Quaternary Science Reviews 30 (2011) 3457–3466

Contents lists available at SciVerse ScienceDirect

Quaternary Science Reviews

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

Moisture dynamics in central Asia for the last 15 kyr: new evidence from Yili Valley, Xinjiang, NW China

Xiaoqiang Li[a,b,*], Keliang Zhao[a,b], John Dodson[c], Xinying Zhou[a,b]

[a] The Laboratory of Human Evolution, Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Academy of Sciences, Beijing 100044, China
[b] State Key Laboratory of Loess and Quaternary Geology, Institute of Earth Environment, Chinese Academy of Sciences, Xi'an 710075, China
[c] Institute for Environmental Research, Australian Nuclear Science and Technology Organisation, Kirrawee, NSW 2232, Australia

ARTICLE INFO

Article history:
Received 1 May 2011
Received in revised form
3 September 2011
Accepted 14 September 2011
Available online 2 October 2011

Keywords:
Moisture evolution
Yili valley
Central Asia
Last deglaciation
Holocene
Westerlies

ABSTRACT

Based on high resolution palynological investigations and AMS^{14}C dating, the continuous lacustrine sediments contained in Yili Valley, Xinjiang provide an opportunity to reconstruct the effective moisture changes for the last 15 kyr in central Asia. The relatively warm and humid climate of the Bølling-Allerød (15–12.9 cal kyr BP) is a generalization, but it seems to show some fluctuations. The time of the Younger Dryas (YD) interrupted the increasing trend of effective moisture in the study region, the climate was cold and relatively dry in the early YD period (12.9–12.0 cal kyr BP), whereas the desert vegetation community appeared around 11.8 cal kyr BP, almost the driest time since the 15 cal kyr BP. A sharp increase in effective moisture marked the beginning of the Holocene in the Yili Valley. The early Holocene (10.6–7.6 cal kyr BP) was the wettest time with a developed temperate steppe. A dry climate with desert vegetation arose in the early mid-Holocene (7.6–6.5 cal kyr BP), spanning 1100 years. A second humid phase emerged between 6.5 and 5.2 cal kyr BP, whose vegetation community was represented by temperate steppe. Moisture was reduced again and the climate became drier between 5.2 and 3.3 cal kyr BP when vegetation was dominated by desert steppe in the Yili Valley.

Regional comparisons indicate that the moisture changes in Yili Valley were mainly influenced by the North Atlantic Ocean SSTs through the westerlies. The mean position of the Siberian High Pressure cell probably made a great contribution to the drought between 7.6 and 6.5 cal kyr BP. The climate changes were generally consistent between the westerly-dominant central Asia and Asian monsoon regions since the last deglaciation, possibly forced by summer insolation conditions in the Northern Hemisphere.

1. Introduction

Variability of the Asian Monsoon and westerlies played a key role in climatic changes in Asia (Gao, 1962; Chen, 1991), and is thus an important component in global change research programs (Porter and An, 1995; Liu and Ding, 1998; Thompson et al., 2000; Shi et al., 2001). We now have a broad understanding of the formation, evolution and mechanisms of the Asian palaeomonsoon from research results that have been published over the past several decades (Ding et al., 1995; Guo et al., 1998; An, 2000; An et al., 2000; Wang et al., 2005a,b, 2010; Herzschuh, 2006; Yang et al., 2010). However, climate changes in that part of central Asia dominated by the westerlies are poorly documented and understood. We still know little about the climate evolutionary patterns and mechanisms that drive the westerlies (Yu and Wang, 1998; Chen et al., 2008).

Xinjiang, owing to its central Asian position and arid environment, has caught the attention of many Quaternary geologists. Researches on paleoclimate and paleoenvironment there mainly focus on the Jungar and Tarim basins, and the Tien Shan Mountains, and include records from Barkol Lake (Han and Qu, 1992), Manas Lake (Sun et al., 1994; Thomas et al., 1996), Aibi Lake (Wu et al., 2003), Bosten Lake (Chen et al., 2006), Wulungu Lake (Liu et al., 2008), Lop Nur (Yan et al., 2000), loess and peat sediments (Ye, 2000), and tree rings (Yuan et al., 2000) (Fig. 1). However, we still lack the long-term palaeoecological records with precise dating to expand on these in the region.

At present, there remains controversy about the heat-moisture patterns in Xinjiang. One viewpoint is that warm-humid and cold-dry patterns alternated (Sun et al., 1994; Yuan et al., 1998; Fang et al., 2002), while for others there were warm-dry and cold-humid

* Corresponding author. The Laboratory of Human Evolution, Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Academy of Sciences, 142 Xizhimenwai Str., P O Box 643, Beijing 100044, China. Tel.: +86 01 88369179; fax: +86 01 68337001.
E-mail address: lixiaoqiang@ivpp.ac.cn (X. Li).

0277-3791/$ – see front matter
doi:10.1016/j.quascirev.2011.09.010

patterns (Li, 1990; Han and Qu, 1992; Yang et al., 2002). As for the influencing mechanisms of climate in central Asia, some researchers argue the westerly-dominated arid central Asia experienced synchronous and coherent moisture changes during the Holocene and the effective moisture history in arid central Asia is out-of-phase with that in monsoonal Asia (Chen et al., 2008). This implies the monsoon hardly extended to central Asia during Holocene (Chen et al., 2008; Liu et al., 2008). Others hold that the moisture brought by the westerlies is not critical to environmental changes observed in central Asia, and the Asia monsoon made an important contribution to the humidity of the early and mid-Holocene (Mischke and Wünnemann, 2006; Rudaya et al., 2009; Zhong et al., 2010).

Yili Valley is situated in the west of Xinjiang, far from ocean influence and chiefly controlled by the westerlies (Li, 1991) (Fig. 1). It is an ideal region for studying possible changes in the westerlies, and here, we selected a lacustrine sediment section covering the last deglaciation and Holocene in Yili Valley. Based on AMS^{14}C dating, a high resolution pollen record has been used to recover a vegetation history and climatic changes for the last 15 kyr in the region. Our aim is to reveal climatic changes in Yili Valley and assess any relationship with global climate changes, and influencing factors of climatic changes.

2. Study area

Yili Valley (42°14′–44°50′N, 80°09′–84°56′E), is an intramontane basin in the western part of the Tien Shan mountains, and is effectively part of central Asia. The valley is 350 km long from east to west and 280 km wide from south to north, with altitude from 500 m to 5500 m. The Yili River, has a drainage area of 65,000 km^2, and runs through the valley from east to west.

Yili Valley has a temperate semiarid continental climate, and is dominated by westerly winds throughout the year. The winter climate is controlled mainly by the intensity and position of the Siberia High pressure cell, and is also influenced by the north branch of the westerlies; the summer climate is in part affected by the Indian Low pressure cell, when the southern branch of the westerlies shifts northwards (Li, 1991). Yili Valley has one of the most abundant rainfalls in Xinjiang, because it is open on the west to humid airflow. The mean annual temperature varies from 2.6 to 9.2 °C depending on the terrain. The mean annual precipitation is between 200 mm and 500 mm on the plains, but can reach 800 mm in the mountain zones (Ye, 1999). Since the valley is confined by high mountain ranges summer ice melt and possibly groundwater flow could be expected to control the hydrology of water courses and lakes on the valley floor.

The vertical vegetation zones possess a fairly evident and complete structure, classified from top to bottom into an alpine cushion-like vegetation zone, alpine meadow zone, subalpine meadow zone, montane forest-meadow zone, montane steppe and then a desert zone (Xinjiang Integrated Expedition Team and Institute of Botany, CAS, 1978).

3. Materials and methods

The Yili section (43°51′25.7″N; 81°57′54.3″E; 928 m a.s.l.), is a 900 cm deep sedimentary profile which was sampled by digging

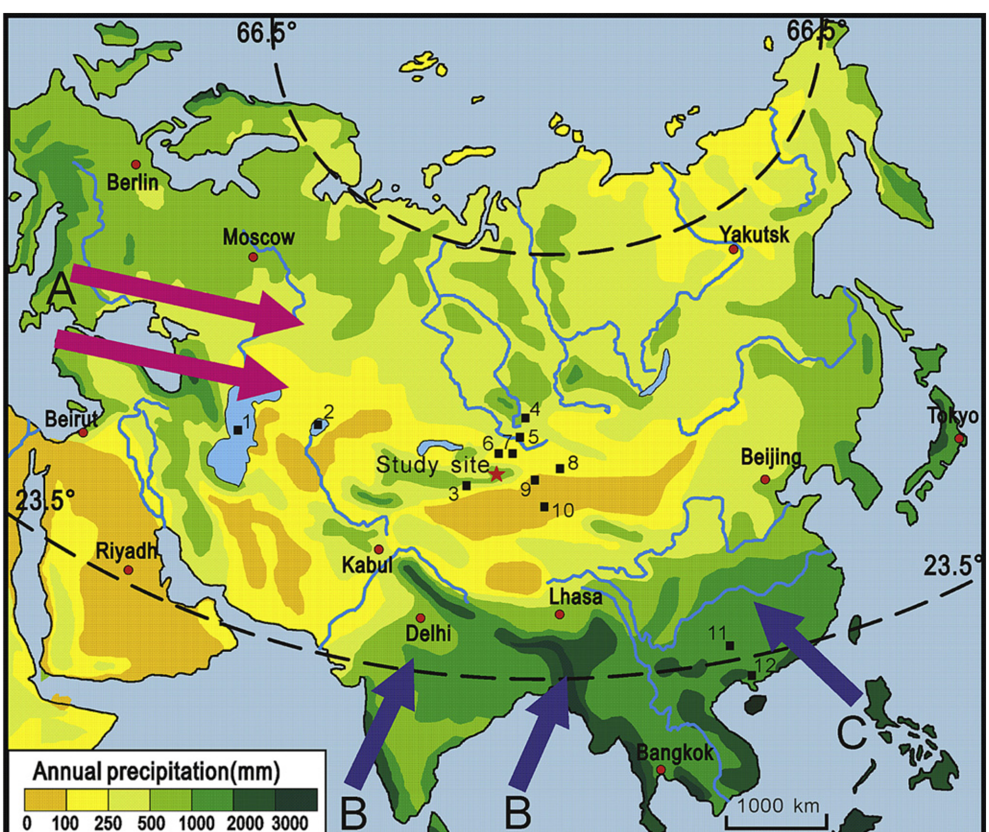

Fig. 1. The map showing the distribution of average annual precipitation in Eurasia (after Klett International, 2006), and the dominant circulation systems (arrows) of the westerlies (A), Indian monsoon (B), East Asian monsoon (C). Position of study site is shown by red pentagon and the main sedimentary records referred in this paper by black squares with numbers ((1) Caspian; (2) Aral Sea; (3) Issyk-Kul Lake; (4) Hoton Nuur; (5) Wulungu Lake; (6) Aibi Lake; (7) Manas Lake; (8) Barkol Lake; (9) Bosten Lake; (10) Lop Nuur; (11) Dongge cave; (12) Huguangyan Maar Lake.).