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A high-resolution stable isotopic record from the Junggar Basin (NW China): Implications for the paleotopographic evolution of the Tianshan Mountains

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ABSTRACT

This study presents high-resolution oxygen and carbon isotopic records of paleosol carbonates from fluvial sediments and lacustrine carbonates, sampled from the Jingou He and Kuitun He stratigraphic sections, located in the northern Tianshan piedmont. These sections expose remarkable outcrops of Junggar foreland basin sediments that have been previously dated by high-resolution magnetostratigraphy to between ~23.6 and ~1 Ma, and ~10.5 and ~3.1 Ma. A total of 216 samples of fluvio-lacustrine sediments were collected from which isotopic analyses yield $\delta^{18}O$ (SMOW) values that range from 13.7‰ to 29.9‰ in the Jingou He section, and 16.3‰ to 21.0‰ in the Kuitun He section. $\delta^{13}C$ (PDB) values range from −12.9‰ to 3.0‰ in the Jingou He section and from −7.8‰ to −4.0% in the Kuitun He section. $\delta^{18}O$ values decrease between ~25 and 23 Ma, and then remain relatively steady, with the exception of one period that contains samples with higher oxygen isotope values at ~16 Ma. During the periods when there are samples that overlap in time from the Kuitun He and Jingou He sections, we observe a difference of ~1.7% between values from the two locales. The $\delta^{13}C$ values also decrease between ~25 and 23 Ma, and then remain relatively steady until ~10 Ma with, again, one short period of higher values at ~16 Ma. Then, between ~10 and 3.1 Ma, carbon isotope values progressively increase. We interpret that $\delta^{18}O$ and $\delta^{13}C$ isotopic values during lacustrine periods (~25–23 Ma and ~16 Ma) as largely controlled by evaporation and opening/closing of the lake to external inputs. We interpret the $\delta^{18}O$ values of paleosol carbonate in the Junggar Basin to be influenced by the hypsometry of the high Tianshan range while the $\delta^{13}C$ values may record the uplift history of the depositional area in the foreland basin itself as well as the isotopic composition of plants. Consequently, we conclude that the Jingou He and Kuitun He drainage basins in the Central Tianshan have remained at relatively unchanged elevations for the past ~20 Ma. We also suggest that the elevation of the southern part of the foreland basin increased between ~10 and ~3.1 Ma, probably as a result of tectonic deformation in the piedmont and sedimentary filling of the sedimentary basin. The carbon isotope record remains relatively stable through time, and isotopic values suggest that there was little or no expansion of C4 plants in this region in the late Miocene.

1. Introduction

Mountains are the complex expression of the interactions between tectonic deformation, climate, and surface processes such as sedimentation and erosion (e.g Avouac and Burov, 1996; Beaumont et al., 1988; Burbank, 1992; Cobbold et al., 1993; Koons, 1987; Molnar and England, 1990; Whipple and Meade, 2006), both of which drive mass transfer from the uplifting zone toward the flanking basins (e.g. Charreau et al., 2009b; Métivier et al., 1999; Zhang et al., 2001). To better decipher the relative impact of these processes, long term and quantitative estimates of

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paleotopographic variations are needed. This is particularly true in Asia, where the India collision that began ~55 Ma ago (Leech et al., 2005; Patriat and Achache, 1984) has generated the growth of ranges with some of the greatest relief on Earth. The Tianshan Mountains lie 1700 km north of the India–Asia suture zone and dominate the topography of Central Asia over an E–W distance of over 2500 km with summits higher than 7000 m. Present-day shortening rates exceed 20 mm/yr across the range (Abdrakhmatov et al., 1996; Reigber et al., 2001), and attest to the great magnitude of intracontinental deformation. While the geological structure of the range has resulted from a complex Paleozoic history of accretionary and intracontinental deformation (e.g. Gao et al., 1998; Hendrix et al., 1992; Wang et al., 2008; Windley et al., 1990), the present topography appears to be related to the tectonic reactivation of these structures induced by the India–Asia collision (e.g. Dumitru et al., 2001; Sobel and Dumitru, 1997; Tapponnier and Molnar, 1979). This uplift has widely affected Central Asian climate and environment during Cenozoic times (Fluteau et al., 1999; Raymo and Ruddiman, 1992; Ruddiman and Kutzbach, 1989). Indeed, the amount of rainfall in the northern Tianshan piedmont today is one order of magnitude greater than in the southern Tianshan (Fig. 1), indicating that the Tianshan acts as a significant topographic barrier to atmospheric circulation from the north, including the Central Asian and Arctic airmasses (Araguas-Araguas et al., 1998). Thus, understanding how and when this relief was built will greatly improve our knowledge of how mountain building has driven climate changes under the influence of the convergent tectonic setting (i.e. India–Asia collision).

It has been shown that the isotopic composition of authigenic minerals from terrestrial sedimentary sequences adjacent to mountain belts may record the surface elevation of the windward mountain ranges (Dettman and Lohmann, 2000; Garzione et al.,

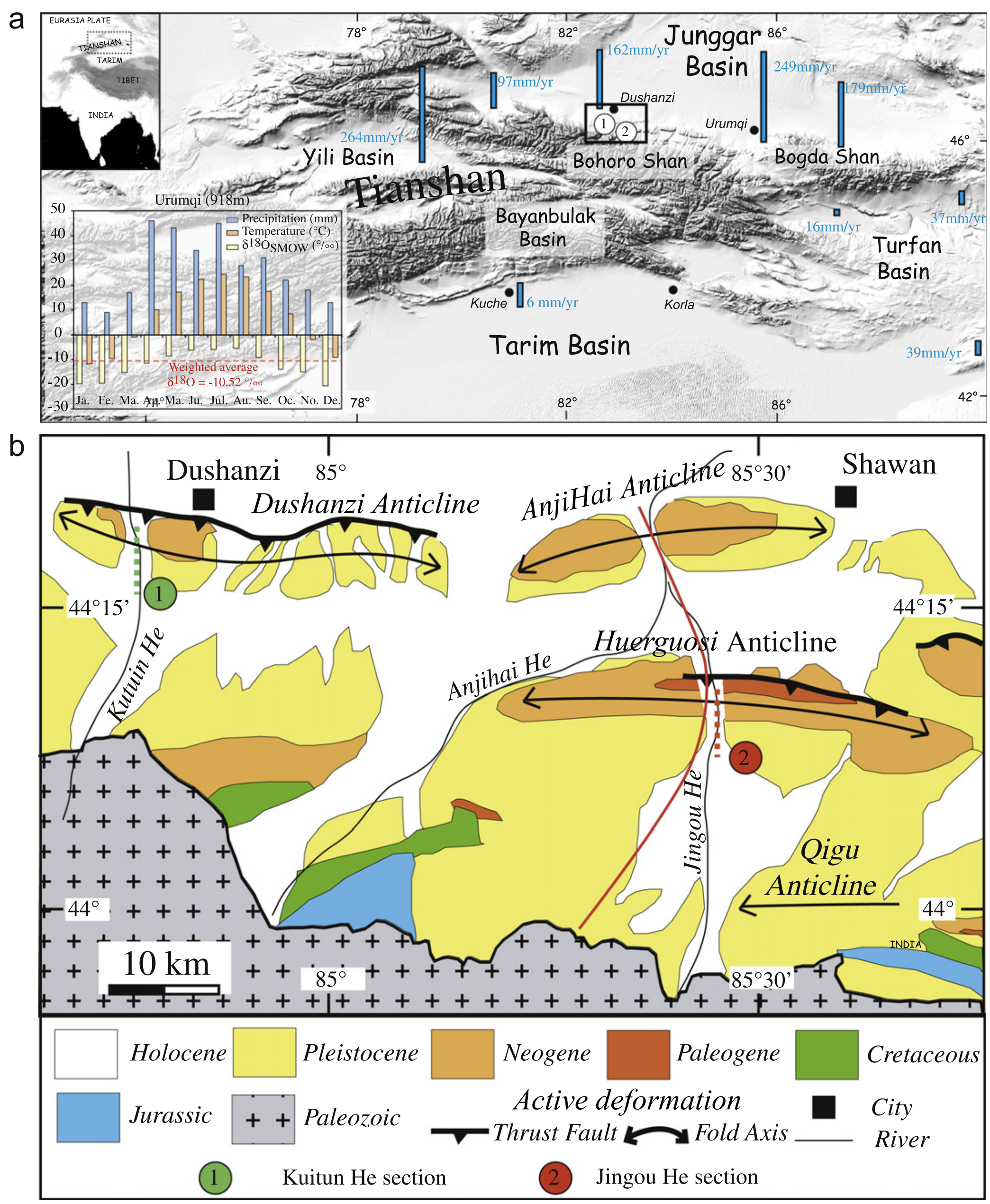

Fig. 1. (a) Topographic map of central Asia (inset shows precipitation, temperature and isotopic composition of rainfall at Urumqi according to the Global Network of Isotope Precipitation database); (b) geological map of the Dushanzi area with the location of the Jingou He and Kuitun He sections (modified after BGMRX (1985)).