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Palynological evidence for the Mid-Miocene Climatic Optimum recorded in Cenozoic sediments of the Tian Shan Range, northwestern China

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ABSTRACT

Thick Cenozoic deposits were shed into the foreland basin of the Tian Shan Range, providing great potential for understanding the relationship between tectonic history and paleoclimatic changes. In the present study, we compiled a pollen record for the interval 26.5–2.6 Ma based on a palynological analysis of a latest Oligocene–Pliocene stratigraphic sequence in the northern foreland basin of the Tian Shan. Our results indicate that a remarkable warm climate occurred at ca. 18–15 Ma ago, corresponding to the Mid-Miocene Climatic Optimum, while a change to an arid climate occurred at 6 Ma, marked by an increase in the drought-tolerant herb taxa *Artemisia* and Chenopodiaceae. This latter change was coincident with the late Cenozoic climatic deterioration recorded at high latitudes in the Northern Hemisphere. These inferred climatic events are further supported by the results of principal component analysis of the pollen data, such records are important archives in reconstructing the paleoclimate of the Asian interior.

1. Introduction

Earth's climate changed during the Cenozoic from an ice-free, warm climate to a cold climate marked by the development of massive continental ice sheets. The details of this climate change have been reconstructed using composite high-resolution deep-sea oxygen isotope records (e.g., Miller et al., 1987; Zachos et al., 2001). Many significant warm and cool climatic events occurred during the stepwise Cenozoic cooling process. One of the most intriguing climatic events of the Neogene was the Middle Miocene (~15–18 Ma) global warming known as the Mid-Miocene Climatic Optimum (e.g., Flower and Kennett, 1994); subsequent to this event, the earth's climate showed a gradual cooling, with the increasing global ice volumes (Shackleton and Kennett, 1975; Escutia et al., 2005).

In contrast to deep-sea sediments, terrestrial deposits usually record hiatuses in deposition. It is difficult to find a single continuous sequence of deposits covering the entire Cenozoic. Among the various parameters used in reconstructing long-term terrestrial climate change, pollen analysis is one of the most useful because vegetation type shows a direct relation with climate change. In China, many recent studies have investigated the palynology of Neogene sediments (e.g., Wang, 1990; Wang et al., 1990; Hu and Sarjeant, 1992; Liu and Leopold, 1994; Ma et al., 1998, 2004; Liang et al., 2003; Sun and Wang, 2005; Sun et al., 2007; Xu et al., 2008), however, the long-term paleoclimate records of the thick Cenozoic deposits of the northern foreland basins of the Tian Shan Range remain to be studied in detail.

In this context, the objectives of the present work are to: (1) present pollen record for the Tian Shan region from the latest Oligocene to early Pleistocene, and (2) discuss climate change over this period based on our palynological data.

2. Regional setting

The Tian Shan Range is one of the longest mountain ranges in Central Asia, stretching more than 2500 km from Tashkent (Uzbekistan) in the west to northwestern China in the east (Fig. 1a). The average elevation of ridges along the range is about 4000 m above sea level (asl), while the highest summits exceed 7400 masl. Geologically, the range is a Paleozoic fold belt (e.g., Allen et al., 1992; Gao et al., 1998) that was eroded during the Mesozoic (Deng et al., 2000). The range was strongly reactivated during the Cenozoic as a result of intracontinental deformation associated with the India–Eurasia convergent system (e.g., Avouac et al., 1993; Hendrix et al., 1994; Yin et al., 1998; Burchfiel et al., 1999; Deng et al., 2000; Fu et al., 2003; Sun et al., 2004). In response to N–S crustal shortening during the Cenozoic, thick Cenozoic sediments were folded to form three relatively low-lying ranges oriented parallel to the E–W trend of the main Tian Shan Range. The Cenozoic deposits in the northern foreland basins of the Tian Shan are up to 5000 m thick, and are exposed where a series of northward-flowing rivers transect the basins. The section considered in the present study is exposed along the Taxihe River (Fig. 1b), where Cenozoic deposits can be observed at elevations ranging from about 800 to 1300 masl.

The studied deposits are part of the Tugulu Anticline (Fig. 2a), an overturned fold (Fig. 2b) some 50 km long and 10–15 km wide. The best exposures are found along the Taxihe River (transect A–B in

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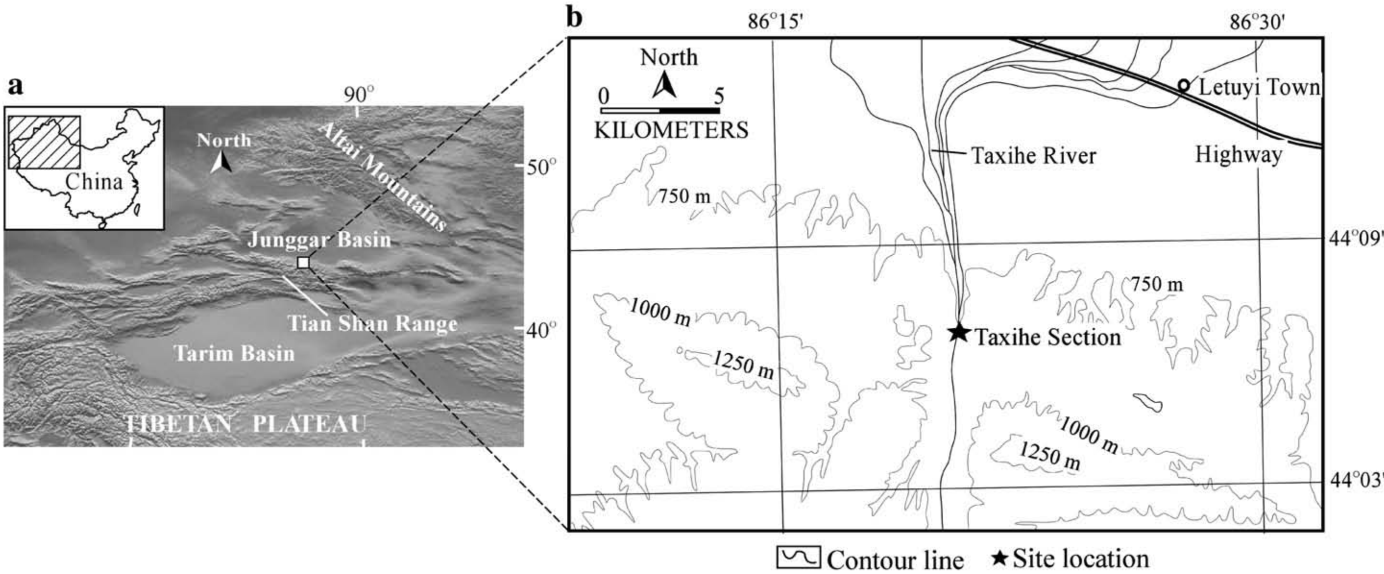

Fig. 1. Digital elevation model image of the Tian Shan Range and surrounding region (a) and topographic map of the study area (b).

Fig. 2a). The studied part of the section consists of grey lacustrine mudstone of the Oligocene Anjihaihe Formation (E_{3A}), reddish mudstone of the latest Oligocene Shawan Formation (E_{3S}), dominant lacustrine mudstone of the Miocene Taxihe Formation (N_{1T}), alternations of grey gravels and brownish siltstone of the Pliocene Dushanzi Formation (N_{2D}), and the coarse molasse deposits of the early

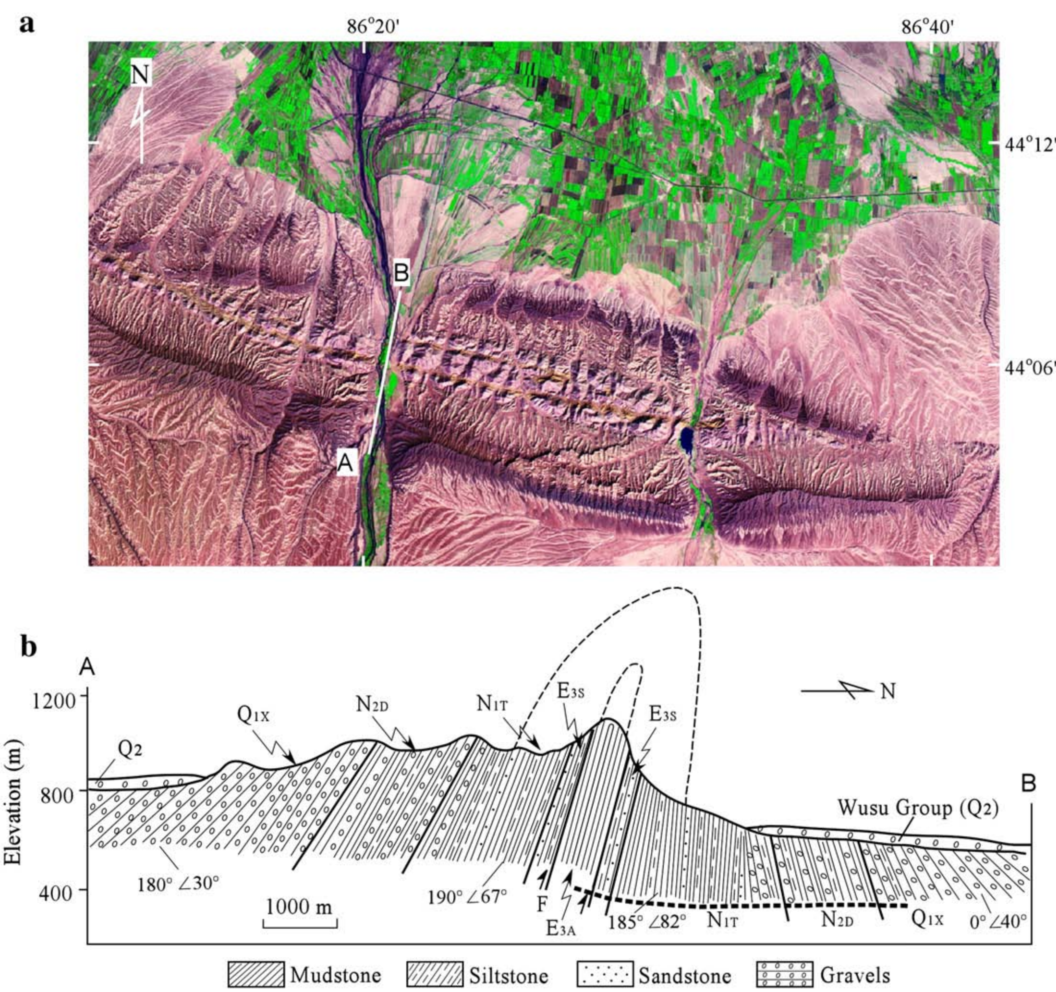

Fig. 2. (a) Landsat image of the Tugulu Anticline, and (b) the exposed Cenozoic strata of the Tugulu Anticline along cross-section A–B, cut by the Taxihe River. The bold dashed line in the lower part of (b) shows the sampling route. E_{3A}: Oligocene Anjihai Formation; E_{3S}: Late Oligocene Shawan Formation; N_{1T}: Miocene Taxihe Formation; N_{2D}: Pliocene Dushanzi Formation; Q_{1X}: Early Pleistocene Xiyu Formation; Q_2: Middle Pleistocene; F: Thrust fault.