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Large-scale displacement along the Altyn Tagh Fault (North Tibet) since its Eocene initiation: Insight from detrital zircon U–Pb geochronology and subsurface data

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ABSTRACT

Marking the northern boundary of the Tibetan plateau, the Altyn Tagh fault plays a crucial role in accommodating the Cenozoic crustal deformation affecting the plateau. However, its initiation time and amount of offset are still controversial despite being key information for the understanding of Tibet evolution. In this study, we present 1122 single LA-ICP-MS detrital zircon U–Pb ages obtained from 11 Mesozoic to Cenozoic sandstone samples, collected along two sections in the northwestern Qaidam basin (Eboliang and Huatugou). These data are combined with new 3D seismic reflection profiles to demonstrate that: (1) from the Paleocene to early Eocene, the Eboliang section was approximately located near the present position of Anxi, 360 ± 40 km southwest from its current location along the Altyn Tagh fault, and sediments were mainly derived from the Altyn Tagh Range. At the same period, the Huatugou section was approximately located near the present position of Tula, ca. 360 km southwest from its current location along the Altyn Tagh fault, and the Eastern Kunlun Range represented a significant sediment source. (2) Left-lateral strike-slip movement along the Altyn Tagh fault initiated during the early-middle Eocene, resulting in northeastward displacement of the two sections. (3) By early Miocene, the intensive deformation within the Altyn Tagh Range and northwestern Qaidam basin strongly modified the drainage system, preventing the materials derived from the Altyn Tagh Range to reach the Eboliang and the Huatugou sections. The post-Oligocene clastic material in the western Qaidam basin is generally derived from local sources and recycling of the deformed Paleocene to Oligocene strata. From these data, we suggest enhanced tectonic activity within the Altyn Tagh Range and northwestern Qaidam basin since Miocene time, and propose an early-middle Eocene initiation of left-lateral strike-slip faulting leading to a 360 ± 40 km offset along the Altyn Tagh fault.

1. Introduction

Two competing end-member mechanisms have been proposed to explain the accommodation of the ongoing convergence between India and Eurasia since the early Eocene collision: (1) a homogeneous crustal thickening of the Tibetan plateau (e.g. England and Houseman, 1989; Searle, 1996); and (2) an eastward extrusion of the Tibetan plateau and southeast Asia away from the indenting Indian plate (Molnar and Tapponnier, 1975; Peltzer and Tapponnier, 1988; Avouac and Tapponnier, 1993; Tapponnier et al., 2001). The second model requires large-scale displacement along lithospheric strike-slip fault zones to allow extrusion of the Tibetan crust (e.g. Searle, 1996; Tapponnier et al., 2001). Marking the northern boundary of the Tibetan plateau (Fig. 1), the lithospheric-scale left-lateral strike-slip Altyn Tagh fault (ATF) plays a crucial role in accommodating the crustal deformation and appears to be an ideal field laboratory for ascertaining the dynamics of plateau formation (Molnar and Tapponnier, 1975; Wittlinger et al., 1998; Jolivet et al., 1999, 2001; Yin and Harrison, 2000; Yin et al., 2002; Searle et al., 2011). Understanding the kinematic pattern of the ATF, especially the exact Cenozoic initiation time and the amount of Cenozoic offset, is of major importance for unraveling the crustal accommodation processes within the plateau since the India-Eurasian collision and for deciphering the growth history of the entire Tibetan plateau.

Several authors proposed that a large scale Jurassic basement cooling event associated to tectonic exhumation affected a corridor along the ATF (e.g. Delville et al., 2001; Sobel et al., 2001; Wang et al., 2005). In addition, many researchers consider that deformation along the ATF initiated after the late Mesozoic, during the early Cenozoic, or even during the Neogene (e.g. Tapponnier et al., 1986; Jolivet et al., 1999; Chen et al., 2001; Jolivet et al., 2001; Yin et al., 2002; Wang

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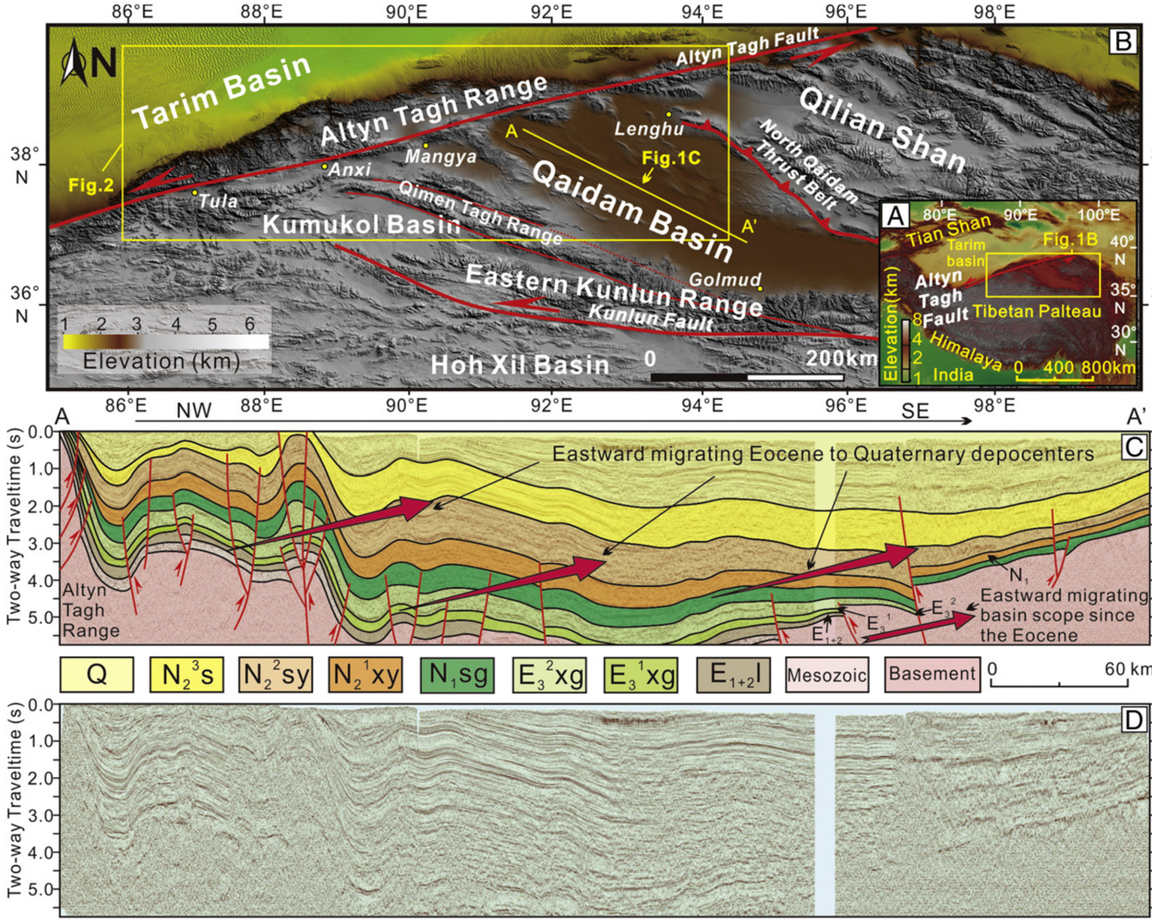

Fig. 1. (A) SRTM based digital topographic map of the Tibetan plateau. (B) Digital elevation model (DEM) and major tectonic elements of the Altyn Tagh Range, the Qaidam basin and the surrounding regions. The location of Fig. 2 is identified by the solid box. The DEM map was generated from the 90 m SRTM data. Note that the yellow solid line refers to the location of seismic profile AA'. (C) Interpreted and (D) non-interpreted seismic profile AA'. Note that the succession of Cenozoic depo-centers is marked along the long axis of the basin. These depo-centers gradually migrated eastward since the Eocene.

et al., 2006a; Wu et al., 2012a, 2012b; Zhang et al., 2012, 2014a). Similarly, estimations of the total displacement along the ATF vary widely from ~1200 km to less than 90 km (e.g. Tapponnier et al., 1986; Wang, 1997; CSBS, 1992; Ritts and Biffi, 2000; Yin and Harrison, 2000; Yang et al., 2001; Yue et al., 2001; Chen et al., 2002; Yin et al., 2002; Cowgill et al., 2003; Gehrels et al., 2003a, 2003b; Darby et al., 2005; Yue et al., 2005; Searle et al., 2011; Cheng et al., 2015a). These tremendous discrepancies may be partially attributed to the immense size and extent of the Altyn Tagh Range, making it difficult to locate ideal piercing points to estimate the total displacement along the ATF. Furthermore, due to strong Cenozoic deformation, continuous Mesozoic to Cenozoic stratigraphic sections necessary to estimate the time of initiation of left-lateral slip movement are seldom preserved (e.g. Yin and Harrison, 2000; Cheng et al., 2015a).

Detrital zircon analysis of a continuous, well dated stratigraphic succession has become a powerful tool for unraveling source to sink relationships and constraining the tectonic and topographic evolution of an area (e.g. Fedo et al., 2003; Thomas, 2011; Gehrels, 2014). To bring more constraints on the kinematic evolution of the ATF, we conducted an integrated analysis on two Jurassic to Pleistocene sedimentary sections in the western part of the Qaidam basin, adjacent to the ATF (Fig. 2). We then combined the detrital zircon U–Pb geochronology

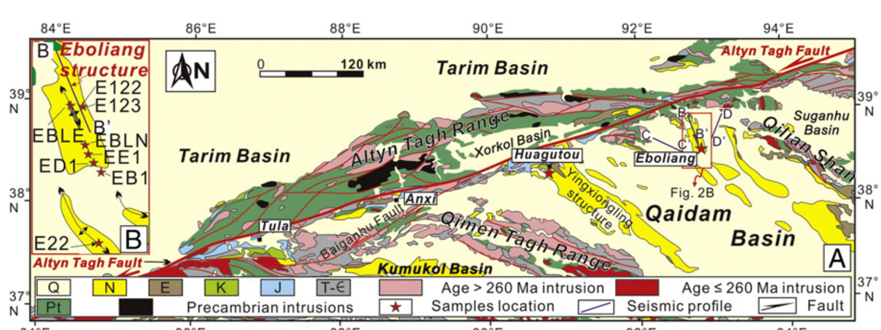

Fig. 2. Simplified geological map of the northwestern Qaidam basin and eastern segment of the Altyn Tagh Range, adapted from the Geologic Map of the Tibetan plateau and adjacent areas compiled by the Chengdu Institute of Geology and Mineral Resources and Chinese Geological Survey (map scale, 1:1,500,000).