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Late Quaternary alluvial sequence and uplift-driven incision of the Urumqi River in the north front of the Tian Shan, northwestern China

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ABSTRACT

This work focuses on the driving force behind the late Quaternary river incision and terrace formation of the Urumqi River in the north piedmont of the Tian Shan, northwestern China. Field investigations on geomorphic surfaces, terrace deposits, and its underlying bedrock identify four most significant features, which creates a local applicable framework for subdivision of the late Quaternary terrace sequence in the study area. Nine stepped river terraces are defined and designated as T_1 to T_9 increasing systematically in elevation. Morphologically, the highest T_9 correlates with the oldest alluvial fan F_1 of the Urumqi River. River incision and the resultant abandonment of fan F_1 are chronologically constrained at ca. 550 ka. The stratigraphic geometry of the Saerqiaoke anticline, a structure developing at the fan end of F_1, reveals the existence of growth strata, implying continuous growth of this fold when the F_1 alluvial sediments were deposited. In the range front of the Urumqi River, growth of the Saerqiaoke anticline has derived tectonically from uplift and basinward thrusting of the Tian Shan range. Such thrusting and basinward extension of the range are expected to force rock uplift of the headwater of the Urumqi River with respect to the Chaiwopu basin to the north and thus river incision occurring at ca. 550 ka. During the subsequent period, several younger terraces have been formed in response to the further uplift of the Saerqiaoke anticline as well as climate changes during glacial–interglacial transitions. In the present study area, the total incision during Quaternary comes close to 400 m, with about 85% contribution likely attributed to rock uplift of the Saerqiaoke anticline.

1. Introduction

For an active orogenic belt, the topographic evolution derives from the interactions of tectonics and surface processes (Burbank and Pinter, 1999; Burbank, 2005; Burbank and Anderson, 2011; D'Arcy and Whittaker, 2014). Among the geomorphic systems, fluvial terrace is particularly sensitive to allogenic factors (such as tectonism and climate) (Blum and Törnqvist, 2000; Westaway et al., 2006; Daniels, 2008; Burbank and Anderson, 2011; Zhang et al., 2014), which makes the study of fluvial landforms fundamental for reconstructing the history of regional environmental evolution (e.g., Avouac and Peltzer, 1993; Li et al., 1999; Bridgland, 2000; Sun, 2005; Hanson et al., 2006; Lu et al., 2010a; Macklin et al., 2013; Pan et al., 2013; Gong et al., 2014). However, the relative role of tectonism and climate in the recent topographic evolution, especially terrace formation, remains an issue of debate (e.g., Pan et al., 2000, 2003; Starkel, 2003; Bridgland and Westaway, 2008; Daniels, 2008; Lu et al., 2010a). The Tian Shan and its surrounding area provide such an excellent natural laboratory to probe this scientific question.

The modern Tian Shan has been built largely by basinward thrusting along range-bounding faults (Fig. 1A) (Avouac et al., 1993; Deng et al., 2000; Lu et al., 2010b). As a result, the present topography in both the northern and southern Tian Shan foreland basins is characterized by several fold-and-thrust belts roughly parallel to the trend of the range (Fig. 1) (Avouac et al., 1993; Deng et al., 2000; Zhang, 2004). Transverse rivers emanating from the high range of the Tian Shan across the piedmonts incise into the anticlines roughly perpendicular to their strike (Fig. 1). We focus on the range front of the Urumqi River, where a small-scale anticline (here referred to as the Saerqiaoke anticline) develops at the fan end of the oldest alluvial fan of the river (the area covered by the lower Pleistocene strata in Fig. 2). Well-developed terrace staircase and alluvial fans display along the course in the range front (Fig. 2). Previous studies have analyzed the effect of Quaternary glaciation on the piedmont alluviation in this area (e.g., Yang and Qiu, 1965; Zhou et al., 2002), whereas relatively few studies have focused on the geomorphic processes forcing river incision and terrace formation (e.g., Zhou et al., 2002). In order to better understand the driving force behind river incision and terrace generation in the range front of the Urumqi River, we have measured five terrace cross sections and defined the types and distributions of terraces and their correlations with alluvial fans. From these, we have dated five samples using optically

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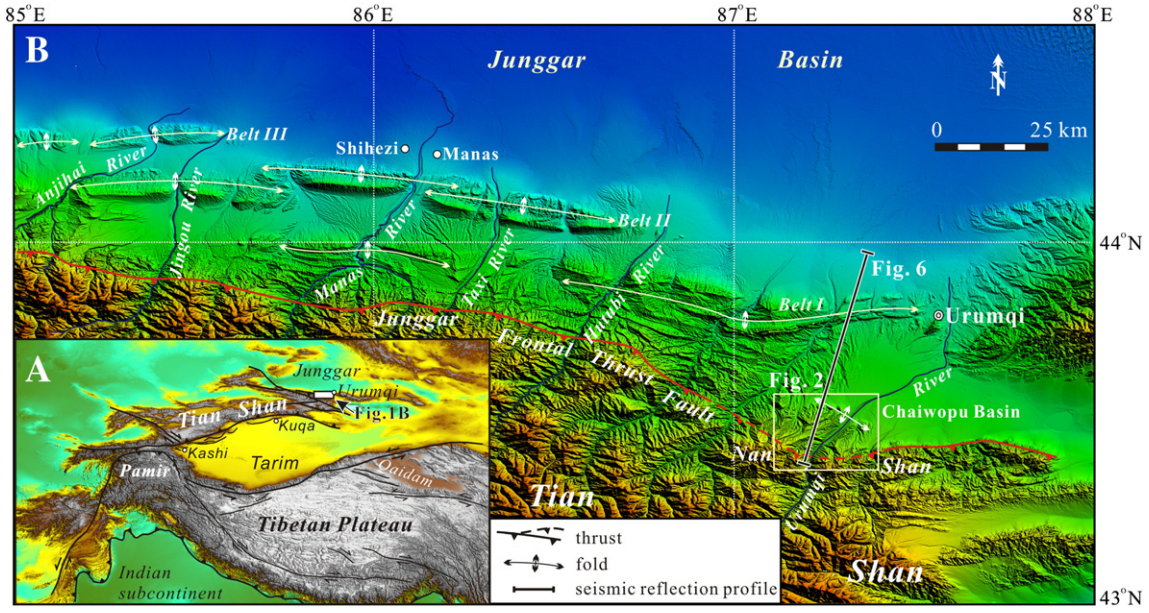

Fig. 1. (A) Map shows overall topographical pattern and tectonic setting of the interior of Asia. (B) Digital elevation model (DEM) of the northern Tian Shan foreland, where three fold-and-thrust belts (belt I, II, and III) characterize the regional topography (Deng et al., 2000; Zhang, 2004).

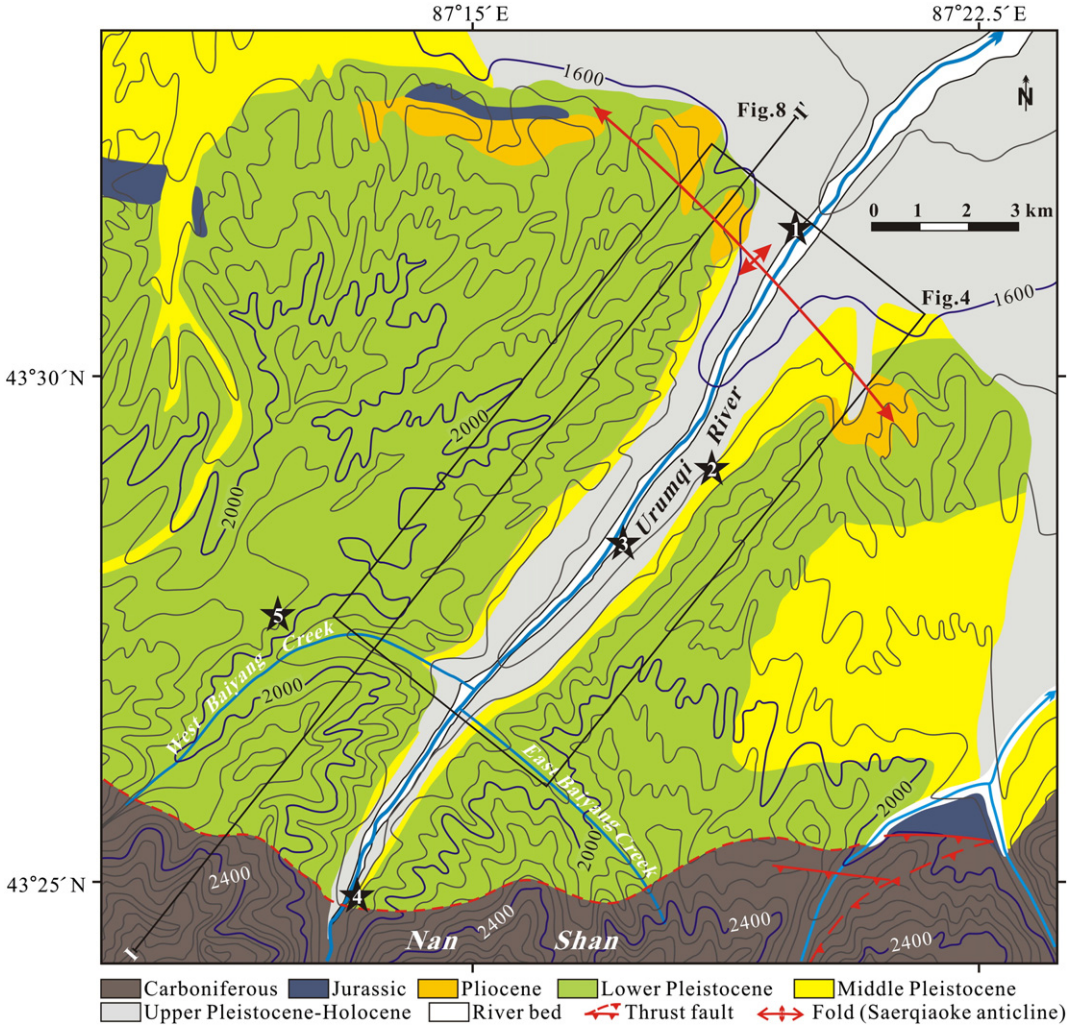

Fig. 2. Geological map (based on 1:50,000 geological map) in the range front of the Urumqi River, where intense incision exposes thick Quaternary alluvium as well as Jurassic and Pliocene strata. Stars show the sampling sites for ESR, OSL, and AMS ^{14}C dating, as reported in Table 1.