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A high-resolution geochemical record from the Kuche depression: Constraints on early Miocene uplift of South Tian Shan

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ABSTRACT

The building of Tian Shan is often simplified to a Cenozoic reactivation of a Paleozoic fold belt. During the past decades extensive case studies have arrived at the conclusion that Tian Shan experienced diachronous uplift during the Cenozoic, however, understanding of the specific location and duration of the mountain building is still hindered by complex tectonic history of the orogenic belt. Considering the geochemical differences of various tectonic units within the mountains, we studied the chemical composition variability for the carbonate-free fine-grained samples collected from the longest terrestrial outcrop in the Kuche depression, southern Tian Shan, at a high resolution in order to better constrain the orogenic process. Our data show significant increases in mobile elements during the interval of 23–17 Ma, departing substantially from the stable long-term weathering trends and limited sedimentary sorting effects. We interpret the trend as provenance changes, which provide crucial evidence to support that the South Tian Shan experienced significant surface uplift during the early Miocene. This argument is supported by other studies conducted on both local and regional scales. Mineralogical analyses for the study section have shown that, since the early Neogene, a marked increase of detrital limeclasts derived from the South Tian Shan is accompanied by the decreases of the abundance of garnets derived from an ultrahigh-pressure metamorphic fold belt in the central Tian Shan. Moreover, low-temperature thermochronological results revealed that the central Tian Shan merely experienced pre-Neogene cooling, contrasting to the southern piedmont of the mountain where Neogene cooling dominated. Taken all together, we conclude that the uplift of the South Tian Shan initiated at ~23 Ma and the paleoelevation may exceed the height of the central Tian Shan at ~17 Ma.

1. Introduction

With peaks higher than 7000 m, the Tian Shan Mountains dominate Central Eurasian landscape over an E–W distance of 2500 km. The tectonic history of the mountains may be tracked to Paleozoic, when the region was deformed into a fold belt (Windley et al., 1990; Xiao et al., 2015). The mountains are sandwiched by the Junggar and the Tarim basins throughout the Meso- and Cenozoic eras (Hendrix et al., 1992; Windley et al., 1990) and shed thick clastic sediments on its flanks. The present Tian Shan is predominately a product of tectonic rejuvenation in response to the India–Asia collision during the Cenozoic (Avouac et al., 1993; Molnar and Tapponnier, 1975; Yin et al., 1998).

Although the tectonic process that formed the Tian Shan has been extensively studied, the precise timing and duration of the building of the present Tian Shan are still open to debate. By applying modern shortening rate across the Tian Shan, a middle Miocene (Abdrakhmatov et al., 1996; Artyushkov and Hofmann, 1998), which roughly agrees with those ages derived from mass balance calculation between the Tian Shan and its adjacent basins (Métivier and Gaudemer, 1997). These arguments, however, are undermined by poor chronological constraints, the assumption that shortening rate did not change for ~15 Ma, and the basin fill were precisely dated. Low temperature thermochronology studies suggest that the onset of exhumation varies from the late Oligocene (Dumitru et al., 2001; Heermance et al., 2007; Hendrix et al., 1994; Macaulay et al., 2014) to the middle to late Miocene (Bullen et al., 2001, 2003; Sobel et al., 2006) at different parts of the mountains.

Within improved chronostratigraphic framework based on high-resolution magnetostratigraphy, the onset of growth strata, the timing of initiation of coarse clastic sedimentation, and the increase in

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sedimentation rates in sedimentary basins can represent the minimum ages of the onset of the deformation in the Tian Shan. Results from various locations within the Tian Shan generally show that deformation occurred during four time intervals: early Miocene (25–20 Ma, e.g., Heermance et al., 2008; Huang et al., 2006; Tang et al., 2012; Wack et al., 2014; Yang et al., 2015; Yin et al., 1998), middle Miocene (17–15 Ma, e.g. Charreau et al., 2009a; Heermance et al., 2007, 2008; Huang et al., 2006; Tang et al., 2012), early late Miocene (11–10 Ma, e.g. Bullen et al., 2001; Charreau et al., 2005; Charreau et al., 2006; Charreau et al., 2009b; Wack et al., 2014), and latest Miocene (7–5 Ma; e.g. Jing et al., 2011; Li et al., 2010; Sun et al., 2009; Sun and Zhang, 2009). Taking into account the heterogeneous mountain building and complex tectonic history of the orogenic belt, such observations have poor constraints on the specific location and duration of the deformed region.

The Kezilenuer section in the Kuche depression is the longest known fluviolacustrine sequence within the southern Tian Shan (Huang et al., 2006; Li et al., 2006b). The section spans from the late Paleogene throughout the Miocene. We here assess previous magnetostratigraphic correlations by using a statistical method and present chemical compositions of bulk fined-grained rock samples collected from the section. By combining these data with previously published low-resolution data of detrital mode and mineral composition, we aim at constraining the exhumation histories and determining the location and duration of the mountain building of the southern Tian Shan.

2. Geological setting

The Tian Shan orogenic belt consists of microcontinental blocks containing Precambrian basements and Meso-Cenozoic depositional covers. In the southwestern Chinese Tian Shan, the Tarim plate and the Central Tian Shan plate were assembled during the early Carboniferous, resulting in widespread ultrahigh-pressure eclogite and blueschists along the Southern Central Tian Shan Suture (SCTS, Han et al., 2011, Fig. 1a). To the south of the suture deformed Paleozoic carbonate shelf is well exposed, on the Harke Mountain, which is the summit of the present South Tian Shan. The Paleozoic sedimentary rocks mainly consist of Silurian to Carboniferous limestone, marble, flysche, chert and clastic sedimentary rocks (Fig. 1b & c).

The Kuche depression is a foreland basin resulting from southward thrusting of the South Tian Shan (Yin et al., 1998). It extends 300–400 km west to east with a width of 40–70 km, occupying ca.

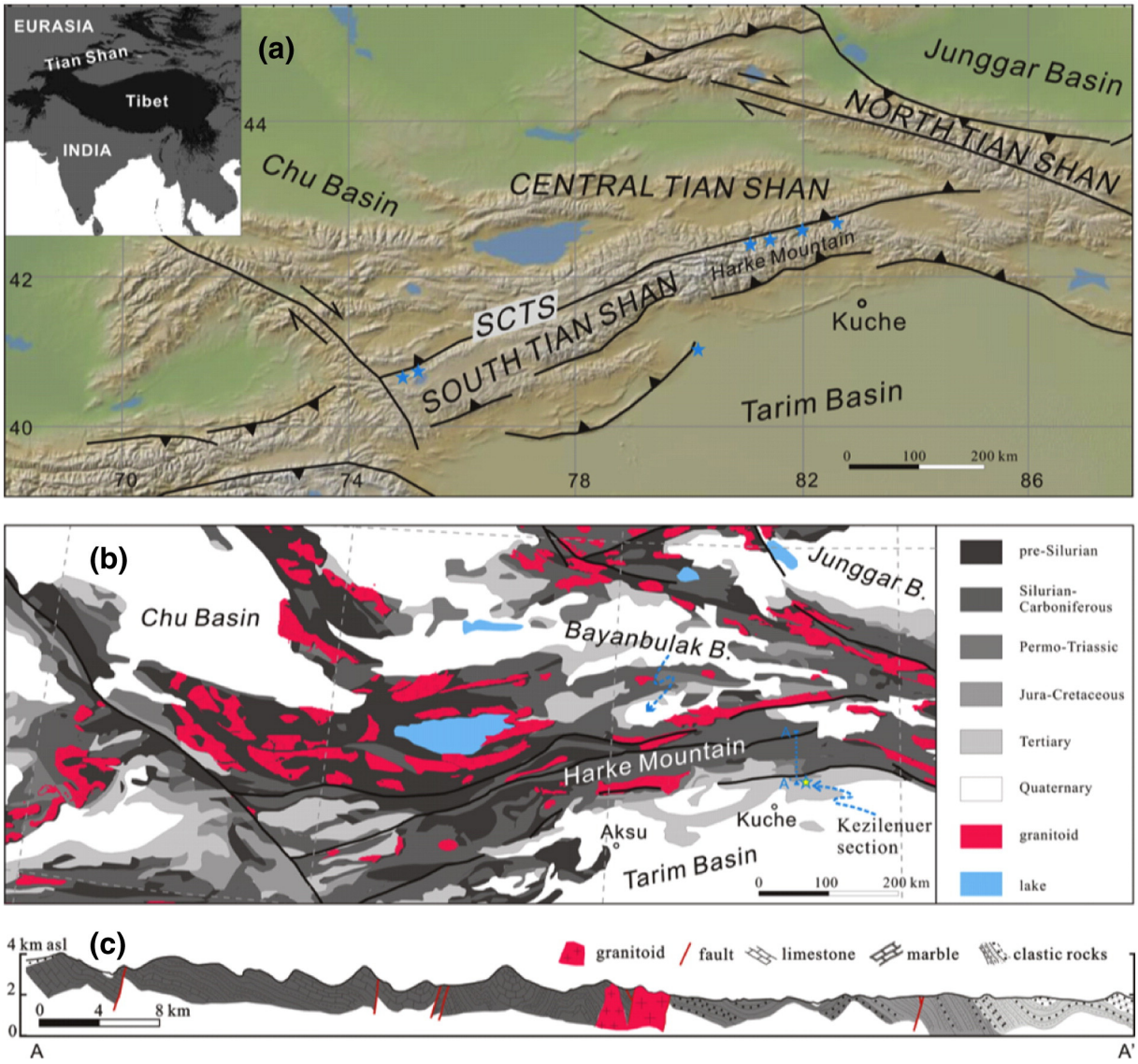

Fig. 1. (a) Topographic map of the Tian Shan with main faults that divide the mountain into North, Central and South Tian Shan. SCTS represents the Southern Central Tian Shan Suture and the blue stars indicate the sites of UHP metamorphic rocks (Han et al., 2011); (b) simplified geological map of the study area, showing the location of the study section. Note the transection A–A′; (c) transection A–A′ in (b). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)