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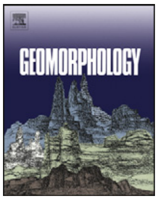

The evolution of a terrace sequence along the Manas River in the northern foreland basin of Tian Shan, China, as inferred from optical dating

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ABSTRACT

The Tian Shan range lies in the actively deforming part of the India–Asia collision zone. The uplift rate and deformation pattern of the Tian Shan are important for understanding the dynamics of crustal deformation in the region. The river terraces in northern Tian Shan provide key records of past changes in climate and/or regional tectonics. In this study, a terrace sequence along the Manas River in a tectonically active zone in the northern foreland basin of Tian Shan is investigated. Six river terraces were identified and dated using optically stimulated luminescence (OSL). The results show that the six terraces were abandoned at ~0.5 ka, ~1.4 ka, ~3.1 ka, ~4.0 ka, ~12.4 ka and ~19.9 ka, respectively. Together with high resolution Global Positioning System (GPS) measurements on the terrace treads, the fluvial history of Manas River is reconstructed. From ~20 ka to ~4.8 ka, the height of the fluvial bed of Manas River decreased at an average rate of 2.2 ± 0.6 mm/yr. From ~4.8 ka to the present, the height of the fluvial bed decreased at an average rate of 13.5 ± 0.6 mm/yr, corresponding to intensified incision of Manas River during the late Holocene. This accelerated incision is very likely caused by the tectonic forces rather than climatic influences alone, suggesting that the tectonic uplift activity was significantly intensified since ~4.8 ka in the northern piedmont of Tian Shan. Other controlling factors on the incision of Manas River are also discussed.

1. Introduction

In response to the Cenozoic collision of the Indian and Eurasian continental plates, Tian Shan has been one of the most active intracontinental mountain building belts in central Asia (Fig. 1A) (Molnar and Tapponnier, 1975; Tapponnier and Molnar, 1979; Avouac et al., 1993; Fu et al., 2003; Sun and Zhang, 2009). Tian Shan experiences frequent large earthquakes and rapid rates of deformation, which has drawn the attention of many scientists on the neotectonic activity of Tian Shan (e.g. Avouac et al., 1993; Abdrakhmatov et al., 1996; Deng et al., 1996; Sun et al., 2004; Zhang, 2004; Sun and Zhang, 2009; Lu et al., 2010b). The quantification of late Quaternary tectonic uplift activities in the region is important for understanding mountain-building process and evaluating seismic hazards.

Several rivers originate from glaciers in the northern foreland basin of Tian Shan, transversely cutting the thrusting and folding zones towards the Junggar Basin (Fig. 1A, B). Terrace systems were developed along the banks of the rivers, which provide important records for studying the past changes in climate and/or regional tectonics. On the one hand, the past climatic fluctuations may have significant effects on the formation of river terraces. On the other hand, active tectonics, as indicated by the existence of the Cenozoic folding, may also affect the river incision in this area. Given their importance for studying the paleo-climatic changes and regional tectonics, the river terraces in northern Tian Shan have been extensively studied (Avouac et al., 1993; Deng et al., 1996; Yang et al., 2011). However, further correlation of the river terraces with past climate changes and/or regional tectonics has been impeded by the lack of a reliable chronological framework for the fluvial sequences.

To interpret the evolution of a fluvial system, a robust chronology is very important. In addition to radiocarbon dating and cosmogenic exposure dating, optically stimulated luminescence (OSL) dating offers an alternative for dating fluvial sediments beyond the 50,000 year limit of radiocarbon dating. Such luminescence technique has been widely applied to many aeolian depositional sequences, e.g. sandy deposits from deserts in northeast China and loess deposits from the Chinese Loess Plateau (e.g. Li et al., 2002; Sun et al., 2006; Li et al., 2007; Li and Li, 2011). Although fluvial sediments are not the ideal materials for optical dating due to possible heterogeneous bleaching at the time of deposition, it is still possible to date the sediments by assessing the degree of

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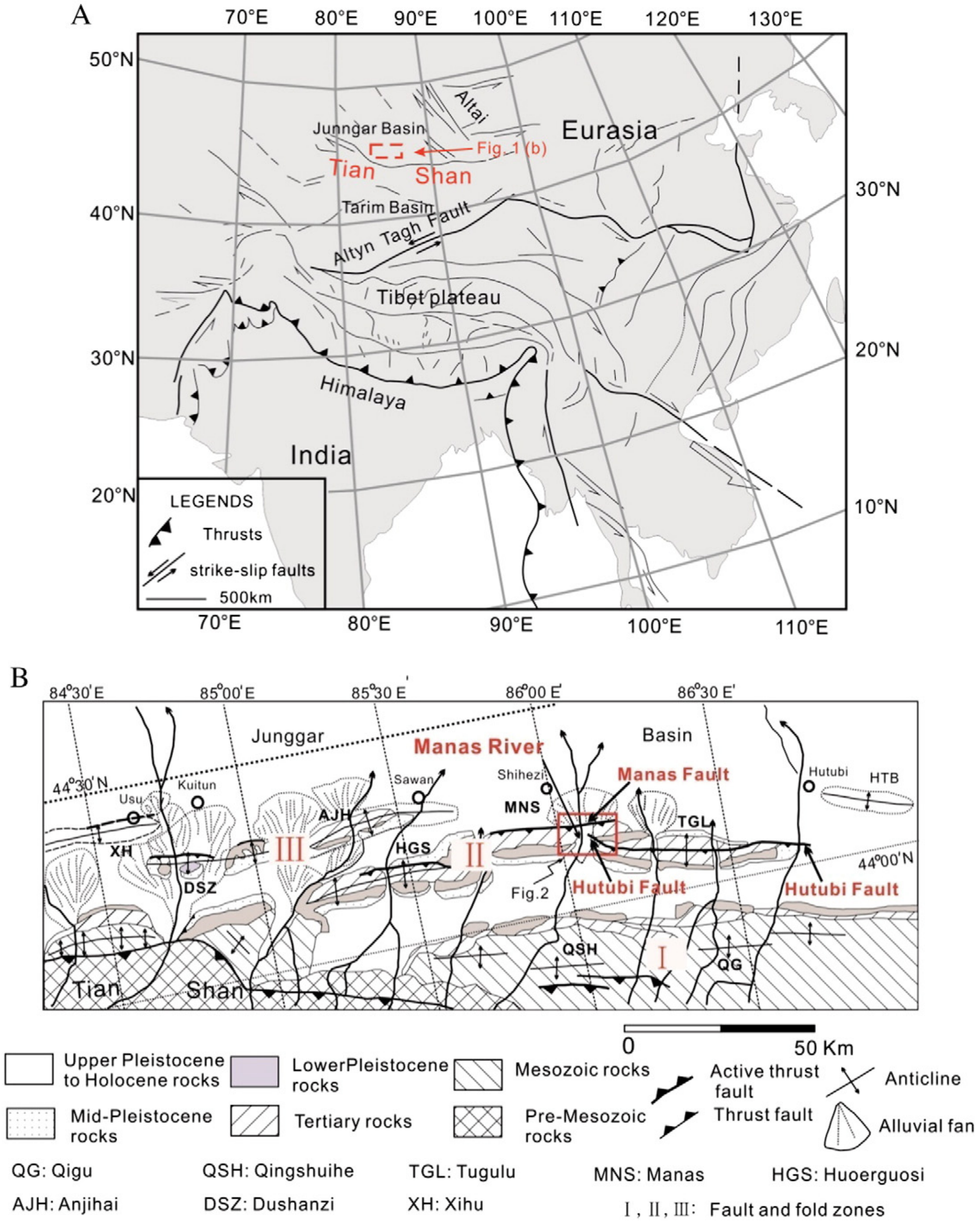

Fig. 1. (A): Geologic map showing the location of Tian Shan. The intra-continental regions were deformed within the Eurasia continent, in response to the convergence of India and Eurasia continents. (B): Geologic structural map of the three roughly east–west stretching fold and fault zones in the northern foreland basin of Tian Shan (modified from (Fu et al., 2003)). The Manas River transversely incises across the Manas Anticline towards the Junggar Basin.

bleaching of sediments using statistical methods (Li, 1994; Galbraith et al., 1999; Olley et al., 1999; Zhang et al., 2001; Wallinga, 2002; Zhang et al., 2009).

In this study, the quartz single-aliquot regenerative-dose (SAR) OSL dating technique (Murray and Wintle, 2000) was applied to date the terrace sequence along the Manas River in the northern foreland basin of Tian Shan. At the site studied, six terraces were identified along the eastern bank. By dating the underlying fluvial sand and the overlying aeolian loess on the terraces, a luminescence chronology for the terrace sequence was established. Together with high resolution Global Positioning System (GPS) measurements on the terraces, the incision history of Manas River was evaluated and its climatic and tectonic implications discussed.

2. Study area

2.1. Geological setting

Lying on northwestern China, the Tian Shan range extends east–west for more than 1700 km with a width of 250–300 km, separating the Tarim Basin to the south from the Junggar Basin to the north (Fu et al., 2003). The active neotectonics of Tian Shan resulted in the intensive deformation of the Mesozoic to Cenozoic strata in the foreland basins (Fu et al., 2003; Zhang, 2004; Sun and Zhang, 2009). During the late Cenozoic, three subparallel rows of roughly east–west striking fold and reverse fault zones formed in the northern foreland basin (Fig. 1B). In this study, the three zones were termed as zones I, II and III from the mountain front