remains in the laminated sediments were unlikely transported far over the large very flat lake bottom from nearshore low-energy areas. The correlation of the two layers suggests that the two central subbasins were a few meters deep and colonized by *Ruppia*, the rooted aquatic plants, for several decades. In the following 300 years or so, total carbonate content (TCC) increases from 20% to 33% (Fig. 1C a), alongside with an increase in both total organic carbon (TOC) and nitrogen (TN), as well as increasing amount of organic remains in the sediments. This suggests that the lake was increasing in both organic and carbonate production. The increase in carbonate production around 10,700 to 10,300 years BP was more apparent in the subunit IVb of Q16C as shown by TCC increase (mainly aragonite) from 20% to 40% (Fig. 1C d). Thereafter, TCC sharply increased in subunit IVa from 33% to 80% in Q14B and from about 40% to 70% in Q16C and a dolomite band formed on top of Unit IV in both cores. This indicates that climate was more arid around 10,400 to 10,000 years BP, leading to the formation of a nearly desiccated carbonate playa in the entire lake.

Around 10,700–10,000 years BP, the lake levels, as reconstructed, ranged from near desiccation to a few meters deep, shallower than both in the earlier period when Unit V deposited and in the early-Holocene. At about 10,700 years BP, a decrease of precipitation in the large catchment is suggested by an abrupt cessation of clastic laminations and a decrease in detrital influx to both southern and eastern subbasins. Precipitation to evaporation balance of the closed lake since then turned to be more negative. The negative trend appeared to be gradual around 10,700–10,300 years BP and then sharp around 10,300–10,000 years BP. The detailed correlation of lithology and carbonate mineral records suggests that waters in the two subbasins were too shallow to be connected all the time around 10,400–10,000 years BP, and groundwater supply to the eastern subbasin became more influential on water chemistry so that subfacies were different from those in core Q14B. Nevertheless, aridification is the commonplace indicated by the subfacies occurred in the two subbasins of the lake.

The arid interval at Qinghai Lake ended abruptly around 10,000 years BP, as marked by a sudden termination of the nearly desiccated carbonate playa. The Early Holocene at the lake site is characterized by a warm and wetter climate in which the lake deepened with high organic and carbonate production. The sediments deposited at ~ 10,700–10,000 years BP showed evidence for an aridity-increased interval occurred before the onset of the Holocene. But the increase in both organic matter and carbonate contents in the sediments is very much different from the sediments deposited during a cold and dry climate before 11,600 years BP (Yu and Kelts, 2000).

The sediment evidence from Qinghai Lake indicates that short-term oscillations in hydro-climatic conditions occurred across the Late Glacial to Holocene transition. This provides further evidence to suggest that climatic instability during the transition is a global phenomenon, probably as a consequence of increasing seasonality of insolation and changing surface boundary conditions accompanying deglaciation, which is greatly different from today. The arid event at Qinghai Lake is chronologically synchronous with the Younger Dryas originally recognized in climate records from northwest Europe. It may be interpreted as a YD equivalent in the NE Tibet-Qinghai Plateau, although a return to cold conditions is not evident. Increased aridity around 10,700–10,000 ^{14}C years BP at Qinghai Lake probably resulted from short-term recession of monsoon moist to the NE Tibet-Qinghai Plateau.

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Lake Level Fluctuation of Lake Lisan/Dead Sea and Lake Van (Turkey)

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ABSTRACT. During the Last Glacial Maximum two prominent Near East depressions were filled with vast internal lakes: Lake Lisan/Dead Sea and Lake Van/East Anatolia. Both lakes left terraces composed of carbonate/detritus laminae and gypsum beds (in case of Lake Lisan). Here we present a study of geochemistry, mineralogy and sedimentology from two sites on the Jordan side of the Dead Sea rift valley. Elemental distribution was investigated within the finely laminated sediments by microprobe. The 'normal' sedimentation cycle is characterised by alternating clay and aragonite layers. In Lake Lisan periods of drought are identified by annual triplets of clay, aragonite and gypsum. ^{14}C-dates yield information about past lake levels. Comparison of lake level fluctuations between Lakes Lisan and Van revealed equivalent amplitudes, but the simultaneity of their phases still has to be shown.

KEY WORDS: palaeoclimate, varves, lake level, Lake Lisan, Lake Van.

Introduction

Between 70 and 15 ka the Dead Sea rift was occupied by a large, saline lake: Lake Lisan (e.g. Kaufmann, 1971; Schramm, 1997). It left terraces of up to 50 m thick laminated, i.e. varved, marl deposits (the Lisan Formation) (Begin et al., 1974). They rest unconformably on either older lacustrine sediments or bedrock of various age. Laminae alternate between light aragonite and dark detrital layers (e. g. Stein et al., 1997). Holocene sediments, up to 20 m thick, occur in fan delta regions near the Dead Sea shore consisting of detrital clay and authigenic aragonite as well (Migowski et al., 1998).

Methods and material studied

Two profiles were sampled. Profile LSM1 (32°00.2'N, 35°32.3'E) is situated about 7 km NW of the city of Karama. Here, the Jordan river has cut through over 50 m of deposits. The profile top is at 305 m below m.s.l., but patches of sediment and microbialites occur nearby as high as 280 m below m.s.l.. Profile LSM2 (31°17.3'N, 35°28.1'E, top at 370 m below m.s.l.) is located on the Lisan Peninsula, the type locality of the Lisan Marls. Two sample series were collected from the upper 26 m of each profile: a set of ca. 40 discrete samples for geochemical analyses and a continuous profile - using metal boxes overlapping each other - for the preparation of thin-sections and polished plates. Set 1 was used to conduct X-ray diffraction (XRD) and CNS-analyses. Distribution of Si, Al, Ca, Mg, S, K and Fe within the varves were studied on six thin-sections using a microprobe.

Results and discussion

Fig. 1 shows the lithology, chronology and geochemistry of the two profiles. The upper 10 m of LSM1 consist of dark laminated clay and silt, intercalated by non-laminated sections with several sand layers. Whitish coloured, laminated clay and silt mark a thin horizon at 2 m and a thick one from 10 to 21 m. Within the latter, sections with deformed lamination caused by slumping are observed. These occur preferentially below layers with elevated detritus content and may be caused by earthquakes (seismites, Marco et al., 1996). During an earthquake sediments are consolidated, causing the pore water to move upward. This flux may be blocked by the detritus rich layers leading to a pore water supersaturation and hence to sliding planes. Severely slumped sections, sand layers and turbidites mark the dark sediments of the lowest profile section.

The most striking feature of profile LSM2 is the alternation of horizons dominated by gypsum or aragonite. Under the arid climate of the Lisan peninsula the gypsum layers are resistant to erosion forming flat, step-like platforms promi-