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Spatial patterns of vegetation and climate on the Chinese Loess Plateau since the Last Glacial Maximum

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ABSTRACT

In order to identify the spatial patterns of vegetation and climate on the Chinese Loess Plateau since the Last Glacial Maximum (LGM), pollen analysis was conducted for loess deposits from seven sites, which constitute two north–south and west–east transects across the Plateau. Results show that steppe prevailed both in the LGM and the Holocene Optimum. During the LGM, vegetation in the northwest mainly consisted of *Artemisia*, *Echinops*-type, *Taraxacum*-type, and Chenopodiaceae, and vegetation in the southeast was characterized by the same types but with a slight increase in Poaceae. During the Holocene Optimum, vegetation was more diverse, with Poaceae, *Artemisia*, *Echinops*-type, and Chenopodiaceae dominant in the northwest, and *Pinus*, *Corylus*, Poaceae, *Artemisia*, and *Selaginella sinensis* dominant in the southeast. Our records also show that from the LGM to the Holocene Optimum, the presence of *Echinops*-type and *Taraxacum*-type pollen decreased, while Poaceae pollen became more prevalent. As it has been found that most species of Poaceae prefer relatively humid conditions and abundances of *Echinops*-type and *Taraxacum*-type increase in desert vegetation, a new proxy, Poaceae/(*Echinops*-type + *Taraxacum*-type) ratio (P/(E + T)), was thus developed to compare the spatial differences in climate between the LGM and the Holocene Optimum, with high P/(E + T) values indicating relatively warm and wet conditions. The P/(E + T) ratio shows an overall southward and eastward increase for both the LGM and the Holocene Optimum. Furthermore, it exhibits a prominent north–south and west–east gradient during the Holocene Optimum but displays a flat one during the LGM, indicating more pronounced spatial contrasts in climate during the Holocene than in the LGM. This phenomenon may be attributed to the unique geographic location of the Loess Plateau, which was located in the marginal zone of the East Asian summer monsoon during interglacials but was dominated by the winter monsoon during glacials due to a southward displacement of climate zones.

1. Introduction

Loess is a wind-blown, silt-sized material. It covers an area of ~440,000 km^2 on the Loess Plateau in North-central China (Liu, 1985). The main body of the Plateau is found in the middle reaches of the Yellow River (Fig. 1), and is characterized by an arid and semi-arid climate. The present-day climate is mainly controlled by the East Asian monsoon, which comprises two seasonally alternating atmospheric circulations. In winter, a northwesterly dry–cold air mass from Siberia leads to a cold and dry climate, while in summer, a southeasterly air mass transports heat and moisture inland from the low-latitude oceans. Therefore, a strong climatic gradient spans the Loess Plateau, with mean annual precipitation and temperature increasing from ~300 mm and ~8 °C in the northwest to ~700 mm and ~14 °C in the southeast (Fig. 1A).

Studies of several aspects of loess, such as colour reflectance (Yang and Ding, 2003), grain size (Yang and Ding, 2004, 2008), magnetic susceptibility (Hao and Guo, 2005), major element composition (Gao and Ding, 2008), and stable isotope composition (Liu et al., 2005; Yang et al., 2012), have shown an evident climatic gradient across the Loess Plateau both in glacials and interglacials. Furthermore, a steeper climatic gradient in the interglacials than in the glacials was proposed (Yang and Ding, 2003; Gao and Ding, 2008). However, these conclusions were mainly based on indirect palaeoclimate proxy evidence, and the mechanism for the climate gradient changes on the Loess Plateau remains elusive. Clearly, further definitive evidence such as vegetation record is needed, not only because the vegetation information is crucial to an understanding of monsoon rainfall belt migrations and as a means of

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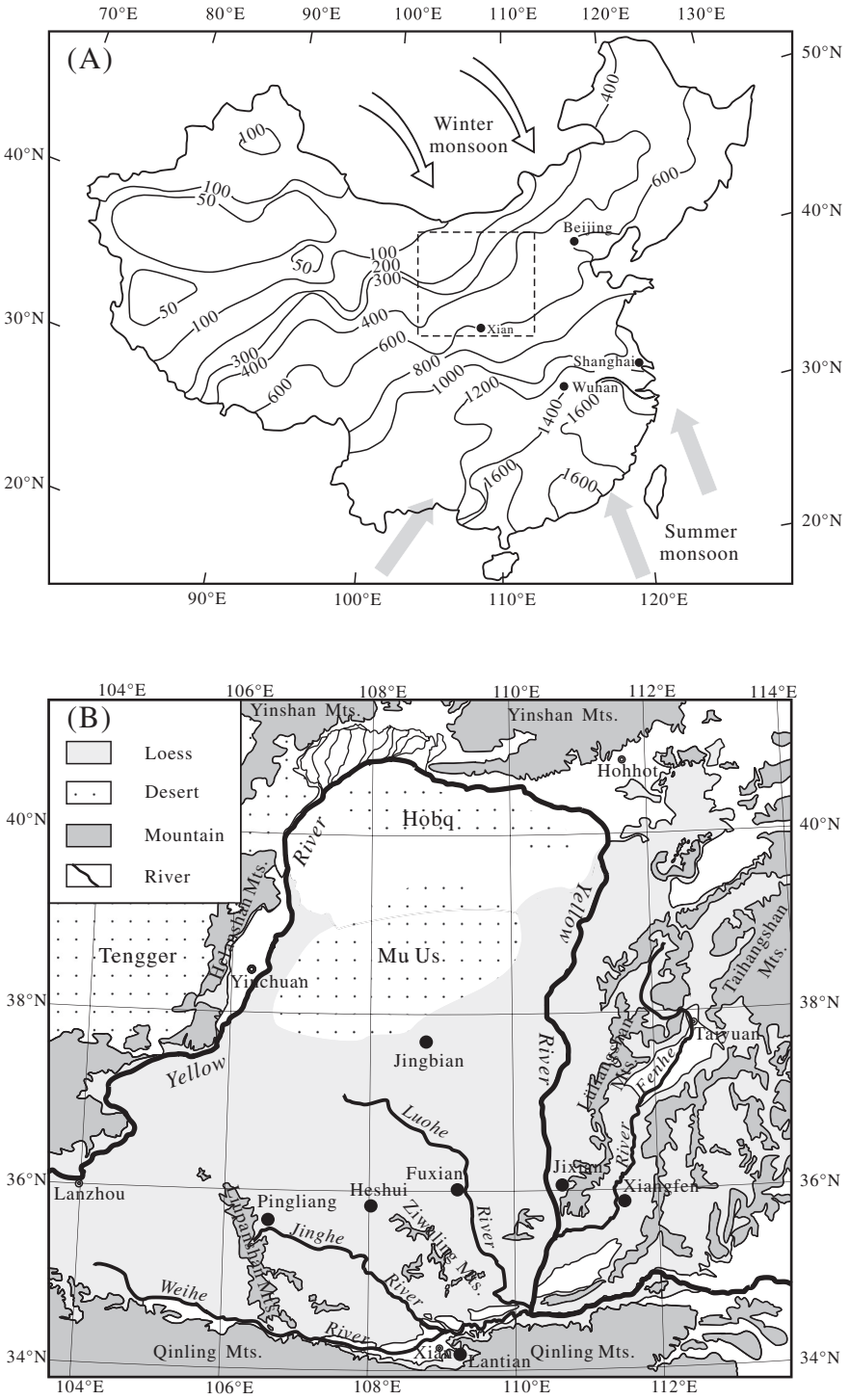

Fig. 1. (A) Mean annual precipitation (mm) in mainland China (modified after Domrös and Peng, 1988). (B) Enlarged view of the inset in (A), showing the study sites (solid circles) and the distribution of loess in the middle reaches of the Yellow River (adapted from Liu, 1964). The open and shaded arrows indicate the East Asian winter and summer monsoon winds, respectively.

defining model boundary conditions (Jiang and Liu, 2007), but also because it provides a valuable reference for ecological restoration in the ongoing and future greening programs (Jiang et al., 2013).

Pollen analysis is a robust tool to reconstruct past vegetation and climate of arid and semi-arid regions (Jiang et al., 2006, 2010, 2013; Y.Y. Li et al., 2006; Wang et al., 2006; Zhao et al., 2009). Although pollen records of several loess sections have been obtained in the past two decades (Sun et al., 1997; Li et al., 2003; Jiang and Ding, 2005; Shang and Li, 2010), they mainly come from the southern Loess Plateau (especially the Weihe River valley) and continuous pollen records covering a complete cold–warm cycle from the northern part remain scarce, which hinders obtaining an overall picture of the Loess Plateau vegetation pattern. In this study, we conduct pollen analysis of seven loess sections from the Loess Plateau. These sites constitute two broad north–south and west–east transects (Fig. 1B), which allow us to examine the temporal and