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Assessment of the effects of historical strong earthquakes on large-scale landslide groupings in the Wei River midstream

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ABSTRACT

Regional active tectonics and historical earthquake records indicate the importance of the triggering effects of historical strong earthquakes on groups of large-scale landslide occurrences in the Wei River midstream section. In this study, a method to assess the triggering effects of historical earthquakes on regional large-scale landslides is presented. The greatest epicentral distances of seismically induced landslides were calculated. The triggering effects of four key historical strong earthquakes with epicenters within 300 km of the Wei River midstream section were analyzed; these are the M_s 7.0 Qishan earthquake of 780 BCE, the M_s 8.0 Tianshui earthquake of 1654 CE, the M_s 8.25 Huaxian earthquake of 1556 CE, and the M_s 8.5 Haiyuan earthquake of 1920 CE. Taking the Qishan earthquake as an example, a seismically induced landslide displacement and hazard assessment method based on the Newmark displacement model was developed. The degree of spatial matching of the results for historical-earthquake-triggered landslides and the distribution of actual large-scale landslide deposits were compared quantitatively using the success rate curve method. The results show that of the four historical earthquakes, the Tianshui earthquake had the strongest effect of inducing large-scale landslides regionally along the Wei River midstream section.

1. Introduction

The Loess Plateau in Northwest China was formed by the deposition of windblown dust. Loess is easily eroded, and many slope collapses, such as landslides, occur in areas with loess deposits (Ishihara et al., 1990; Jefferson et al., 2003; Wu et al., 2017; Zhang et al., 2017). The midstream section of the Wei River lies in the southern part of the Loess Plateau and at the western end of the Weihe seismic zone. Strong historical earthquakes have been reported in this area, and many of the landslides in the region were triggered by such earthquakes (Derbyshire, 1991; Zhang et al., 2017). Seismically induced landslides make up a relatively high proportion (> 50%) of all loess landslides in Northwest China. Study of the effects of historical strong earthquakes on clusters of large landslides is of great significance to earthquake disaster mitigation.

Major earthquakes, such as the 1994 Northridge earthquake in the USA (Harp and Jibson, 1996), the 1999 Chi-Chi earthquake in Taiwan (Lee et al., 2008), the 2005 M_w 7.6 Kashmir earthquake in Pakistan (Sato et al., 2007; Owen et al., 2008), the 2008 M_w 7.9 Wenchuan earthquake in China (Huang and Li, 2009; Xu et al., 2014), the 2010 M_w 7.0 Port-au-Prince earthquake in Haiti (Gorum et al., 2014), and the 2011 M_w 9.0 Tohoku-Oki earthquake in Japan (Wartman et al., 2013), have induced a large number of high-intensity, large-scale landslides, which have caused great loss of life and property. In recent years, earthquake-triggered landslides have received increasing attention in the fields of active tectonics, geomorphology, engineering geology, and environmental geology (Keefer, 1984, 2002; Rodríguez et al., 1999; Harp et al., 2011; Guzzetti et al., 2012; Xu et al., 2012, 2014; Lee et al., 2008; Grant et al., 2016; Saade et al., 2016). Several studies have been conducted on groups of loess landslides; these studies have focused mainly on the structure, formation conditions, and evolution of such landslides (Derbyshire, 1991; Dijkstra et al., 1994; Shi et al., 2016). However, the triggering factors of landslides linked to historical strong earthquakes have rarely been examined. The specific strong-earthquake processes that induced these landslides have not been evaluated previously. In fact, analyses of historical earthquakes are often based on studies of earthquake-induced landslides; therefore, it is important to investigate the landslide-inducing processes generated by historical strong earthquakes to understand the formation mechanisms of groups of earthquake-induced landslides.

The effects of the 2008 M_w 7.9 Wenchuan earthquake on the midstream section of the Wei River provide new opportunities to

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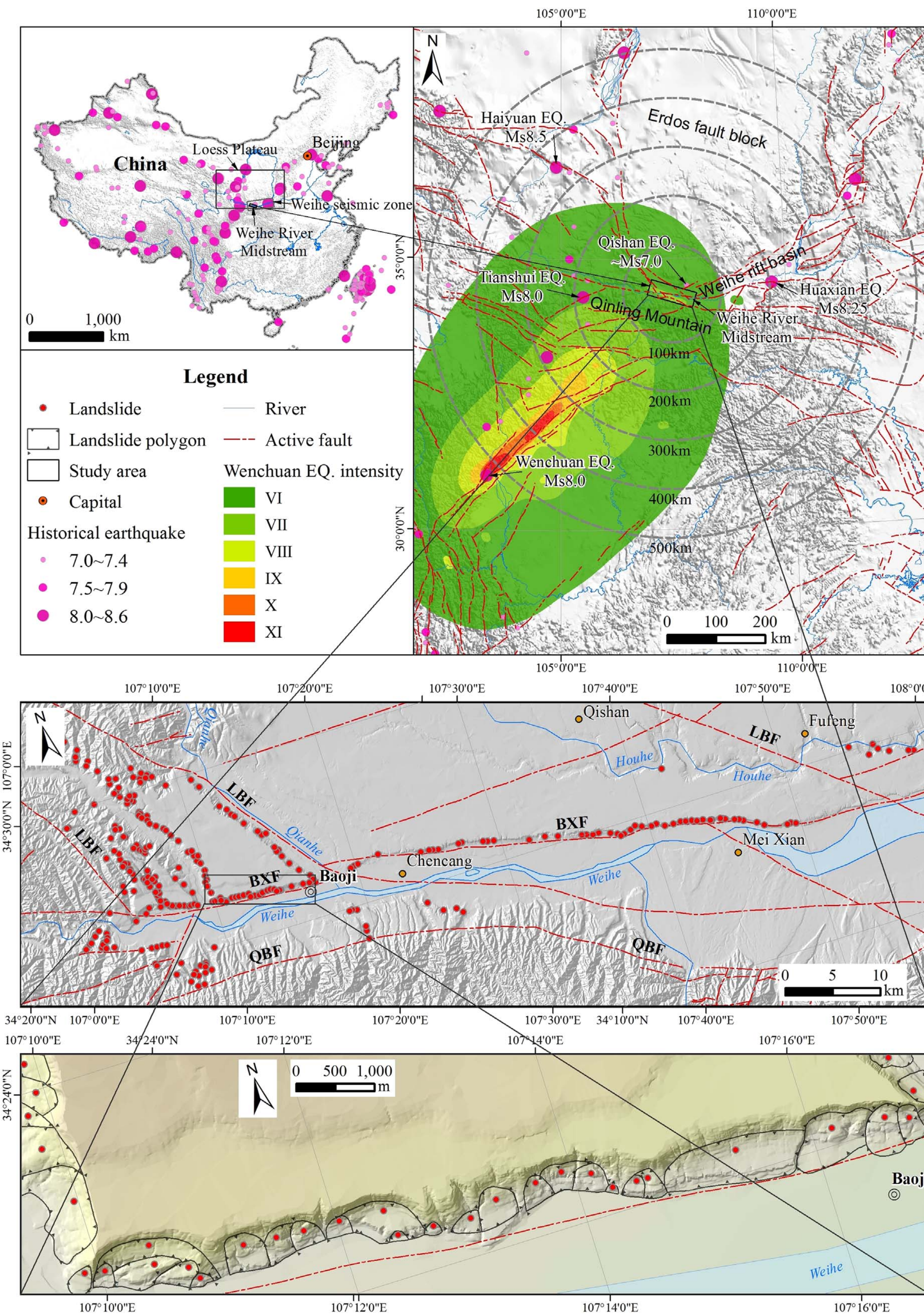

Fig. 1. Distribution of active faults and historical epicenters around the midstream section of the Wei River. QBF: North Qinling rim fault zone; BXF: Baoji–Xianyang fault zone; WBF: North Weihe Basin rim fault zone; LBF: Longxian–Baoji fault zone.