Palaeoenvironmental and chronological constraints on the Early Pleistocene mammal fauna from loess deposits in the Linxia Basin, NE Tibetan Plateau

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ABSTRACT

The Longdan mammal fauna from the central part of Linxia Basin, NE Tibetan Plateau, is the first Early Pleistocene fauna in China in which the fossils are derived loess deposits, and it provides an excellent opportunity to document mammalian and environmental evolution in Asia. However, the precise age and palaeoenvironmental setting of the fauna are controversial due to the poor exposure of the outcrop section. In the present study, a 105-m-long drill core was obtained from Longdan village and used for detailed magnetostratigraphic dating. The results demonstrate that the late Pliocene- Pleistocene loess deposits in the Longdan section deposited since ca. 3 Ma and that the Longdan fauna has an age range of 2.5—2.2 Ma. In addition, the results of lithological and rock magnetic analyses demonstrate that paleosols are weakly developed throughout the whole core and that in the lower and middle parts the core the magnetic susceptibility and its frequency dependence are relatively low and uniform. These observations, combined with the ecological characteristics of the Longdan fauna, indicate that during the Early Pleistocene the climate in the Longdan area, and even in the Linxia Basin, was sub-humid and that the aeolian dust was frequently subjected to post-depositional reworking by water.

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1. Introduction

Continuous Cenozoic sedimentary sequences are widely distributed in the northeastern part of the Tibetan Plateau (TP). They contain abundant terrestrial faunal assemblages and thus provide an opportunity to reveal the mammalian and environmental evolution in Asia associated with the stepwise uplift of the TP (Deng et al., 2013; Qiu et al., 2013; Wang et al., 2013). So far, the most complete late Cenozoic records in this region have been found in Qinghai Province and Gansu Province. Those from the Linxia Basin (Fig. 1) are highly representative (Fang et al., 2003; Qiu et al., 2004; Deng et al., 2013) and the 700 to 2000-m-thick late Cenozoic deposits in Linxia Basin contain four typical mammal faunas (Deng et al., 2013). They are the Late Oligocene *Dzungariotherium* fauna, the Middle Miocene *Platybelodon* fauna, the Late Miocene *Hipparion* fauna, and the Early Pleistocene *Equus* fauna. Over the past several decades, attention has been focused on the controversial subject of

the timing and paleoenvironmental background of these mammal faunas and their association with stepwise TP uplift. These studies have greatly improved our understanding of the biological response to environmental change in High Asia.

In contrast to the aforementioned three mammal faunas, which were excavated from fluvial-lacustrine siltstones, mudstones or gravelly sandstone, the Early Pleistocene *Equus* fauna (Longdan fauna) was discovered in the lower part of the loess profile of Longdan (Fig. 2a and c), Linxia Basin (Qiu et al., 2004; Deng et al., 2013). It is the first Early Pleistocene site in China where the fossils were retrieved from the loess and not from caves, fissure fillings or fluvio-lacustrine deposits. Of the 33 known species of the Longdan fauna, there are 6 small mammals, 2 primates, 17 carnivores, 4 perissodactyls and 4 artiodactyls, including horse (*Equus eisenmannae)*, macaque (*Macaca cf. anderssoni*), tiger (*Panthera zdanskyi*), woolly rhino (*Coelodonta nihowanensis*), beaver (*Castor anderssoni*), and bear (*Protarctos yinanensis*) (Qiu et al., 2004; Deng et al., 2013). These well-preserved fossil mammals provide a rare window into mammalian and paleoenvironmental evolution on the NE margin of the TP. However, compared to the Oligocene-Late Miocene mammal faunas in the Linxia Basin, the Early

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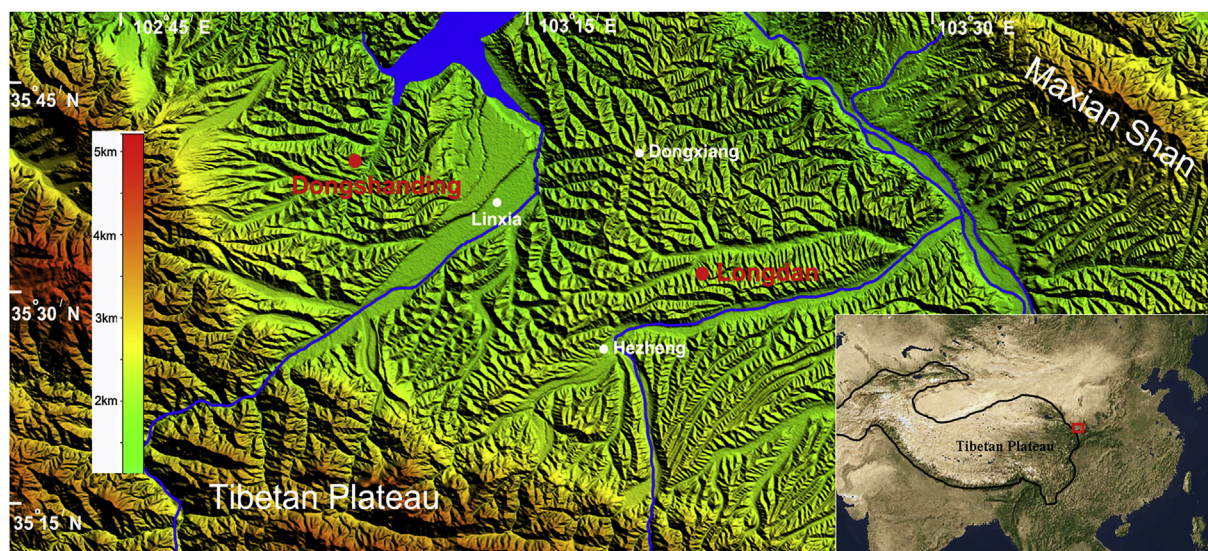
Fig. 1. DEM of the region of the Linxia Basin in the Asian arid interior; inset map shows the location of the study area in China.

Fig. 2. (a). Photograph illustrating the topography of the Longdan borehole site. (b) A picture of the drilling devices. (c) Photograph of the lower fossil-rich layer in the Longdan section. (d) Photograph illustrating bluish-gray silty sediments with sub-horizontal bedding at the surface of the section.

Pleistocene Longdan fauna has received scant attention in the last few decades; and its precise age and palaeoenvironmental setting for this fauna remain controversial (Qiu et al., 2004; Xue et al., 2006; Liu et al., 2008a; Deng et al., 2013).

Qiu et al. (2004) conducted the first magnetostratigraphic study of the lower 25 m of the Longdan loess section. Their preliminary work revealed that the Longdan fauna was about 2.5 Ma in age; however, subsequent magnetostratigraphic investigations of the lower 50 m of the loess deposits challenged this age model and argued that the fauna spans the age range of 2.2—1.9 Ma (Liu et al., 2008a). A recent overview of the mammal faunas in Linxia Basin generated a much younger age model (2 Ma) for this fauna (Deng

et al., 2013), further exacerbating the controversy. In addition, the Early Pleistocene paleoenvironments in Linxia Basin are still largely unconstrained. Although mammals are relatively sensitive to environmental changes, the diversity of habitats demonstrates that the use of taxonomic identifications alone to constrain the general environmental setting of Linxia Basin is complex and the conclusions are ambiguous. At present, due to the limited availability of high-resolution palaeoenvironmental data, few studies have considered the environmental background of the Longdan fauna and the reasons for the abundance of mammal fossils in the Early Pleistocene loess deposits (Qiu et al., 2004).

The poor exposure of the Longdan outcrop section may