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Tectonosedimentary evolution model of an intracontinental flexural (foreland) basin for paleoclimatic research

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A B S T R A C T

Intracontinental flexural (foreland) basin sediments are now frequently used as archives for detailed paleoclimatic and sedimentary environmental reconstruction, fossil and stratigraphic correlation, and tectonic evolution and uplift of basin and orogen. However, sedimentologic characteristics vary considerably in time-space with the evolution of flexural basin, apt to cause misinterpretation of climatic change and stratigraphic correlation. Based on high resolution fossil mammal and magnetostratigraphic constraints and sedimentary facies analysis, here we took the Linxia Basin at the front of the NE Tibetan Plateau as a case to demonstrate and figure out a model how sedimentology and stratigraphy vary temporospatially with the evolution of such flexural basin. The results show that the Linxia Basin is a type intracontinental foreland basin subjected to two phases of flexural deformation exerted by the West Qin Ling (Mts.) and NE Tibetan Plateau to the south. Phase I began latest at the beginning of the Miocene (23.3 Ma), indicated by a balanced fast flexural subsidence and mostly fine sediment infilling giving rise to the early underlying unconformity. It manifests as an obvious sediment wedge with high filling rate, thickening toward mountains and an occurrence of a mountains-parallel big river – shallow lake system along the foredeep, suggesting a less high mountain topography. In the late Phase I, from ~13 Ma to 8 Ma, the subsidence and thickening rates began to decrease, accompanied by faults and deformation propagating gradually into the basin, causing gradual basinward migration of the foredeep and its accompanying river-lake system. Since ~8 Ma in Phase II, the West Qin Ling and NE Tibetan began to uplift rapidly and thrust/load onto the Linxia Basin, causing strong mountain erosion, thrust-fold belt propagation and basin overfilling. This forced the mountains-parallel river - lake system to turn to the mountains-perpendicular alluvial - braided river system, and finally to an outflow system by the Quaternary onset of the Yellow River in the basin. Concurrent are rapid rotation of the basin, occurrence of growth strata and late unconformities, widespread expansion of boulder conglomerates, great decreasing and increasing sedimentation rates above and before the hanging wall of the fault-fold system and new supplementary provenance from the thrust-fold system. This demonstrates that in stable climate, same lithologic units such as distinct lacustrine sediments and alluvial conglomerates will migrate basinwards with the foredeep moving into basin, causing a great diachroneity and often misleads to recognize the same lithologic unit in space as one unit in time. A dynamic model is presented that should help to avoid such pitfalls in tectonic basin evolution, especially concerning stratigraphic correlation and paleoclimatic change research.

1. Introduction

High-resolution loess-paleosol and red-clay sequences on the Chinese Loess Plateau and their climatic proxy records, constrained by detailed paleomagnetic, TL/OSL and radiocarbon dating, have widely been used for precise stratigraphic constraints for reconstructing Asian monsoon and global climatic changes, leading to great progress in our knowledge of the late Miocene – Quaternary Asian monsoon evolution and mechanism (e.g. Liu et al., 1985; An et al., 1991, 2001; Ding et al., 1995; Fang et al., 1999; Guo et al., 2000). This success encourages to expand such approaches to Cenozoic basin sediments in order to understand how the Asian monsoon evolved in pre-late Miocene time and how this evolution is related to global change and uplift of the Tibetan Plateau (e.g. Li et al., 1995; Guo et al., 2002; Fang et al., 2003, 2005, 2007a; Lu et al., 2004; Dai et al., 2006; Jiang et al., 2007; Sun et al., 2009a; Qiang et al., 2011; Sun et al., 2011a; Tang et al., 2011). However, such attempts caused large uncertainties and many debates on the

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stratigraphic ages derived from paleomagnetism and fossil mammals and the sedimentary facies and climatic history in the studied basins, e.g. the Sikouzi Basin (Young and Chow, 1956; Jiang et al., 2007; Wang et al., 2011), the Tianshui Basin (e.g. Guo et al., 2002; Alonso-Zarza et al., 2009; Peng et al., 2012; Zhang et al., 2013), the Lanzhou Basin (e.g. Opdyke et al., 1999; Qiu et al., 2001; Yue et al., 2001; Xie, 2004; Sun et al., 2011a), the Linxia Basin (Li et al., 1995; Fang et al., 2003; Deng et al., 2004, 2013; Deng, 2004; Qiu et al., 2004; Garzione et al., 2005), the Xining Basin (Qiu et al., 1981; Lu et al., 2004; Dai et al., 2006; Wu et al., 2006; Dupont-Nivet et al., 2007; Xiao et al., 2010), the Subei Basin (Gilder et al., 2001; Sun et al., 2005), the Tarim Basin (e.g. Charreau et al., 2006, 2009a; Huang et al., 2006, 2010; Sun and Zhang, 2009; Sun et al., 2009b, 2011b; Zhang et al., 2014, 2015), and the Jungger Basin (e.g. Sun et al., 2004, 2009b; Charreau et al., 2005, 2009b; Ji et al., 2008; Li et al., 2011) (See Fig. 1 for locations). Reasons are not only the difficulties in determining stratigraphic ages due to the lack of datable volcanic ash layers and fossil mammals, but also because of the pervasive ignorance of stratigraphic diachroneity, sedimentary facies

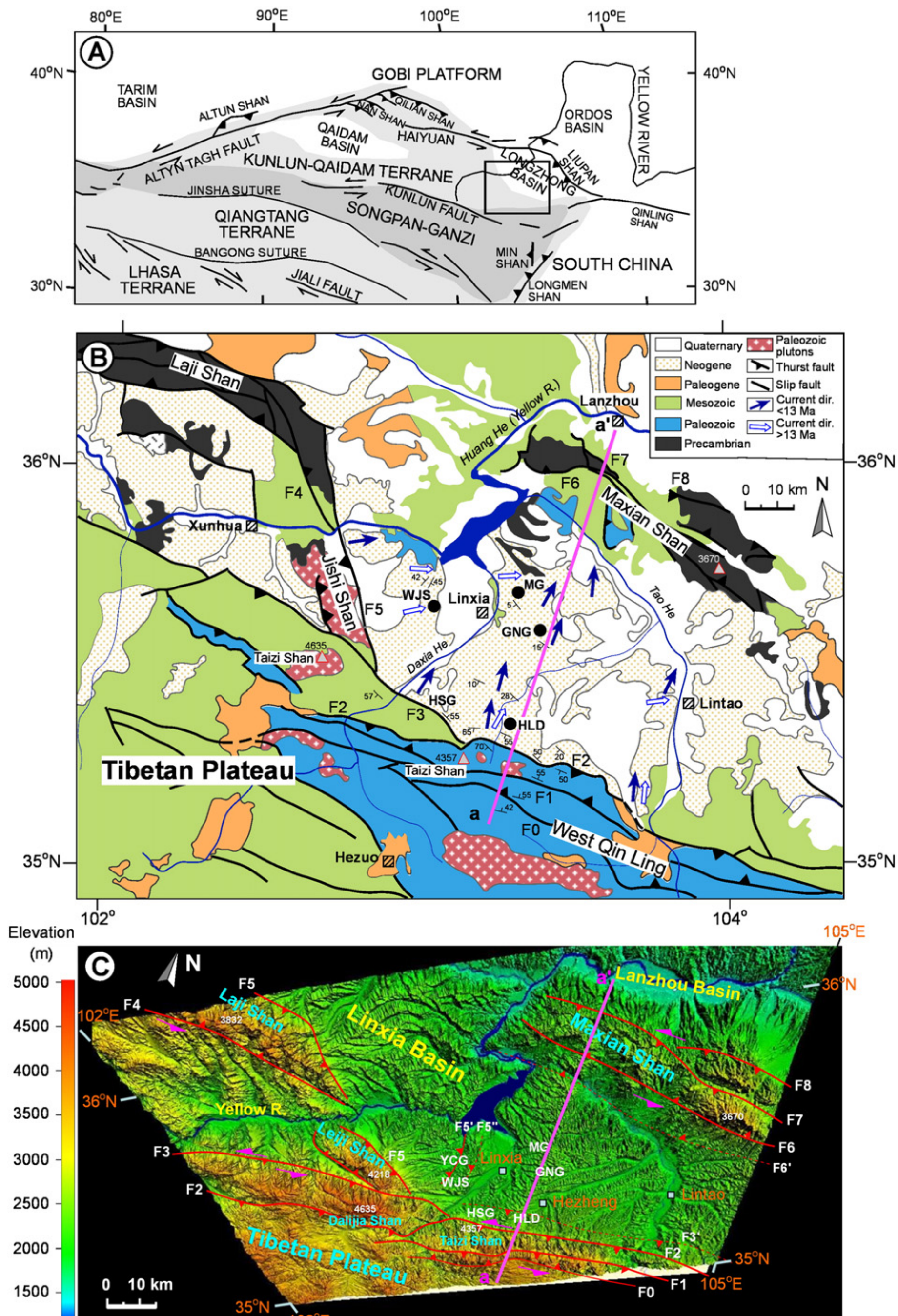

Fig. 1. (a) Location of the Linxia Basin in the NE Tibetan Plateau with respect to the terranes in the Tibetan Plateau, modified from Qinghai Geology Bureau (1989) and Fang et al. (2003, 2005). (b) Geologic map of the Linxia Basin showing the distribution of the Cenozoic stratigraphy and its relationship with the tectonic units and major faults which impact the basin; (c) 3-D DEM image of the Linxia Basin in (b) showing the studied sections and their relationships with faults and geomorphology. Note the north direction is just reversed for a striking 3-D view. Cross section a-a' is presented in Fig. 2a. HLD: Heilinding; GNG: Guonigou; WJS: Wangjiashan; MG: Maogou; HSG: Huaishuguan Fold; YCG: Yinchuangou Anticline. Solid (dotted) red lines are surface (subsurface) transpressional faults or thrusts.