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Intensified tectonic deformation and uplift of the Altyn Tagh range recorded by rock magnetism and growth strata studies of the western Qaidam Basin, NE Tibetan Plateau

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ABSTRACT

As the tectonical and geographical northern edge of the Tibetan Plateau, the evolution of the Altyn Tagh range has attracted wide attention. Precise dating of its activities is believed essential for understanding the possible mechanisms of the Tibetan Plateau uplift and its effects on climate changes. Under the framework of basin–mountain coupling, both magnetic susceptibility and rock magnetic researches were carried out in this study on the Late Cenozoic sediments of the Honggouzi (HGZ) section (ca. 17–5 Ma) in the western Qaidam Basin to explore the tectonic and climatic evolution as well as their interactions of the Altyn Tagh range.

The obtained magnetic susceptibility record in the HGZ section displayed a two-step variation, which kept relatively low and stable values for sediments from the stratigraphic levels of 120–596 m (ca. 17–10 Ma) (stage I), but increased rapidly from 596 to 1014 m (ca. 10–5 Ma) (stage II). The rock magnetic results revealed that paramagnetic minerals or clay minerals, maghemite and hematite are dominant in stage I, which were replaced by magnetite and maghemite in stage II. A detailed comparison of magnetic susceptibility record in the HGZ section with regional tectonic and climate records was carried out. Combined with sedimentary facies, lithology and angular unconformity in the sequence, as well as seismostratigraphy data, paleocurrent and provenance analyses, the possible mechanisms for the magnetic susceptibility variation were explored. The results indicated a direct link between magnetic susceptibility change and the uplift of the Altyn Tagh range at ca. 10 Ma.

1. Introduction

The Cenozoic collision of the Indian subcontinent with the southern margin of Asia has deformed a large region in Central Asia. This collision raised the Himalaya and the Tibetan plateau, activated major boundary faults such as the Karakorum and Altyn Tagh faults (Fig. 1a, b) (e.g., Tapponnier et al., 1986). As one of the most prominent tectonic events during the Cenozoic, uplift of the Tibetan Plateau has exerted enormous impacts on regional and global tectonics, sedimentation, climate and magmatism (Molnar and Tapponnier, 1975; An et al., 2001; Molnar, 2005; Xu et al., 2006; Garzione, 2008; Jia, 2009; Mo, 2009; Molnar et al., 2010; Yin, 2010; Li et al., 2014). The Altyn Tagh range (including the Altyn Tagh fault (ATF) and the Altyn Tagh Mountains (ATM)) define the tectonic and geographical northern edge of the Tibetan Plateau in the inner Asian continent, respectively (Fig. 1a, b), and provide an ideal platform to understand uplift, erosion, stress dissipation, and their relations to lithospheric deformation and global or regional climate changes that linked to the India–Asia collision and Tibetan Plateau uplift dynamics (Yue and Liou, 1999; Sobel et al., 2001; Tapponnier et al., 2001; Yin et al., 2002; Cowgill et al., 2003; Wang et al., 2006; Ritts et al., 2008; Zhuang et al., 2011; Lu et al., 2014). In addition, the Altyn Tagh range is a case example of an active inter-continental mountain belt, where the history of mountain building might be deciphered from the sediment accumulation in the adjacent Qaidam and Tarim Basins. Thus, precise dating of the tectonic activities of the Altyn Tagh range is essential for understanding the possible mechanisms of Tibetan Plateau uplift and its effects on climate changes and basin–mountain coupling. However, most of the previous studies were concentrated on Mesozoic, specifically Cretaceous, or early Cenozoic rocks (Yue and Liou, 1999; Jolivet et al., 1999, 2001; Yue et al., 2001, 2004; Sobel et al., 2001; Li et al., 2002; Yin et al., 2002; Ritts et al., 2004; Sun et al., 2005a; Wang et al., 2005; Liu et al., 2007); the timing of the tectonic deformation of the Altyn Tagh range from Miocene to Pliocene remains poorly understood and controversial (Sun et al., 2005b; Ritts et al., 2008; Lu and Xiong, 2009; Chang et al., 2012; Zhang et al., 2013; Lu et al., 2014).

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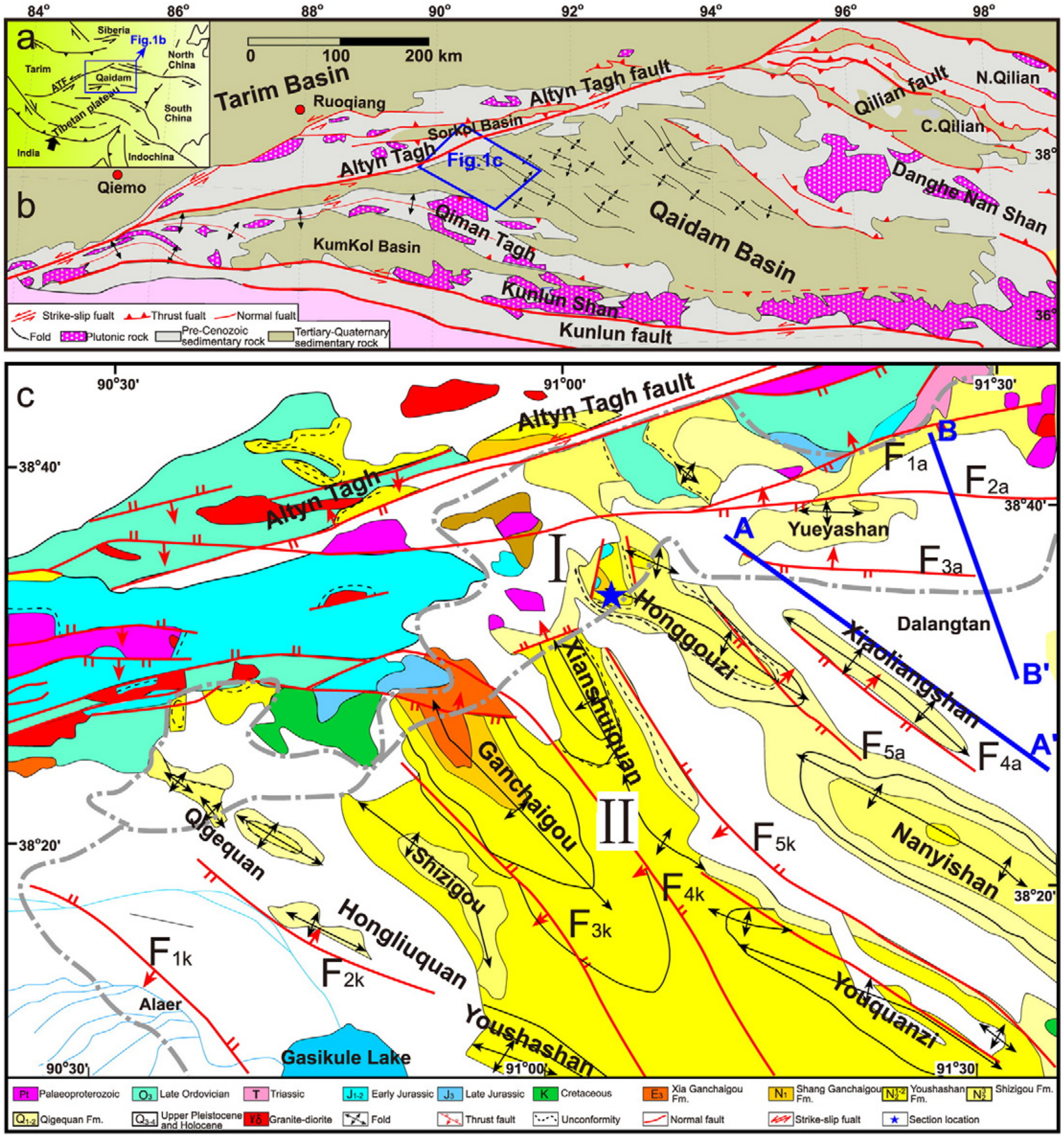

Fig. 1. (a) Map of Tibetan Plateau and adjacent regions showing major structures. AFT: Altyn Tagh fault; (b) Tectonic map of the Qaidam Basin and adjacent regions at the northeastern front of the Tibetan Plateau (modified from Yin et al., 2002); (c) Detailed geologic map of the study area in the western Qaidam Basin showing the distribution of folds and the locations of the Honggouzi section (blue asterisks). See panel b for its location within the basin. The regions (I & II) of gray broken lines indicate roughly scopes of the frontal regions of the Altyn Tagh (Mts.) thrust belt and the east Kunlun Shan (Mts.) thrust belt, respectively (modified from Zhang et al., 2013). A–A′ and B–B′are location of Fig. 9a,b respectively.

The Qaidam Basin, located in the southeastern Altyn Tagh range (Fig. 1), has been a closed basin since the Paleocene and filled with a maximum thickness of approximately 12,000 m of Cenozoic sediments derived from the surrounding mountains (Huang et al., 1996; Xia et al., 2001; Fang et al., 2007). It is an ideal place to archive the spatial–temporal patterns of range exhumation and erosion, fault activity, and basin infilling. The recently discovered Honggouzi (HGZ) outcrop section, a middle Miocene fluvial–lacustrine sequence in the western Qaidam Basin, which was well dated by magnetostratigraphy (Fig. 1c) (Fang et al., 2006; Song et al., 2014), provide a great chance to explore the evolution of tectonic and climatic changes as well as their interactions.

Magnetic susceptibility has been regarded as an effective economic and non-destructive proxy to determine the pedogenic degree and strength of the Asia summer monsoon in the Chinese Loess Plateau (Liu, 1985; Zhou et al., 1990; Ding et al., 1992; Nie et al., 2007). It has also been successfully applied to fluvial–lacustrine sediments, either for the reconstruction of climate history in the monsoon regions of Asia and the Tibetan Plateau (Ao et al., 2010; Chang et al., 2012; Xiao et al., 2012; Zhang et al., 2012a; Herb et al., 2013), or for constraining the infilling history of foreland basins during the uplift of orogenic belts (e.g., Gilder et al., 2001; Sun et al., 2005b; Charreau et al., 2006; Huang et al., 2006; Lu and Xiong, 2009; Chang et al., 2012; Yan et al., 2014). Therefore, magnetic susceptibility, combined with systematic rock magnetism, growth strata and paleocurrent analyses, were performed here to reveal the tectonic or climatic regime documented in the HGZ section.

2. Geological setting and stratigraphy

The Qaidam Basin, which contains thick continuous Cenozoic strata and covers an area of approximately 120,000 km^2, is the largest intermontane basin in the northeastern Tibetan Plateau. It is now surrounded by high mountains (generally 4200–5200 m in elevation), e.g., the Qiman Tagh and Kunlun Mountains to the south, the Altyn Tagh Mountains to the northwest, the Qilian Mountains to the northeast (Fig. 1a, b). The high relief between the Qaidam Basin and the surrounding mountains is controlled by large boundary faults (Yin et al., 2002; Wang et al., 2006; Fang et al., 2007) (Fig. 1a, b), e.g., the impressive