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Flexural fold structures and active faults in the northern–western Weihe Graben, central China

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ABSTRACT

Field investigations and analyses of tectonic topography related to late Pleistocene–Holocene activity of faults and fault-related flexural folds in the northern–western Weihe Graben, central China, reveal that: (1) four main active faults are present in the study area, the Beishan Piedmont Fault (BPF), the Kouzhen-Guanshan Fault (KGF), the Qishan-Mazhao Fault (QMF), and the Weihe Fault (WF), of which the BPF, KGF, and WF are normal faults whereas the QMF is a left-lateral strike-slip fault; (2) active flexural folds trending ENE–WSW are widely developed on the late Pleistocene–Holocene loess tablelands and alluvial fans, as well as on terrace risers; (3) vertical slip rates on the BPF, KGF, and WF are ~0.5–1.1 mm/yr, and the left-lateral slip rate on the QMF is ~1.5 mm/yr; and (4) a recent seismic faulting event with a magnitude (M) > 7 occurred in the past ~3000 yr. Our results show that active faults and fault-related flexural folds are developing in the Weihe Graben under an ongoing extensional regime, with listric faulting occurring along pre-existing faults associated with the spreading of continental crust in intracontinental graben systems around the Ordos Block.

1. Introduction

Intracontinental rift systems generally contain normal faults, fault-related folds that are offset, and deformed sedimentary sequences deposited on basement rocks (e.g., Bradley and Kidd, 1991; Schlische, 1995; McNeill et al., 1997; Yeats et al., 1998; Khalil and McClay, 2002; McCalpin, 2009). However, while active normal faults that developed in extensional environments are widely reported in the literature (e.g., Yeats et al., 1997; Axen, 1999; Cowie and Roberts, 2001; Lin et al., 2013a; Rao et al., 2014), the flexural folds associated with active normal faulting, which record the deformation of unconsolidated sedimentary deposits, are rarely reported.

The Weihe Graben, an intracontinental graben system that has developed in an extensional regime around the Ordos Block, since the Eocene, provides a unique natural laboratory for studying the long-term tectonic history of active normal faults and related flexural fold structures (Fig. 1). Our research has revealed that active normal faults developed in the southeastern Weihe Graben, which are distributed in a zone <500 m wide along the southeastern border of the graben (Rao et al., 2014). These faults are characterized by a distinctive series of stepped fault scarps that dip into the graben at angles of 40–71°, with an average dip-slip displacement rate of ~2–3 mm/yr (Rao et al., 2014). The slip rates of main active faults in the northern and western graben, the target region of this study, are estimated to be on the order of 0.1–0.5 mm/yr (Xu et al., 1988). However, the deformational features and dynamic mechanisms associated with the active normal faults and fault-related flexural folds developed in the northern and western graben are still unknown, although previous studies have reported the presence of active faults based on geological and geophysical data (e.g., Peng, 1992; Feng et al., 2003; Tian et al., 2003; Deng, 2007; Shi et al., 2009).

Late Pleistocene–Holocene activity on normal faults in the southeastern marginal zone of the Weihe Graben has been described by Rao et al. (2014), and paleoseismicity in this zone has been studied by Rao et al. (2015). In this study, we focused on active normal faulting and fault-related flexural folds in the northern–western Weihe Graben, adjoining the study area of Rao et al. (2014). We also discuss the formation mechanisms of active fault-related flexural fold structures in the extensional environment of intracontinental grabens around the Ordos Block.

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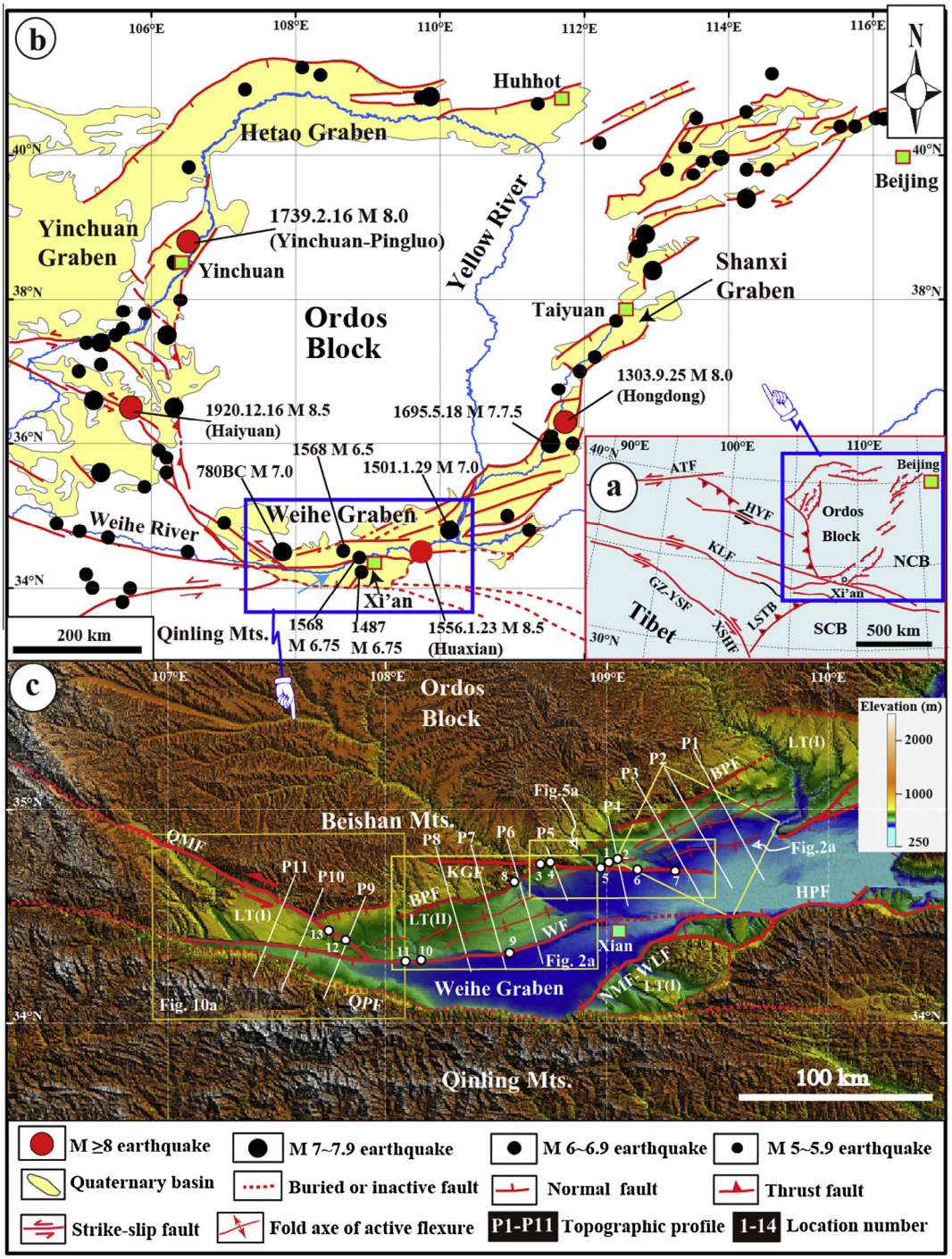

Fig. 1. (a) Location map of the Weihe Graben, showing the distribution of major active faults and large historical earthquakes in the graben systems around the Ordos Block; modified from Deng (2007). (b) Inset map showing the tectonic background. ATF, Altyn Tagh Fault; HYF, Haiyuan Fault; KLF, Kunlun Fault; GZ-YSF, Ganzi-Yushu Fault; XSHF, Xianshuihe Fault; SCB, South China Block; NCB, North China Block; LSTB, Longmen Shan Thrust Belt. (c) Color-shaded relief map showing the location and topographic features of the study area. The red star indicates the epicenter of the 1556 $M \sim 8.5$ Huaxian earthquake (SSB, 1988; CENC, 2007). HPF, Huashan Piedmont Fault; NMF–WLT, North Margin Fault of the Weinan Loess Tableland; BPF, Beishan Piedmont Fault; QPF, Qinling Piedmont Fault; KGF, Kouzhen-Guanshan Fault; WF, Weihe Fault; QMF, Qishan-Mazhou Fault. LT(I), Loess Tableland (I); LT(II), Loess Tableland (II). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

2. Terminology

The term *flexural fold* is a general term used in structural geology to describe flexural flow folds and flexural slip folds in sedimentary rocks with good layering. The deformation mechanisms that produce flexural folds include both folding and slip along layer boundaries, as well as some flow within the layers. In contrast, the term *active flexural fold*, which is used in studies of active tectonics, refers to flexural flow folds developed in weakly consolidated and/or unconsolidated sedimentary deposits during recent geological time. An *active flexural fold*, which is also called an *active flexure*, corresponds to the term *active fault* in Japan (Research Group for Active Faults in Japan, 1991). Generally, it is difficult to recognize whether or not slip has occurred along the boundaries of