Late Pliocene-Pleistocene changes in mass accumulation rates of eolian deposits on the central Chinese Loess Plateau*

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1. Introduction

As the aridity of central Asia is dynamically linked to the phased uplifting of the Himalaya-Tibetan Plateau and the evolution of the East Asian Paleomonsoon, variability in the aridity of dust source regions has been a major focus in previous studies [e.g., *Rea et al., 1998; An et al., 2001; Guo et al., 2002*]. Loess deposits in the Chinese Loess Plateau (CLP), which covers an area of about 500,000 km^2 with a thickness of 150 to 300 m, provide continuous records of the changing climate in Asia since the late Cenozoic; these records include the history and variability of the East Asian paleomonsoon climate and Asian interior aridity.

We investigate two continuous loess-paleosol and red-clay sequences that developed in the central CLP. By measuring the bulk density of each sample and calculating the sedimentation rate for eolian sequences using a refined astronomical timescale, we generate the first continental MAR record spanning the late Pliocene and Pleistocene. The CLP MAR record can be directly compared with those preserved in ice cores and deep-sea sediments. Based upon the temporal changes in the MAR and a detailed comparison of dust records from the land, ocean and ice cores, we address the history and variability of Asian inland aridity over the past 3600 ka and its dynamical linkage to changes in global ice volume and boundary conditions on tectonic and orbital time scales.

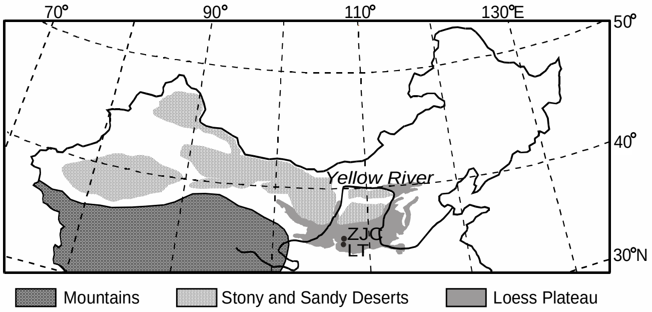

Fig. 1 Map showing locations of the Zhaojiachuan (ZJC) and Lingtai (LT) sections.

2. Materials and methods

The Zhaojiachuan (ZJC, 35°45′N, 107°49′E, 1250 m asl) and Lingtai (LT, 35°04′N, 107°39′E, 1350 m asl) sections are located in the central CLP (Fig. 1), within an area that is highly sensitive to the variations in the relative strengths of the East Asian summer and winter monsoons. In the field outcrops, we took samples at 10 cm intervals at the ZJC section and 8 cm intervals at the LT section. Measurements of magnetic susceptibility, grain size of quartz particles and bulk density of each sample were carried out at the Institute of Earth Environment, Chinese Academy of Science.

Chronologies for the two sections have been generated by paleomagnetic analyses [*Sun et al.*, 1998a,1998b] and refined by using orbital tuning method [*Sun et al., 2005*]. The MAR (g/cm^2/kyr) for eolian deposits is estimated as MAR =f×SR×BD, where f is the fraction of eolian dust in the deposit, SR (cm/kyr) is the dust accumulation rate, and BD (g/cm^3) is the bulk density. Fig. 2 plots variations of magnetic susceptibility (MS), mean grain size of quartz (MGSQ), bulk density (BD) and MAR at the ZJC and LT sections.

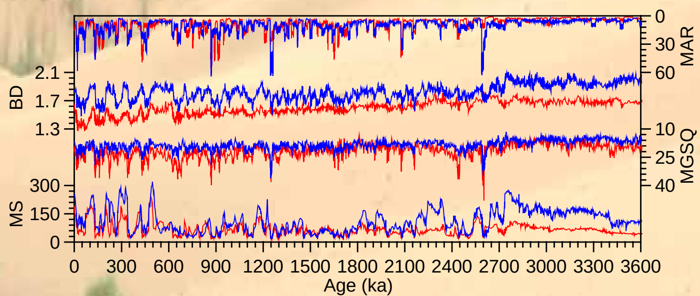

Fig. 2 Variations of MS (SI), MGSQ (μm), BD (g/cm^3) and MAR (g/cm^3/ka) of eolian sequences at the ZJC (red) and LT (blue) sections.

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3. Results and discussion

The reconstructed MARs demonstrate that over the past 3600 ka, distinct aridity-humidity fluctuations occurred over glacial-interglacial time scales, and these were superimposed on a gradual long-term drying trend (dashed lines in Fig. 3C). From 3600 to 2700 ka, the mean MAR is characterized by low-amplitude variability in MARs, ranging from 1.4 g/cm^2/kyr to 14 g/cm^2/kyr. Over the interval 2700 to 1250 ka, the amplitude of the MAR variation increases with a range of 1.5 to 63.8 g/cm^2/kyr. In the last 1250 ka, both the amplitude and frequency of the MAR record have become more variable. For example, the MARs during this period varies from 2.5 g/cm^2/kyr to 58.5 g/cm^2/kyr over interglacial-glacial scales, whilst the frequency of MAR variability changes from orbital to sub-orbital time scales.

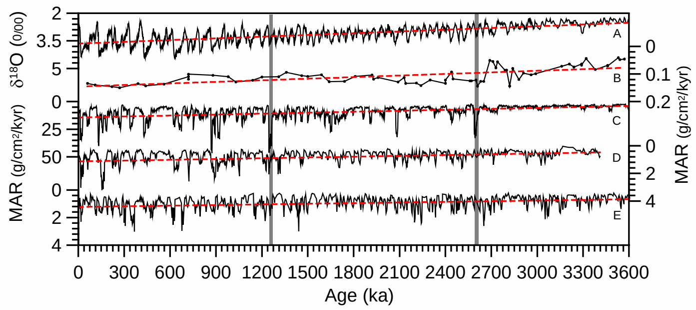

Fig. 3 Mass accumulation rate (MAR) records from land and ocean and their comparison with the deep-sea $\delta^{18}O$ record of ice volume change. A) Stacked benthic oxygen isotope record [*Lisiecki and Raymo*, 2005]; B) MAR record ODP sites 885/886 [*Rea et al.*, 1998]; C) Mean MAR record from the central Chinese Loess Plateau; D) MAR record of ODP site 722 [*Clemens et al.*, 1996]; E) MAR record of ODP site 659 [*Tiedemann et al.*, 1994].

MAR records from the land and deep-sea sediments show that changes in the aridity of the dust source regions in Africa and Asia are linked in two ways: first through drying trends and second in the variability of cyclical processes. A long-term increase in the MAR records is seen in all of the MAR records, suggesting a trend toward greater aridity in the interior of both Africa and Asia over the past 3600 ka. The increased amplitude of the MAR records, except for the low-resolution record from the ODP sites 885/886, after 2700 ka presumably reflects increased sensitivity of regional climate to external (insolation) and internal (e.g. ice volume and boundary conditions) forcing.

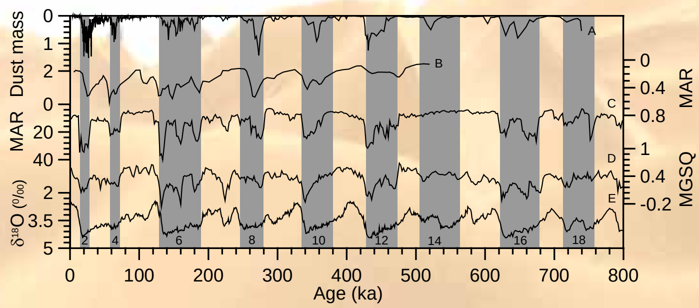

Fig. 4 Correlation of dust records from ice cores, marine sediment and terrestrial loess deposits over the last several glacial cycles. A) Dust mass of the EDC ice core [*EPICA*, 2004]; B) mass accumulation rate (MAR) record of sediment core V21-146, northwestern Pacific [*Hovan et al.*, 1989]; C) Mean MAR record of the central CLP; D) Stacked mean grain size of quartz (MGSQ) of the LT/ZJC sections [*Sun et al.*, 2005]; E) Stacked benthic $\delta^{18}O$ record [*Lisiecki and Raymo*, 2005].

Comparison of the dust records from ice cores in Antarctica with MAR record from the northwest Pacific and loess from the central CLP over the past 800 ka indicates that the MARs were higher in glacial times than in interglacial intervals (Fig. 4). Furthermore, the MAR records change synchronously with the stacked MGSQ and benthic d^{18}O records, that is, enhanced aridity in the source regions apparently was coincident with intensified paleowinds and increased ice volume during glacial times. Correlations among the various climate proxies from ice cores, land and ocean provide evidence that in periods of extensive glaciation, there was a positive relation between source-area aridity and paleowind strength.

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