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Magnetostratigraphy of the Dahonggou section, northern Qaidam Basin and its bearing on Cenozoic tectonic evolution of the Qilian Shan and Altyn Tagh Fault

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ABSTRACT

The timing of uplift of the Tibet Plateau has a central role in the development of tectonic models for the Tibet Plateau and Cenozoic global climate change. A detailed magnetostratigraphic study of the Dahonggou section, northern Qaidam Basin, reveal that the section spans from ~34 to ~8.5 Ma and the ages of the Shang Ganchaigou, Xia Youshashan and Shang Youshashan formations are from >34 to 22–20 Ma, 22–20 to 13 Ma and 13 to <8.5 Ma, respectively. Variations in lithofacies, sedimentation rate and magnetic susceptibility (K) suggest that the southern Qilian Shan was tectonically inactive and didn't respond to the rapid slip on the Altyn Tagh Fault at 30 Ma. In contrast, the similar sedimentary records in the Dahonggou section, the Xishuigou section along the Altyn Tagh Fault, and even more localities along much of the Qilian range front imply that the Qilian Shan and the Altyn Tagh Fault were synchronously tectonically active at about 12 Ma. The lower K between ~12 Ma and ~8.5 Ma in the sediments of the Dahonggou section is interpreted to be due to long-distanced oxidation and sorting, which cause not only that magnetite was oxidated to hematite, but also that magnetic minerals are enriched in fine-grained sediments and coarse-grained sediments bear few magnetic mineral.

1. Introduction

The timing and nature of the uplift of the Tibetan Plateau have recently been a focus of not only tectonic geologists, but also paleoclimatic geologists who prefer to link late Cenozoic regional and global climate changes with the uplift of the Tibetan Plateau. A variety of tectonic mechanisms for the uplift of the Tibetan Plateau has been proposed during the last several decades (e.g., Harrison et al., 1992; England and Houseman, 1989; Molnar et al., 1993). These models can be classified into three categories according to Harrison et al. (1998), namely, the wholesale uplift models, the progressive growth models and the inherited plateau models. Given the complexity of the tectonic history, it seems that different mechanisms may have operated at various periods of time since the India–Asia collision. Recently, in the 'stepwise-diachronous rise' model, the northern Tibet is assigned to be 'Pliocene–Quaternary Tibet' and assumed to be uplifted since the late Miocene (Tapponnier et al., 2001), although better constraints of the timing of the uplift of this region require more works, including high resolution magnetostratigraphic measurements of the sedimentary basins on the periphery and interior of the northern Tibet.

An array of magnetostratigraphic works has currently been conducted within and on the margin of the northern Tibet (Fig. 1) (e.g., Li et al., 1997; Yin et al., 1998; Zheng et al., 2000; Yue et al., 2001; Zhao et al., 2001; Song et al., 2001; Gilder et al. 2001; Chen et al., 2002; Wang et al., 2003; Liu et al., 2003; Pares et al., 2003; Fang et al., 2003, 2005a,b; Sun et al., 2004, 2005a,b; Dai et al., 2005; Charreau et al., 2005, 2006; Dai et al., 2006; Huang et al., 2006; Fang et al., 2007; Heermance et al., 2007, 2008; Sun and Zhang, 2008, 2009). As the largest basin in the northeast of the Tibetan Plateau and with a maximum Cenozoic sediment thickness of ~12,000 m, the Qaidam Basin possesses an important sedimentary archive for the understanding of tectonic evolution, as well as climate change of the northern Tibetan Plateau. Previously, much work on the Cenozoic sediments of the Qaidam Basin have been undertaken and are helpful in revealing not only tectonic implications associated with the India–Asia collision (Métivier et al., 1998, 1999; Chen et al., 1999; Hanson, 1999; Rumelhart, 1999; Gilder et al., 2001; Meng et al., 2001; Yin et al., 2002; Sun et al., 2005a,b; Zhou et al., 2006; Wang et al., 2006; Zhu et al., 2006; Fang et al., 2007; Yin et al., 2008; Ritts et al., 2008; Bovet et al., 2009), but also depositional processes (Wang and Coward, 1990; Huang and Shao, 1993; Huang et al., 1996; Sun et al., 1999; Pang et al., 2004; Rieser et al., 2005; Wang et al., 2007) and inland aridification in Asia (Liu et al., 1996; Wang et al., 1999; Rieser et al., 2005) which are also tightly coupled with the tectonic uplift associated with the India–Asia collision.

However, at least two problems remained in studies on the Cenozoic sediments in the Qaidam Basin. Firstly, the time controls of many previous studies are mainly based on isotope geochronology (Zhou et al., 2006), fission track dating (Liu et al., 1996; Wang et al., 1999) and old magnetostratigraphic study (Wang et al., 1999; Sun et al., 1999; Yin et al., 2002; Zhou et al., 2006; Yin et al., 2008; Rieser et al., 2005; Wang et al., 2007) and not only disagree with one another, but also disaccord with recent magnetostratigraphic ages constrained by mammalian fossils or ostracoda assemblages (Sun et al., 2005a,b; Fang et al., 2007).

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The age assignments of stratigraphy in the Qaidam Basin have remained in dispute. Secondly, compared with recent flourishing magnetostratigraphic studies in the surrounding of Tian Shan and Qilian Shan (Fig. 1), studies of the Qaidam Basin are few and of relatively short interval (Sun et al., 2005a,b; Fang et al., 2007), which limit the understanding of long-term tectonic and sedimentary evolution in the Qaidam Basin.

Here we report a magnetostratigraphic study of a ~3600 m thick and continuous composite section (the Dahonggou section) in the Qaidam Basin (Fig. 2). The results provide new evidence for constraining the timing of the tectonic evolution in the northern Tibetan Plateau.

2. Geological setting and stratigraphy

The Qaidam Basin, with an average elevation of ~3000 m, is the largest intermontane basin (covering an area of ~120,000 km^2) at the northeastern corner of the Tibetan Plateau. The basin is bordered by three large fault systems: the Kunlun thrust belt to the south, the left-lateral strike-slip Altyn Tagh Fault to the northwest and the Qilian Shan–Nan Shan thrust-and-fold belt to the northeast. Seismic reflection studies indicate that the Qaidam Basin is bounded by thrust faults along its northern and southern margins, but its center is relatively tectonically quiet (Di and Wang, 1991; Dai et al., 2003). The thrust system at the northern margin of the Qaidam Basin (Fig. 2B) is considered to form as the long-distanced response of the India–Asia collision, with the process of stepwise thrusting from northeast to southwest since Eocene to Pleistocene (Liu et al., 2005). Our study area (the Dahonggou section) is just in the thrust system of northern Qaidam Basin (Fig. 2B). Like other thrust belts, the thrust in the Dahonggou section also exhibit an L-shaped geometry (Fig. 3A). Because the lateral ramps are subparallel to the left-slip Altyn Tagh Fault, their development may result from a distributed left-slip deformation that transfers motion from the Altyn Tagh Fault to the left-slip ramps via linking thrusts (Yin et al., 2008).

Previous work by petroleum geologists over the last 50 years has established a basin-wide lithostratigraphic framework for the Qaidam Basin. The Cenozoic stratigraphy was divided into seven formations (in ascending order): Lulehe, Xia Ganchaigou, Shang Ganchaigou, Xia Youshashan, Shang Youshashan, Shizigou, and Qigequan. The Dahonggou section is a composite of section-k and section-q, starting from the lower part of Shang Ganchaigou formation, and ending just at the top of Shang Youshashan formation (Fig. 3).

The ~1390 m thick Shang Ganchaigou formation consists mainly of cyclic alternations of gray-green laminated or bedded siltstone and brown mudstone. The Xia Youshashan formation is ~1220 m thick and consists largely of alternating brown laminated or bedded mudstone and gray-green massive sandstone, or conglomerate, or multi-colored (gray-white to yellowish) siltstone. The Shang Youshashan formation is ~1000 m thick and mostly composed of interbedded yellowish massive conglomerate, sandy conglomerate, with brown or yellow massive sandstone intercalated with yellow massive siltstone. Particularly noteworthy are the discoveries of *Chilotherium*, *Cyprideis*, and *Gomphotherium* in the upper and middle part of Shang Youshashan formation and in the upper part of Xia Youshashan formation respectively, by Qinghai BGMR (1984) within our studied section (Fig. 3A). *Chilotherium* was primarily discovered in late Miocene stratigraphy (Deng et al, 2004; Deng, 2005), whereas *Gomphotherium* amply occurred during Mid-Miocene (Deng, 2004; Deng et al, 2004; Deng, 2005; Deng et al, 2007) in the northwestern China. *Cyprideis* have appeared in abundance throughout the Qaidam Basin and become a predominant Ostracoda species since 12 Ma (Yang et al., 2000).

3. Paleomagnetic sampling and analytical method

All samples were collected from section-k and section-q, which are approximately 2.5 km away from each other. Section-k is ~1320 m in thickness and consists of the Shang Youshashan formation and the upper part of the Xia Youshashan formation. Section-q spans ~2380 m

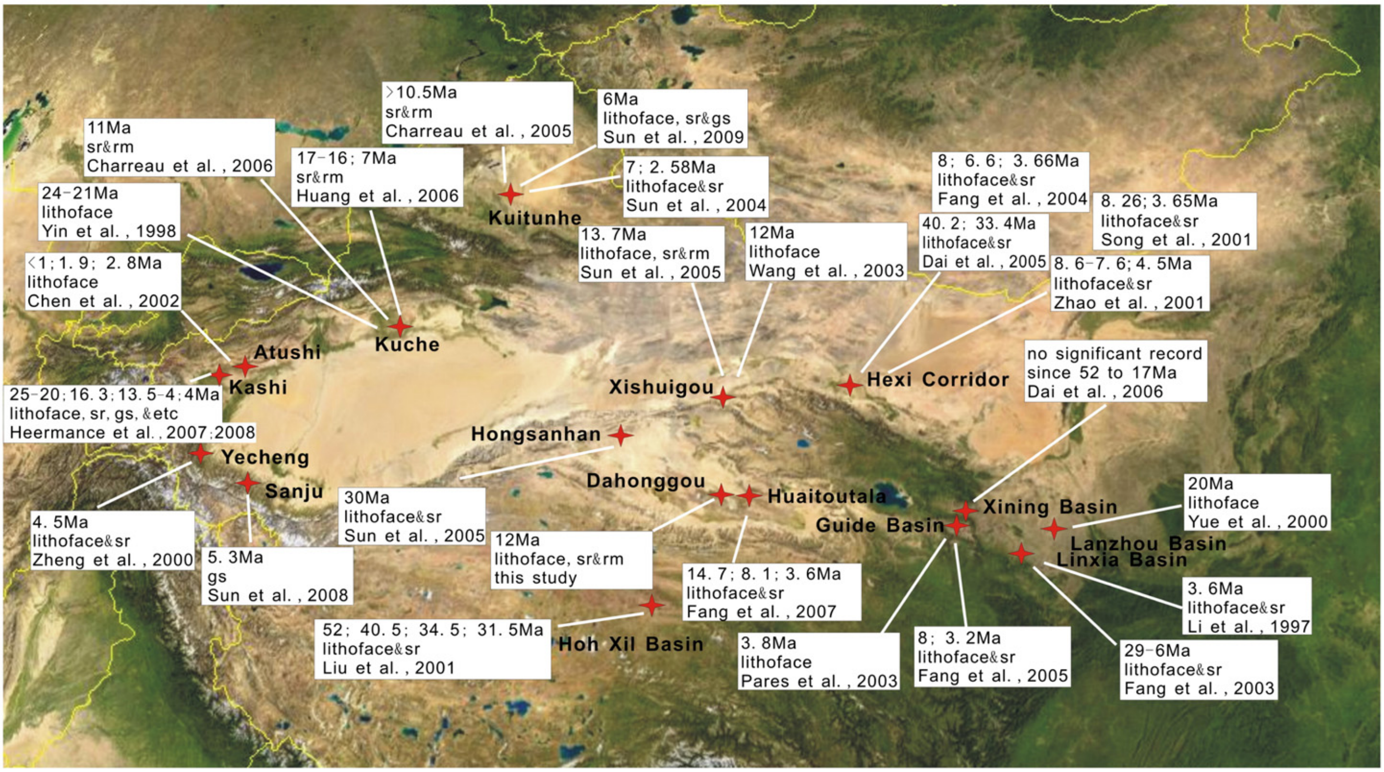

Fig. 1. The recent magnetostratigraphic studies on the northern Tibetan Plateau (Li et al., 1997; Yin et al., 1998; Zheng et al., 2000; Yue et al., 2001; Zhao et al., 2001; Song et al., 2001; Chen et al., 2002; Wang et al., 2003; Liu et al., 2003; Pares et al., 2003; Fang et al., 2003; Sun et al., 2004; Charreau et al., 2005; Fang et al., 2005a,b; Sun et al., 2005; Dai et al., 2005, 2006; Huang et al., 2006; Charreau et al., 2006; Fang et al., 2007; Heermance et al., 2007; Heermance et al., 2008; Sun and Zhang, 2008, 2009). The white rectangles note the timing and signature of tectonic uplift. The sr, rm and gs are sedimentation rate, rock magnetism and growth strata respectively.