Review of Palaeobotany and Palynology 192 (2013) 32–41

Contents lists available at SciVerse ScienceDirect

Review of Palaeobotany and Palynology

journal homepage: www.elsevier.com/locate/revpalbo

Research paper

High-resolution pollen sequence from Lop Nur, Xinjiang, China: Implications on environmental changes during the late Pleistocene to the early Holocene

Dong Yang [a,b], Zicheng Peng [b,c,*], Chao Luo [c], Yi Liu [c], Zhaofeng Zhang [d], Weiguo Liu [b], Pengxi Zhang [e]

[a] College of Geography and Environmental Sciences, Northwest Normal University, Lanzhou 730070, China
[b] State Key Laboratory of Loess and Quaternary Geology, Chinese Academy of Sciences, Xi'an 710054, China
[c] School of Earth and Space Science, University of Science and Technology of China, Hefei 230026, China
[d] State Key Laboratory of Isotope Geochemistry, Guangzhou Institute of Geochemistry, CAS, Guangzhou 510640, China
[e] Institute of Salt Lake Research, Chinese Academy of Sciences, Xi'an 710043, China

ARTICLE INFO

Article history:
Received 20 April 2012
Received in revised form 7 October 2012
Accepted 14 December 2012
Available online 11 January 2013

Keywords:
Lop Nur
pollen
late glacial
paleoclimate
paleoenvironment

ABSTRACT

A 9.35-m long sediment core, CK2, that covers the time span between 31.98 and 9.14 kilo annum before present (ka BP) at the Luobei Depression (Lop Nur, Eastern Xinjiang, Northwest China) was studied by pollen analysis. The pollen assemblages of coniferous trees, temperate deciduous trees, herbs, and shrubs can be divided into the following four stages: Zone I (31.98 ka BP to 19.26 ka BP) corresponds to a steppe or desert steppe landscape, which conforms to the cold-wet climatic environment of the Last Glacial Maximum; Zone II (19.26 ka BP to 13.67 ka BP) corresponds to a steppe–desert or desert landscape, which conforms to the warm-arid climatic environment of the transient interglacial period; Zones III (13.67 ka BP to 12.73 ka BP) and IV (12.73 ka BP to 9.14 ka BP) are similar to Zones I and II, respectively, corresponding to the late last glacial and post last glacial, i.e., Early Holocene, respectively. The climatic environment in Lop Nur was increasingly getting drier based on Artemisia/Chenopodiaceae ratios of ≤ 0.5 in Subzones IVa and IVc. The Heinrich cold events (H3, H2, H1, and YD) and the Dansgaard–Oeschger warm events (IS4, IS3, IS2, IS1) with millennial-scale changes appearing at high latitudes can also be found in the pollen records of Lop Nur. Results show that the climate characteristics of the Lop Nur region are mainly controlled by the westerly belt, as displayed in mainly cold-wet or warm-arid synchronization. These climate characteristics differ from those of the monsoon area, which are mainly displayed in cold-arid and warm-wet synchronization but also restricted by the atmospheric circulation at high latitudes.

1. Introduction

The climatic systems of the late Pleistocene have been demonstrated to have changed on millennial–centennial scales (Bond et al., 1997, 2001). These changes have been well documented in the North Atlantic area at high latitudes (McManus et al., 1994; Oppo et al., 2003) and in the Yangtze River Basin at low latitudes (Wang et al., 2001, 2005). Apparently, an urgent investigation of the regional responses of these millennial–centennial scale climate changes in the northwest part of China in middle latitudes is needed to explore the geographic coherence of these changes.

Eastern Xinjiang in Northwest China is the most arid region of Central Asia located at the boundary between the East Asian summer monsoon and the westerly winds of the Northern Hemisphere (Lehmkuhl and Haselein, 2000; Yang and Williams, 2003). This region is sensitive to the environmental changes in the prominent westerly and monsoonal circulation systems. A number of studies have indicated that the late Pleistocene climatic changes in this region are mostly influenced by the expansion and contraction of the summer monsoonal circulation (e.g., An, 2000; Zhou et al., 2001; Jiang et al., 2006). However, this region may have experienced complex patterns of climate change because of the interplay between the high-latitude atmospheric circulation and the middle-latitude westerlies. Therefore, the climate change in Lop Nur is expected to be mainly controlled by the westerly belt and restricted by the high-latitude circulation.

Environmental and vegetation changes are some of the foci used to study global conditions within and among different climate states as well as land–air interactions under different vegetation conditions during different climate states (Wang and Oba, 1998; Bridgman and Oliver, 2006). However, high-resolution and well-dated pollen records from Lop Nur in the eastern Tarim Basin, Xinjiang, China, especially between the late Pleistocene and early Holocene, are rarely available.

In this paper, a high-resolution reconstruction of the environmental variations and associated vegetation changes is presented based on six uranium–thorium (U–Th) disequilibrium dates and on 180 pollen samples from 100 cm to 1035 cm of the CK-2 core to investigate the paleoenvironmental and paleoclimatic changes at around 31.98–9.14 kilo annum before present (ka BP). The paper also discusses the local

* Corresponding author at: School of Earth and Space Science, University of Science and Technology of China, Hefei 230026, China. Tel./fax: +86 551 63602271.
E-mail address: pzc@ustc.edu.cn (Z. Peng).

0034-6667/$ – see front matter
http://dx.doi.org/10.1016/j.revpalbo.2012.12.002

characteristics of the climatic and environmental changes and their response to global change. The temporal patterns of the Holocene climatic changes documented at Lop Nur are also confirmed. The study provides valuable information on the large-scale mechanisms that control or modulate the climate changes in recent geological history.

2. Physiographic settings

The tectonically active Tarim Basin (4000 m a.s.l.) comprises Miocene to recent sedimentary strata that overlie the Archean and Proterozoic basement (Tang, 1994). The middle and lower portions of the drainage basin are characterized by arid to extremely arid climates. Based on the Koppen classification, the Tarim Basin belongs to dry steppes and deserts, where both summer heat and winter cold are intense.

Lop Nur and its adjacent domains that occupy an area of 105 km^2 are located in the lowest part (780 m a.s.l.) of the Tarim Basin at longitude 90°9.92′–92°10.50′ E and at latitude 39°45.16′–40°45.67′ N (Fig. 1). The annual rainfall in this region is 22 mm, and the annual evaporation is 3000 mm. This region suffers from strong winds of over six scales for more than 100 days in a year. The highest air temperature in summer fluctuates between 40 °C and 50 °C. All these factors make Lop Nur the driest region in northwest China.

Lake Lop Nur, with an area of approximately 20,000 km^2, is historically the drainage playa of the Tarim and Kongque rivers. Lop Nur is located in the driest region of China, where all natural biological populations and their numbers are very meager and rare. In the 1970s, Lake Lop Nur dried up and became a large, salt-crusted, gravel desert-like, wind-eroded landform because of human activities (Yadan areas). The vegetation rapidly decreased to only 13 families, 26 genera, and 36 species (Shen, 1987). The CK-2 core was drilled on October 1997 by the Institute of Salt Lake Research, Chinese Academy of Science from the Luobei depression (91°03′E, 40°47′N).

3. Material and methods

3.1. Laboratory methods

The sampling interval for pollen analyses was 5 cm. The samples were treated with HCl (10%) and HF (39%). One hundred eighty pollen grains (not including spores) were counted for each sample, and the percentage of each pollen type was calculated based on the sum of all counted pollen grains. The raw pollen data expressed as the percentage of the sum of terrestrial pollen were then plotted against depth using Grapher 2.0 (Duane et al., 1990). The experiments were conducted at the Key Laboratory of Western China's Environmental Systems of Lanzhou University.

3.2. Stratigraphy and chronology

The CK-2 core is composed of two types of sediments. The first type is silt and clay, whereas the second type is sulfate and halite. Silt and clay comprise 13.06 m (26.1%) of the drill core's total length (50.14 m). Moreover, calcic mirabilite, gypsum, and halite constitute 54.3%, 6.6%, and 2.3% of the drill core (Gao et al., 2001). Fig. 2 shows the stratigraphic section of the core (1035 cm to 100 cm deep). The upper 2 m is mainly silt-containing halite with the grain size becoming coarser near the top. From 2 m to 7 m, the sediments are mainly silt-containing gypsum with the grain size increasing near the top. The gypsum in the upper 7 m of the core has a spinal shape but becomes schistose-shaped in the lower 7 m section. The lithologic change of the core indicates that the depositional environment was in the late stage of the salt lake evolution. Although the climatic environment had a cold–warm/dry–wet variation, the general trend was toward dry because of a large amount of halide formation.

The six U–Th ages were determined by a Finnigan MAT-262-RPQ mass spectrometry (MS) system and an NU plasma multicollector inductively coupled plasma MS. The 230Th–234U–238U method was employed based on well-preserved U–Th gypsum and halide samples from the CK-2 core (Peng et al., 2001; Haase-Schramm et al., 2004). The ages were measured at the CAS Key Laboratory of Crust–Mantle Material and Environments, University of Science and Technology of China and at the University of Illinois—Urbana Champaign, Urbana, USA. An age-depth model was constructed based on six U–Th dates. The ages were then extrapolated from the bottom (31.98 ka BP at 1035 cm) to the top (9.14 ka BP at 100 cm) of the core. This section corresponded to the period from the late last glacial to the early Holocene. The time resolution of the pollen sequence was approximately 130 years per pollen sample, which was insufficient by 1% for the entire research period (22.84 ka BP). This sequence enabled the high-resolution research on the paleoenvironmental and paleoclimatic evolution from the last millennium in the Lop Nur areas.

4. Results

Fig. 3 shows that the pollen assemblage zones were discriminated based on the variations in pollen concentration as well as on the percentages and concentrations of coniferous trees, temperate deciduous trees, herbs, and shrubs. Four pollen assemblage zones (Zones I to IV) were identified by CONIS analysis (Grimm, 1987) from the bottom to the top of the core.

4.1. Zone I (1035 cm to 680 cm; 31.98 ka BP to 19.26 ka BP)

Zone I corresponds to the bottom portion with the silt-containing, medium-sized gypsum layer of the core that contains very low pollen concentrations ($0.18–0.26\times10^3$ grains/g). The pollen assemblages were dominated by the herbs Artemisia (24.78% to 32.63%), Chenopodiaceae (9.91% to 42.48%), and Polypodiaceae (0% to 1.27%), as well as by the shrub and half-shrub Ephedra (6.74% to 30.85%) and Nirraria (0% to 1.52%), respectively. However, the percentage of conifers (0.46% to 9.83%) were high and included Cupressaceae (0% to 13.86%), Pinus (0% to 5.26%), Picea (0% to 5.93%), *Abies* (0% to 0.94%), and *Cedrus* (0% to 1.02%). Deciduous components (1.92% to 7.35%) included *Betula* (0.96% to 6.84%), *Ulmus* (0% to 0.92%), and *Salix* (0% to 5.71%). Gramineae (1.35% to 14.03%) and Asteraceae (0% to 2.29%), which includes *Cichorium* (0% to 1.38%), Aster-type (0.12% to 3.84%), Leguminosae (0% to 2.87%), Apiaceae (0% to 1.96%), and Caryophyllaceae (0% to 1.01%), as well as a few aquatic plants such as *Typha* (0% to 1.93%), *Sparganium* (0% to 0.93%), and *Alisma* (0% to 0.86%) were also found. Three warmer phases were clearly shown by the vegetational changes.

4.2. Zone II (680 cm to 485 cm; 19.26 ka BP to 13.67 ka BP)

Zone II corresponds to the bottom portion with the gray-green, silt-containing gypsum layer, to the middle portion with silt-containing fine gypsum and silt-clay gypsum layer, and to the upper portion with silt-containing medium-grained gypsum and coarse-grained halide. The zone contained very high pollen concentrations ($1.28–7.72\times10^3$ grains/g). The pollen assemblages were dominated by the herbs Artemisia (25.06% to 49.24%), Chenopodiaceae (22.87% to 44.62%), Ephedra (12.86% to 21.17%), and Gramineae (3.68% to 8.58%), which constituted 85% of the total amount. Conifers (0.04% to 4.78%) and hardwood were reduced, whereas aquatic plants and ferns were scarce.

Zone II can be further divided into four sub-zones as follows.

4.2.1. Subzone IIa (680 cm to 610 cm; 19.26 ka BP–16.45 ka BP)

The pollen concentrations ($2.14–7.72\times10^3$ grains/g) in this subzone were higher compared with those in other Zone II subzones. The herbs Artemisia and Chenopodiaceae retained their dominant characteristics. The percentages of conifers and deciduous components, as well as