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Magnetostratigraphy of Cenozoic deposits in the western Qaidam Basin and its implication for the surface uplift of the northeastern margin of the Tibetan Plateau

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ABSTRACT

Thick Cenozoic deposits in the northwestern Qaidam Basin record erosion of the Altyn Tagh and high terrain west of that basin and presumably the concurrent growth of the northeastern Tibetan Plateau. A detailed magnetostratigraphic study of the Huatugou section, northwestern Qaidam basin, reveals that this section spans the period from ~30 to ~11 Ma. Magnetostratigraphic and sedimentological studies indicate that the accumulation rate abruptly increased near ~15 Ma. The acceleration in sedimentation rate suggests enhanced tectonic deformation in the Qaidam basin since 15 Ma that may have begun simultaneously with accelerated deformation along the Altyn Tagh, Kunlun, and Haiyuan faults, which contributed to the growth history of the Qaidam basin and its surroundings since ~15 Ma.

1. Introduction

Two end-member views of how Tibet has grown outward have prevailed over the past decades: (1) continual outward, northward and northeastward growth, either steadily [e.g. England and Houseman, 1986] or in steps [e.g., Tapponnier et al., 2001], or (2) widespread deformation over virtually the whole of Tibet beginning at or shortly after the time of collision (Yin et al., 2008; Clark et al., 2010; Duvall et al., 2011). In fact, evidence for both seems to exist, with widespread deformation at or just after the time of collision (Wang et al., 2008; Yuan et al., 2013; Staisch et al., 2014), but a later acceleration of deformation on the northern margin and continued expansion of the dimensions of Tibet. When that later phase of deformation began, however, it remains unresolved, with evidence from northeastern Tibet suggesting a date near 8–10 Ma [e.g., Métivier et al., 1998; Jolivet et al., 2001; Wang et al., 2003; Zheng et al., 2006, 2010; Lease et al., 2007; Yuan et al., 2011], but farther west along the Kunlun, cooling ages suggest rapid exhumation earlier, beginning near 15 Ma (Duvall et al., 2013). The Qaidam basin, which has undergone relatively mild Cenozoic deformation, lies between these regions and offers insights into the onset of deformation.

The Qaidam basin marks a transitional region where elevations decrease stepwise toward the north and northeast from approximately 5 km over Tibet to 3 km over the basin, and finally to approximately 1–1.5 km in Tarim Basin north of the Altyn Tagh and in the Hexi corridor in the foreland of the Qilian Shan (Fig. 1a). Similar features, with vast closed sedimentary sub-basins that form relatively flat surfaces surrounded by mountain ranges in the Qaidam basin and higher Tibetan Plateau, suggest that understanding the outward growth of deformation since Eocene time in the Qaidam basin may allow us to unravel how the current morphology of the northern margin of Tibet has developed (e.g., Métivier et al., 1998; Zhou et al., 2006). The thrust faulting and crustal shortening in the northwest part of the basin has formed narrow ranges. The thick Cenozoic sedimentary sequence in the Qaidam basin should record the growth of structures within the basin, as well as the timing of growth of the surrounding mountains (Métivier et al., 1998; Wang et al., 2006; Cheng et al., 2014).

We present new magnetostratigraphy of Cenozoic sediments in the northwestern part of the basin, and then using a compilation of published data, we examine the timing of tectonic deformation of the basin.

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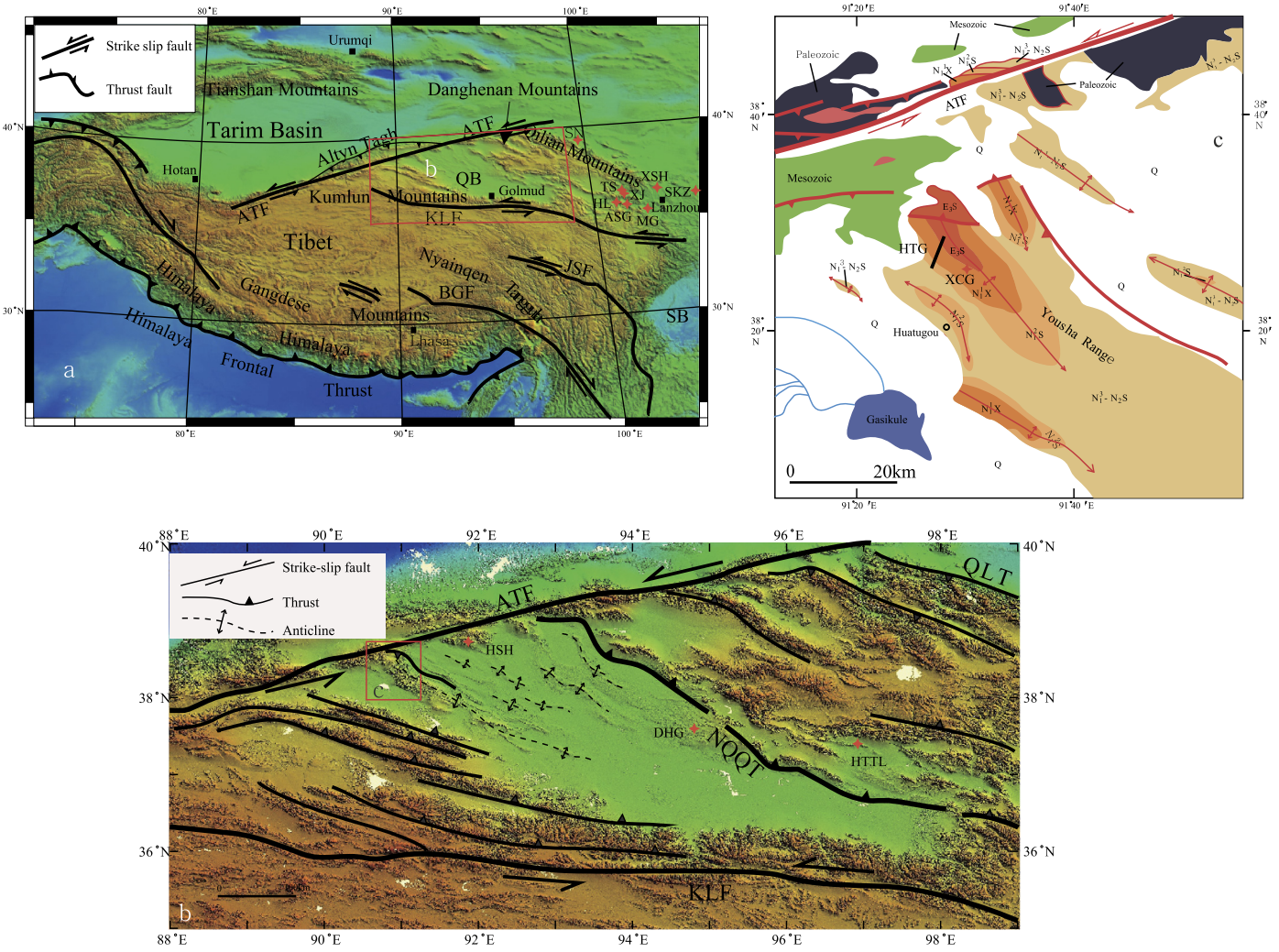

Fig. 1. a. Location of the Qaidam basin in the Tibetan Plateau (based on Yin et al., 2002). b. Morphotectonic map of the Qaidam Basin and locations of the Huatugou and other sections (based on Yu et al., 2014). c. Geological map in the Youshashan range region (based on our field work and Wang et al., 2012). ATF: Altyn Tagh fault, KLF: Kunlun Fault, NQT: North Qaidam thrust, QLT: Qilian thrust, HSH: Hongsanhan section, DHG: Dahonggou section, XCG: Xichagou section, HTTL: Huaitoutala section, HTG: Huatugou section, SKZ: Sikouzi section, XSH: Xianshuihe section, MG: Maogou section, ASG: Ashigong section, HL: Hualong section, XJ: Xiejia section, TS: Tashan section, SN: Sunan section. E_3S: Shangganchaigou Formation, N_1^1X: Xiayoushashan Formation, N_1^2S: Shangyoushashan Formation, N_1^3–N_2S: Shizigou Formation.

2. Regional geology

The triangle-shaped Qaidam basin is characterized by high average elevation and low relief that are similar to morphological features on the higher Tibetan Plateau. It is the largest topographic depression inside the Tibetan Plateau, and it covers an area of 120,000 km^2 and lies at an average elevation of 3000 m. Morphologically the Qaidam Basin is bounded by the Altyn Tagh to the northwest, the Qilian Shan to the northeast, and the Kunlun to the south (Fig. 1b). Tectonically, it is bounded by the Altyn Tagh Fault to the northwest, the North Qaidam thrust system to the northeast and several thrusts related to Kunlun fault to the south (Bally et al., 1986; Song and Wang, 1993; Jolivet et al., 2003; Yin et al., 2007; Cheng et al., 2014).

Cenozoic stratigraphic units in the Qaidam basin were deposited mainly in a fluvial-lacustrine environment. Even if the same units were assigned different ages (Table 1), there is consensus that the depocenters of the Qaidam basin have consistently shifted eastward along the axis of the basin since the Eocene (Song and Wang, 1993; Métivier et al., 1998; Wang et al., 2006; Yin et al., 2007). Analysis of sandstone and mudstone provenance for Cenozoic basin fill suggests that the surrounding mountains are the sources of the basin sediment, especially the Altyn Tagh (Rieser et al., 2005).

3. Stratigraphy and sampling

We studied the Huatugou Section (from 38°25.6′N, 90°53.8′E to 38°22.0′N, 90°52.9′E), which lies at the southwest flank of the Youshashan anticline (Fig. 1c). Here the thickness of the late Oligocene to late Miocene sediment, which includes the Shangganchaigou, Xiayoushashan, and Shangyoushashan Formations, is >4360 m (Song and Wang, 1993; Xia et al., 2001; Rieser et al., 2005; Gao et al., 2009; Cheng et al., 2014).

The Shangganchaigou Formation, 895-m thick, consists of gray, well-sorted fine sand, siltstone, and pisolitic micritic carbonates intercalated with poorly graded clast-supported conglomerate and gypsum layers, most of which was deposited in a fluvial or marginal lacustrine environment. The presence of Ostracoda assembages such as *Mediocypris, Mediocypris Candonaeformis, Cyprinotus and Hemicyprinotus* sp. in the adjacent area of the northwest Qaidam basin suggests an Oligocene age (Sun et al., 1999; Yang et al., 2000; Sun et al., 2005). Two suspected fish fossils were found at levels of 448.8 m and 762 m, respectively, but we could not identify the species or ages of them. Nevertheless, two layers