Earth and Planetary Science Letters 302 (2011) 439–447

Contents lists available at ScienceDirect

Earth and Planetary Science Letters

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

Late Cenozoic central Asian drying inferred from a palynological record from the northern Tian Shan

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ARTICLE INFO

Article history:
Received 14 September 2010
Received in revised form 15 December 2010
Accepted 20 December 2010
Available online 15 January 2011

Editor P. DeMenocal

Keywords:
central Asian aridification
palynology
vegetation
late Cenozoic
Tian Shan
Jingou River section

ABSTRACT

Sediments contained in basins adjacent to great mountains provide opportunities to reconstruct the aridification history of central Asia. Here we use a palynological record from the fluviolucustrine Jingou River section collected from the northern Tian Shan, NW China, to reconstruct aridification in central Asia during the late Cenozoic. Biogeomagnetic results show that the section was continuously deposited through the interval 28–4.2 Ma. The palynological record, with the auxiliary of the principal component analysis and the diversity index, indicates that a late Oligocene wet condition existed in central Asia and shifted to dry conditions at 23.8–23.3 Ma. The dry condition remained until 17.3 Ma and subsequently ameliorated to a relatively wet stage to 16.2 Ma, but then began to increase once again and reached a peak at 13.5 Ma that last throughout the late Miocene and the early Pliocene. Comparing the aridification process to the global temperature trend and history of tectonics, we suggest that the long-term drying trend in central Asia is dominated by late Cenozoic cooling, while the dry events that occurred at 23.8–23.3 Ma and 16.2–13.5 Ma are more likely associated with regional mountain building. The land–sea redistribution further complicated the drying processes.

1. Introduction

Central Asia is the world's largest mid-latitude, inland arid region. Development of arid Asia is generally regarded as a product of interactions between the lithosphere, hydrosphere and atmosphere, and in turn exerts a significant impact on Earth's climate system by influencing the radiative balance and the biogeochemical cycles via dust emission. Although numerous studies on the central Asian environmental history have been published in past decades, little consensus exists between them. Eolian deposits in north China and the North Pacific have been used to trace the aridification history of central Asia back to 2.6 Ma (Ding et al., 1997; Liu, 1985), and then to 7–8 Ma (Ding et al., 1998; Rea et al., 1998), or even to 22–24 Ma (Guo et al., 2002; Rea, 1994; Sun et al., 2010). In contrast to these indirect records, evidence from the continental interior of Asia shows aridity initiation is generally younger than the late Miocene. The Kazakhstan Plain, with an annual precipitation of more than 1000 mm in the Early Miocene (Bruch and Zhilin, 2007), gradually dried after 15 Ma (Akhmetyev et al., 2005; Velichko, 2005). In westernmost China, desert conditions were initiated ca. 7 Ma ago in the Tarim Basin (Sun et al., 2009), slightly older than dry events in the Junggar Basin where xerophilous *Artemisia* and Chenopodiaceae expanded after 6 Ma (Sun and Zhang, 2008). A wide chronological gap in time of arid Asia exists between records from surrounding areas and from the interior, and the history of the aridification is still open to debate.

To better constrain the evolution of drying in central Asia, a promising approach is to reconstruct a long-term, well-dated environmental history for the interior. The Tian Shan separates the Tarim basin to the south from the Junggar basin to the north. Cenozoic uplift of the Tian Shan resulted in the continuous deposition of Tertiary and Quaternary sediments on its flanks (Allen et al., 1991; Yin et al., 1998). These thick fluvial-lacustrine deposits provide a well-dated archive, with a well-preserved pollen record, for reconstructing a long term environmental history. We present here a detailed palynological record of the Jingou River section from a northern foreland basin of the Tian Shan to decipher the inland vegetation and climate evolution.

2. Geological setting

The Tian Shan, a 2500 km long range, has an average elevation of 2500 m above sea level (a.s.l.) with peaks higher than 7000 m a.s.l.

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doi:10.1016/j.epsl.2010.12.042

The range may be traced back to a Paleozoic fold belt (Allen et al., 1993; Tapponnier and Molnar, 1979). It is higher than the surroundings throughout the Mesozoic and Cenozoic and continuously filled the adjacent basins, Junggar Basin to the north and Tarim Basin to the south, with clastic sediments eroded from the range (Hendrix et al., 1992). In response to the Indo–Asian collision, reactivation of the Tian Shan during the late Cenozoic deformed the Cenozoic sediments into three successive fold–thrust belts on the north pediment, which are made up of linear anticlines (Fig. 1). These fold belts are well exposed along north-flowing rivers that incised the piedmont most likely during the late Quaternary (Lu et al., 2009). The section presented here is from the Huoerguosi Anticline in the central fold–thrust belt.

The Jingou River section (44°10.4′N, 85°27.4′E) is exposed along a valley formed by the perpendicular incision of the Jingou River through the center of the Huoerguosi Anticline. In the southern limb of the anticline, from the core to the south, the Jingou River section consists of the Anjihaihe, Shawan, Taxihe, Dushanzi and Xiyu Formations (Li, 1984). The dominant lithology changes from distal fine-grained lacustrine mudstone upward to proximal coarse conglomerates. Specifically, the Anjihaihe Formation is made up of grayish green mudstone with interbedded thin marlstones, sandstones, shales and layers of gypsum. These fine-grained sediments commonly display parallel laminations and are interpreted to represent lake facies. The overlying Shanwan Formation is about 520 m thick and lithologically divided into three units. The lower unit is ~100 m thick and is dominated by dark brown massive mudstones and represents a lacustrine prodelta facies. The middle unit contains ≥18 couplets of red-brown silty mudstone and conglomerates within a thickness of ~250 m, likely deposited in a distal fan-delta environment. The upper unit consists of brown and minor grayish green silty mudstones and mudstones with cross-bedding and parallel-ripple lamination and is interpreted to represent a delta front facies. The Taxihe Formation consists of grayish green mudstone in its lower part and brown silty mudstones with interbeded thin sandstones and conglomerates in the upper part, indicating a lacustrine and a fluvial delta plain facies, respectively. The Dushanzi Formation consists mainly of brown pebbly sandstones, conglomerates and interbeded silty mudstones, representing a braided river and alluvial fan facies. The Dushanzi Formation grades into the overlying Xiyu Formation within about 200 m of strata dominated by conglomerates and subordinate fine-grained sandstones. The Xiyu Formation is characterized by dark grey massive conglomerates with rare siltstones and sandstones in the lower part. These strata do not contain any significant unconformities, while they are unconformably overlain by the Pleistocene Wusu Group.

The Jingou River section has an elevation of ca. 900 m a.s.l. and has a typical continental climate regime with a mean annual temperature of 6.9 °C and a mean annual precipitation of 183 mm. Because of orogenic precipitation, the Tian Shan supports various vegetation types and has five altitudinal vegetation belts on the north slope (Fig. 2): desert steppe occurs below 1200 m a.s.l., dry steppe occurs at elevations of 1200–1800 m a.s.l., montane conifer forest dominated by *Picea* occurs at 1800–2800 m a.s.l., montane meadows occur at

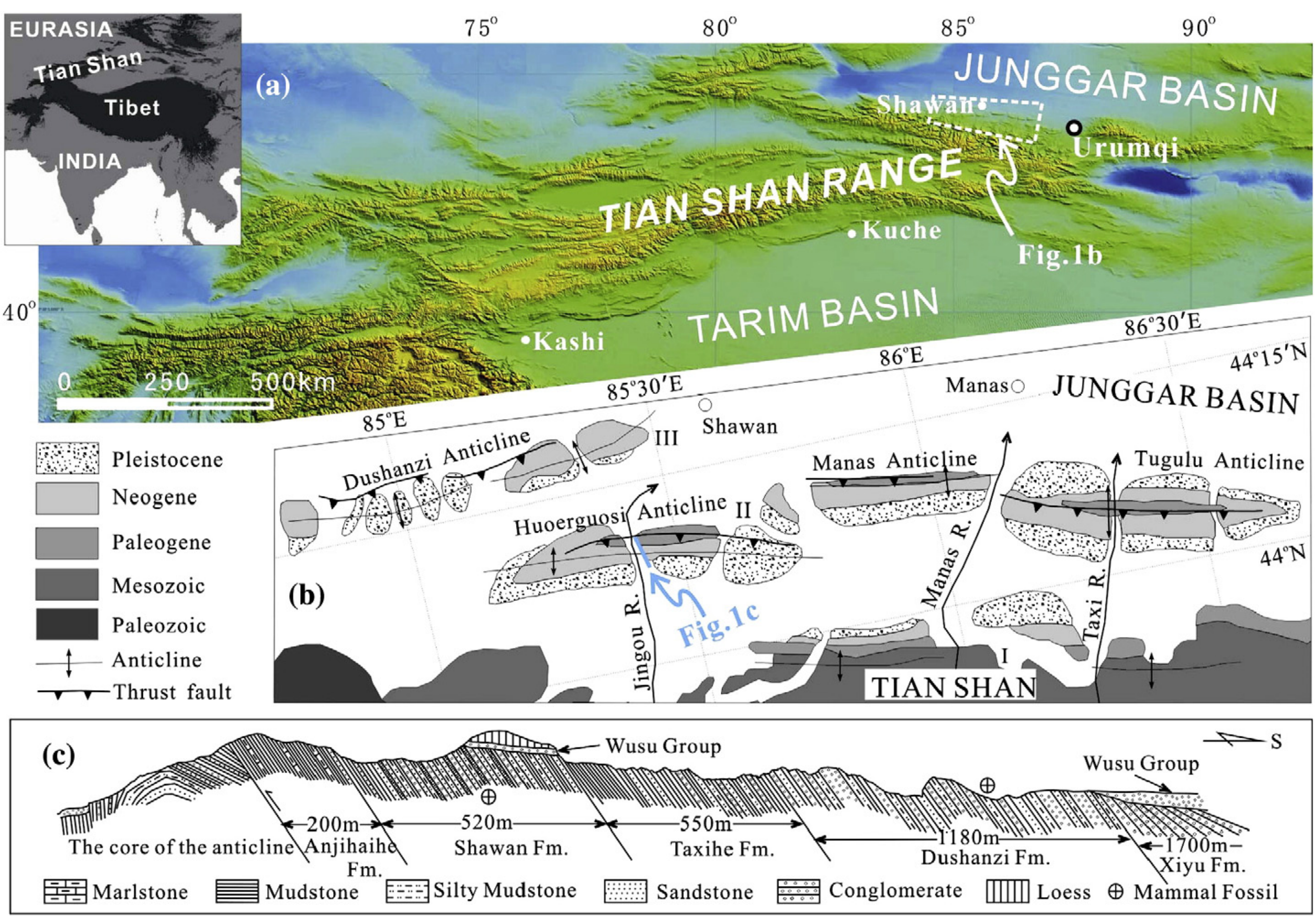

Fig. 1. (a) Topographic map of the central Asia; (b) Simplified geological map of the northern Tian Shan area showing the three fold-thrust zone (I, II, and III) and the location of the Jingou River section; (c) Strata exposed at the Jingou River section.