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Miocene sedimentary environment and climate change in the northwestern Qaidam basin, northeastern Tibetan Plateau: Facies, biomarker and stable isotopic evidences

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ABSTRACT

Facies, biomarker and stable isotopic records from the Miocene lacustrine sediments in the northwestern Qaidam basin were investigated to reconstruct the Miocene sedimentary environment and climatic history. Three distinct facies can be recognized. These include the following: (1) gray–black laminated mudstone and marlstone, which represent a semi-deep fresh to semi-brackish lake environment; (2) gray, yellowish massive mudstone, marlstone and siltstone; and (3) yellowish massive sandstone, which imply a shallow brackish lake environment. The decreasing C_{27}/C_{31} and $(C_{27}+C_{29})/(C_{31}+C_{33})$ values, the increasing ACL (mean chain length) values of n-alkanes and the vertical evolution of sedimentary environments indicate the overall intensified aridity, which is considered to be an integrated result of high elevation of the Himalaya–Tibetan system, retreat of the Paratethys and global cooling. High fluctuations of the $\delta^{18}O$ values and primary dolomite contents reveal the hydrologically closed paleolake with intermittently open conditions in the study area during middle–late Miocene. The Qaidam basin is suggested to be hydrologically segmented, based on the stable isotopic data comparison between the study area and the northeastern area. The most negative end of the oscillations of the $\delta^{18}O$ values (indicating the minimal evaporation), which likely represents the isotopic ratio of the meteoric water, surprisingly conveys stability in the Shang Youshashan and Shizigou Formations and displays a positive ~2.5‰ shift. This significant shift was probably due to the climatic aridification and air mass changes around 10–8 Ma rather than the global cooling.

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1. Introduction

Late Cenozoic climate change in Asia has attracted considerable attention for decades (e.g. Kutzbach et al., 1993; Shi et al., 1999; Wang et al., 1999; An et al., 2001; Graham et al., 2005; Kent-Corson et al., 2009; Heermance et al., 2013). Recently, an increasing number of studies focused primarily on the Miocene aridification in Central Asia and the corresponding driving mechanism (e.g. Dettman et al., 2003; Hough et al., 2011; Miao et al., 2011, 2012, 2013; Zhuang et al., 2011a; Zhang et al., 2012; Song et al., 2014).

Several factors, including the rapid uplift and high elevation of the Tibetan Plateau (e.g. Molnar et al., 1993; An et al., 2001; Dettman et al., 2003), the retreat of the Paratethys and associated variation of land–sea distribution (Ramstein et al., 1997; Zhang et al., 2007b) and the global cooling (e.g. Miao et al., 2012, 2013; Song et al., 2014), are generally suggested to be the potential triggers for the Miocene climatic transition. The dominant factor remains debatable. Dettman et al. (2003) and Hough et al. (2011) investigated the sedimentary carbonate stable isotopes in the Linxia and Xuanhua basins in the northeastern Tibetan Plateau and observed a shift to more arid climate at 12–10 Ma. This climatic shift was further attributed to the topographic growth. Zhuang et al. (2011a) detected a similar stable isotopic evolution history in the eastern Qaidam basin. Their study advocated that the more arid climate was an integrated result of the high elevation of the Tibetan Plateau and the retreat of the Paratethys. By contrast, Miao et al. (2011) and Song et al. (2014) suggested that the global cooling should be the major contributor for the Middle–Late Miocene aridification in the western Qaidam basin.

In addition to these varying arguments, there are disagreements concerning the timing of the aridification. The eolian deposition was well dated to 8–6 Ma on the Chinese Loess Plateau (Liu, 1985; Ding et al., 1998), which was considered to be associated with the desertification in Central Asia. Wang et al. (1999) and Rieser et al. (2009) reported relatively dry climates prevailed in the Pliocene–Pleistocene, whereas Kent-Corson et al. (2009) suggested an increasing aridity during the

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whole Neogene. Furthermore, chemical weathering study results indicated the increase of aridification and the climate cooling during late Cenozoic (Jian et al., 2013a). These disagreements imply that more work is needed in order to acquire a further understanding of the late Cenozoic climatic evolution.

Climatic variations can influence sedimentary environments, and thus result in changes of facies in sedimentary basins (e.g. Ruskin and Jordan, 2007; Wang et al., 2012). The organic compounds in lake fine-grained deposits, such as lipid biomarkers which can be determined by local climate changes, are regarded as one of the most important indicators to reconstruct paleoclimate and paleoevironment (e.g. Meyers and Benson, 1987; Meyers and Ishiwatari, 1993; Ficken et al., 2000; Xie et al., 2003; Zhou et al., 2005; Bai et al., 2009). Additionally, sediments in lakes can record the hydrology and climate changes through the stable isotopes of sedimentary carbonate, which commonly reflect the isotopic compositions of meteoric or/and lake water (Talbot et al., 1990, 1994; Cerling and Quade, 1993; Leng and Marshall, 2004).

The Qaidam basin, which is a typical high-altitude terrestrial sedimentary basin, lies in the northeastern sector of the Tibetan Plateau (Fig. 1A). It preserves an exceptionally thick Mesozoic and Cenozoic

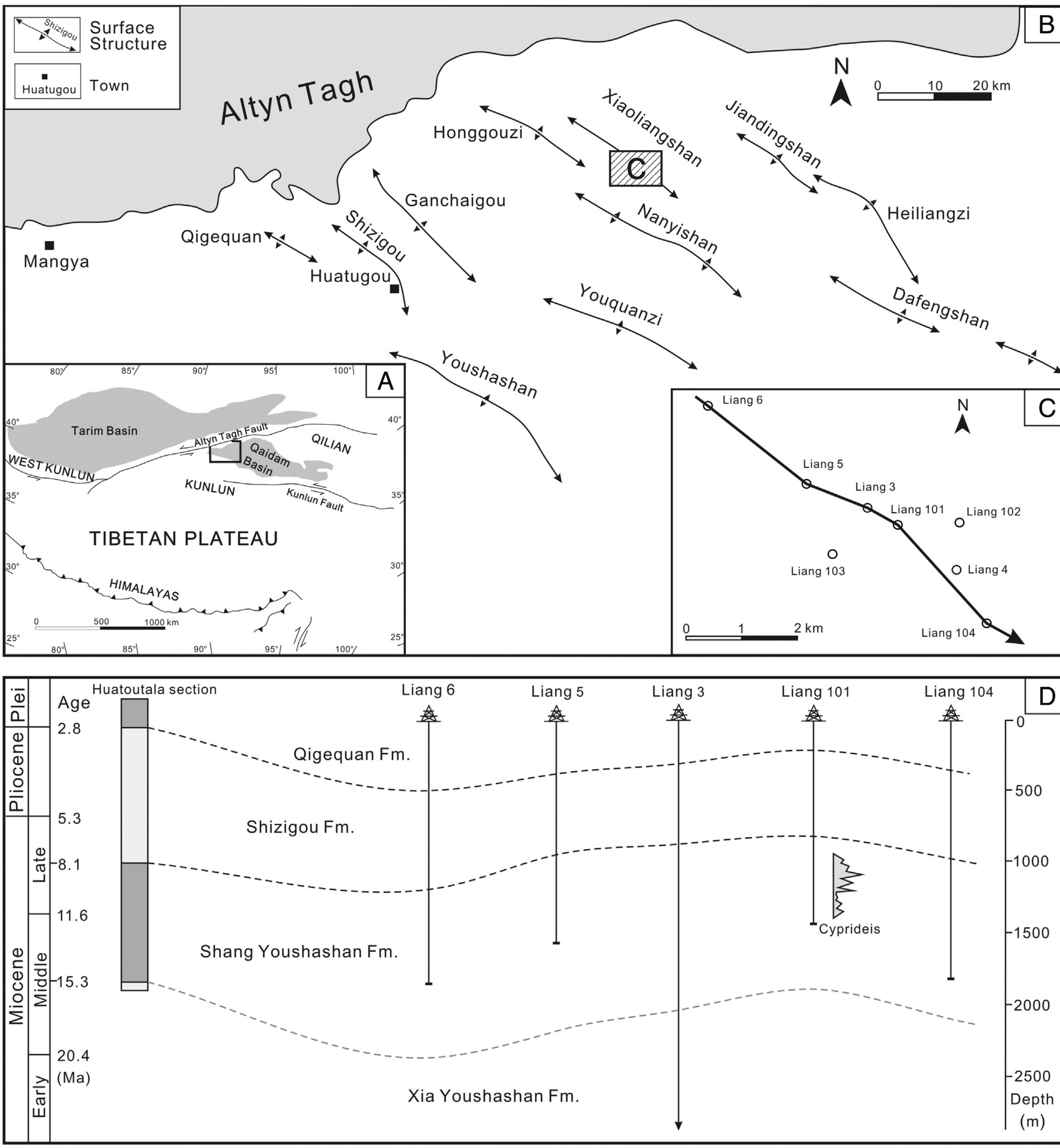

Fig. 1. Geologic settings and stratigraphy of the study area. (A) and (B) The tectonic location of the Qaidam basin and Xiaoliangshang area; (C) Well locations in the Xiaoliangshan area; (D) Subsurface stratigraphy of the drilling wells.

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