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Research Advances

The First Loess-Based Paleoclimatic Reconstruction over the Last Interglacial-Glacial Cycle in the Hunshandake Sandy Land

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Objective

Although extensive lakes and eolian sands within and surrounding the Hunshandake Sandy Land (HSL) are sensitive to paleoenvironmental variations in arid and semi-arid eastern Inner Mongolia (e.g., Yang et al., 2013), these records are commonly confined to the last deglaciation, hampering a complete understanding of climatic fluctuations on glacial-interglacial time scales. Recently, we found a complete late Pleistocene loess-paleosol sequence in southern extremity of the HSL that provides an excellent opportunity to reconstruct regional climatic variations in the monsoonal margin. To this end, we carried out detailed rock magnetic, geochemical and diffuse reflectance spectrometer (DRS) analyses of this loess-paleosol sequence that spans the past 140 ka.

Methods

The 4.72-m-thick Beigou section (42.40°N, 115.71°E) was sampled at 4 cm intervals, and 118 bulk samples were collected. Magnetic susceptibility (χ) was measured using an AGICO MFK1-FB Kappabridge. Anhysteretic remanent magnetization (ARM) and saturation isothermal remanent magnetization (SIRM) were measured using a 2G 755-4k cryogenic magnetometer. DRS were performed by a Cary 5000 UV–vis–IR spectrophotometer. Concentrations of major and trace elements were determined by PW4400 X-ray Fluorescence spectrometer and ICP-MS-PE300D, respectively.

Results

We constructed the depth-age model based on linear interpolation of three OSL dates and detailed correlations between the variations of our Rb/Sr ratio, a faithful proxy of EASM strength, with the LR04 benthic $\delta^{18}O$ stack. This compelling land-ocean resemblance suggests that the sedimentation of the Beigou loess commenced since the last interglacial. During the last interglacial, our magnetic record clearly defines three sub-paleosol layers of S1-1, S1-2 and S1-3 with enhanced pedogenesis corresponding to MIS 5a, 5c, and 5e, and all concentration dependent magnetic parameters (e.g., χ, ARM and SIRM) exhibit concordant variations with higher values reflecting stronger pedogenesis, similar with those of typical loess in the hinterland of the Chinese Loess Plateau (CLP). Contrary to higher $S_{-0.3}$ values of paleosol on the CLP, a case of lower $S_{-0.3}$ values in paleosol is found here, suggesting that higher proportions of pedogenesis-derived high-coercivity magnetic minerals were formed during the interglacial. During the last glacial, the commonly-used grain-size dependent magnetic parameters (e.g., χ_{fd} and ARM), which have been successfully adopted to denote EASM variations (Gong Hujun et al., 2017), show muted variations that are less correlative with loess records from the CLP, reflecting the much weaker influence of EASM on the monsoon-marginal region. By contrast, Rb/Sr and Ba/Sr records exhibit broad comparability with summer precipitation variations and the grain size record from the western CLP, Chinese speleothem $\delta^{18}O$ record, the ice-core $\delta^{18}O$ record in Greenland, and the northern hemisphere summer insolation, demonstrating that eolian deposits in the southern HSL have a good potential for recording sub-orbital EASM variations as well as several millennial-scale cooling events. Interestingly, during the last glacial, both SIRM and Saturation magnetization (M_s) display high-amplitude variations with higher values, and are positively correlative with the variations of Zr/Rb ratio, a robust geochemical indictor of East Asian winter monsoon (EAWM), reflecting a strong control of winter vigor on magnetic signals dominated by lithological ferrimagnetic minerals. We also found that the climatic conditions during the last interglacial-glacial transition are characterized by gradual retreat of EASM but stepwise propagation of EAWM, indicating an anti-phased pattern of EASM and EAWM during this climatic transition.

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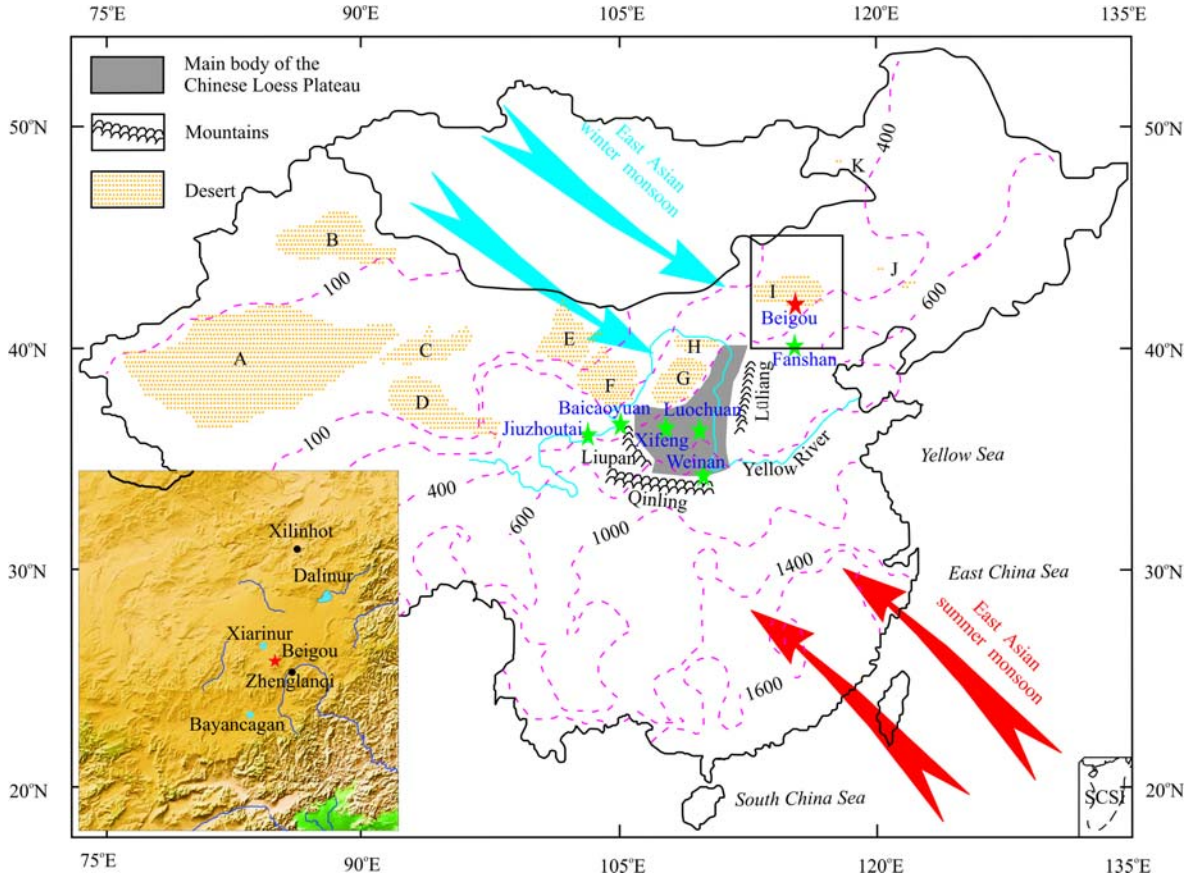

Fig. 1. Schematic map showing the location of Beigou loess section (red star), typical loess profiles (green stars), desert and mean annual precipitation isohyets (mm, dashed lines) in China. The red and blue arrows indicate the wind directions of the EASM and EAWM, respectively. Deserts: A, Taklimakan; B, Gurbantunggut (Junggar); C, Kumtag; D, Qaidam; E, Badain Jaran; F, Tengger; G, Mu Us; H, Hobq; I, Hunshandake; J, Horqin; K, HulunBuir. The inset map showing the location of Beigou section, representative lakes and cities in middle-eastern Inner Mongolia.

Conclusions

We for the first time reported the preservation of complete loess-paleosol sequences spanning the last interglacial–glacial cycle in present southern limit of HSL. Our combined mineral magnetic and geochemical results demonstrate that during the last interglacial the front of the EASM can extend to middle–eastern Inner Mongolia. A negative correlation between SIRMs and ZR/Rb during the last interglacial but a positive correlation during last glacial suggest that SIRMs are controlled by pedogenesis during interglacial and by wind vigor during glacial, respectively. We attribute this complex magnetic record to a threshold response to the East Asian monsoon variations in eastern Inner Mongolia. The spatially uniform REE patterns between the loess studied here and those on the main body of the CLP suggest the loess source materials developed in the southern margin of the HSL have been thoroughly mixed prior to deposition.

Acknowledgments

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