




# Climatic variations over the last 4000calyr BP in the western margin of the Tarim Basin, Xinjiang, reconstructed from pollen data

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## Abstract

The nature of Holocene climate patterns and mechanisms in central Asia are open areas of inquiry. In this study, regional vegetation and climate dynamics over the last ca. 4000years are reconstructed using a high resolution pollen record from the Kashgar oasis, on the western margin of the Tarim Basin, central Asia. *Ephedra*, Chenopodiaceae and Cannabaceae dominate the pollen assemblages, and Chenopodiaceae/*Ephedra* ratios and percentages of long-distance transported pollen taxa are used to infer regional variations in moisture and vegetation density. Three periods of increased humidity are identified, from ca. 4000–2620calyr BP, ca. 1750–1260calyr BP and ca. 550–390calyr BP and these periods coincide with the respective Holocene Bond Events 2, 1 and 0, which are reported in the North Atlantic. Any increase in strength, or southward migration, of the mid-latitude westerlies would result in more precipitation and meltwater on mountains surrounding the study site. Warm and dry conditions are detected between ca.1260 and 840calyr BP (AD 690–1110), and cool and wet conditions are detected between ca. 840 and 680calyr BP (AD 1110–1270), during the Medieval Warm Period (ca. AD 800–1200). The climate variations in the Kashgar region over the last 4000years appear to have been dominated by changes to the westerly circulation system and glacier dynamics on surrounding mountains. However, the question of whether the Asian monsoon delivers precipitation to the western Tarim Basin, a region that is influenced by several climate systems, is still open to debate.

## Highlights

► New pollen records for the last 4000calyr BP in the western Tarim Basin. ► Four humid and three dry periods were identified in the study region. ► Increase in the strength of the westerlies resulted in the three humid periods. ► The climate was warm and dry during the early Medieval Warm Period (AD 690–1110).

## Introduction

Variability of the Asian monsoon and mid-latitude westerly systems has played a key role in driving Holocene climate changes in Asia, and is thus an important component of global change research programmes (Porter and An, 1995, Liu and Ding, 1998, An et al., 2000, Herzschuh, 2006a, Chen et al., 2008). The climate patterns and mechanisms of central Asia, where the mid-latitude westerlies are a dominant influence, are not as well understood as the monsoon-dominated areas of Asia (Chen et al., 2008, Li et al., 2011).

At present, theories about the nature of climatic patterns in central Asia are conflicting. One viewpoint is for an alternating warm–humid and cold–dry pattern (Yuan et al., 1998, Fang et al., 2002), while others argue for a warm–dry and cold–humid pattern (Li, 1990, Han and Qu, 1992). As for the main mechanisms influencing the climate of central Asia, some researchers argue that the mid-latitude westerlies dominated moisture changes during the Holocene (Chen et al., 2008, Liu et al., 2008), while others hold that the Asian monsoon was the most important factor affecting humidity, especially during the early and mid-Holocene (Mischke and Wünnemann, 2006, Rudaya et al., 2009, Zhong et al., 2010).

The Tarim Basin is a large inland basin in southern central Asia, which centres on the Taklimakan Desert. Oases occur along the margins of the basin and are fed by surface water and groundwater flowing from surrounding mountains (Xinjiang Expedition Team, Chinese Academy of Sciences, 1978a). The Tarim Basin, and surrounding mountains, are ideal areas for exploring past climatic changes in central Asia, as their fragile ecosystems are sensitive to climatic fluctuations, and they contain natural archives of past climate change, including glaciers, lakes, peat and loess deposits.

The main Holocene climate patterns in the Tarim Basin and surrounding areas are poorly understood, as are the dominant mechanisms that affect those climatic patterns. It is recognised that the mid-latitude westerlies and the Indian and East Asian monsoon system are the principle factors influencing the climate of the Tarim Basin. However, opinions differ about the relative importance of each of these factors. At Bangong and Sumxi basins, a moist period in the early Holocene has been attributed to a strengthened Indian and East Asian summer monsoon and more arid conditions in the middle to late-Holocene, to a weakened monsoon (Gasse et al., 1991, Gasse et al., 1996). At Issyk-Kul, a humid period in the early to mid-Holocene is suggested to be due to either an increase in moisture brought by the mid-latitude westerlies or a strengthened Asian monsoon (Ricketts et al., 2001).

A change from dry conditions in the early Holocene to humid conditions in the mid-late Holocene at Bosten Lake is suggested to be connected to change in the westerly circulation and North Atlantic climate systems, rather than changes to the Asian monsoon (Chen et al., 2006). Glacier oscillations in the West Kunlun Mountains during the Late Glacial and Holocene are suggested to be affected by both conditions in the North Atlantic Ocean and changes to the mid-latitude westerlies, with only a minor influence from the south Asian monsoon (Seong et al., 2009).

Existing Holocene climate records in the Tarim Basin are few in number and sparsely distributed, and most lack sufficient sampling resolution and dating methods to allow regional climate patterns to be deduced. Holocene records of vegetation and climate change in the Kashgar area are few in number, and consequently understanding of past climate changes in this important region is limited. This study provides an AMS<sup>14</sup>C dated, high resolution pollen record for a lacustrine sediment section near to Kashgar. The study aims to both reconstruct vegetation and climatic changes during the late Holocene in the western margin of the Tarim Basin, and improve understanding of the factors influencing climate in this region of central Asia.

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## Section snippets

### Study area

The Tarim Basin is surrounded by high mountain ranges: the Tianshan Mountains (also referred to as Tianshan) to the north, the Pamir Mountains to the west, and the Kunlun Mountains to the south (Xinjiang Expedition Team, Chinese Academy of Sciences, 1978a). The climate of the Tarim Basin is characterised by extreme aridity. Mean annual precipitation is between 30 and 60mm, and mean annual evaporation reaches 2536mm. The climate of the Tarim Basin is influenced by Siberian high-pressure cells,...

### Sediment and dating

The Wupaer section (39°16'53.6"N, 75°35'43.6"E) is located near Wupaer Town, approximately 45km southeast of Kashgar City, at an elevation of 1402m a.s.l. (Fig. 1). The 855cm deep section was exposed by erosive action of a small river. The sediments are composed of silts, sandy silts and silty sands and show considerable variation through the

section (Table 1). The varied lithology is likely to be due to the sediment's dual origins: from melt-water deposits associated with spring floods, and...

## Results

In total, 16 arboreal and 29 non-arboreal pollen types were identified in the Wupaer section (Table 3). The pollen of herbs and shrubs dominates the section (averaging 88.5%) and of those plant types, *Ephedra*, Chenopodiaceae and Cannabaceae dominate the pollen sum. Tree pollen has an average value of 11.5% throughout the section, of which *Picea* pollen occurs in highest proportions, contributing up to 70.8% of the terrestrial pollen sum.

The pollen assemblage was divided into seven pollen zones...

## Discussion

The western Tarim Basin lies in a climatic transition zone under the influence of the mid-latitude westerlies and Asian monsoon (Mischke et al., 2010). The glaciers on the Kunlun, Pamir and Tianshan Mountains also influence environments in the Tarim Basin, especially at the margins of the basin (Benn and Owen, 1998, Yang et al., 2002, Mischke et al., 2010).

The Wupaer pollen record presented here provides an opportunity to study vegetation and climate changes over the last 4000 years in the...

## Conclusions

The pollen data presented here indicate that four humid periods (ca. 4000–2620 calyr BP, ca. 1750–1260 calyr BP, ca. 840–680 calyr BP and ca. 550–390 calyr BP) and three dry periods (ca. 2620–1750 calyr BP, ca. 1260–840 calyr BP and ca. 680–550 calyr BP) occurred over the last 4000 yr BP in the Kashgar area of western Tarim Basin. This is a region where very few palaeoclimate records currently exist.

Three of the humid periods (ca. 4000–2620 calyr BP, ca. 1750–1260 calyr BP and ca. 550–390 calyr BP) are...

## Acknowledgements

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...In addition, there are few millennial-scale studies on Holocene climate events and their environmental responses in this region (Teng et al., 2015; Liu et al., 2016), which impedes our understanding of the response of regional environments to northern high-latitude abrupt cold events. Southern marginal regions of the TB contain the thickest eolian loess deposits, which contain abundant information on paleoenvironmental change at different time scales (Tang et al., 2007; Zhao et al., 2012; Teng et al., 2015; Shu et al., 2018; Yang et al., 2021). In this study, the Kunyu (KY) loess section, located on the northern slopes of the Kunlun Mountains, was selected to explore paleoclimate and millennial-scale abrupt events....

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...yr BP and ~550–390 cal. yr BP (Zhao et al., 2012), which are correlative with Zones 6, 8, 10, respectively. In the upper and middle reaches of the Tarim River, alluvial or flood deposits accumulated at ~7300 cal....

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