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Terminations and their correlation with solar insolation in the Northern Hemisphere: a record from a loess section in Northwest China

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Abstract

A high-resolution loess section in Northwest China is analyzed for the major climate terminations and their correlation with solar insolation over the past 0.8 Ma. Based on age controls and a grain size age model proposed by Porter and An (Porter, S.C., An, Z.S., 1995. Correlation between climate events in the North Atlantic and China during the last glaciation. *Nature* 375, 305–308.), a timescale for the Shagou loess section is constructed, which is independent of orbital tuned results. The timescale is similar to other loess sections, and the mid-point ages of the boundary between a paleosol and its underlying loess layer are very close to that of terminations recorded in the marine record. Shagou section records indicate that grain size changed sharply during the termination process. Terminations occurred at the time of the maximum or increase of July radiation in the Northern Hemisphere at high latitudes, suggesting that insolation might be a factor affecting terminations in the Chinese loess. This result supports the Milankovitch hypothesis. However, variations in the amplitude of the insolation and grain size records are not proportionally matched, so that the mechanism remains unsolved.

Keywords: Loess; Grain size; Termination; Insolation

1. Introduction

The Milankovitch hypothesis holds that global climate is forced by solar radiation received by the earth. Marine oxygen isotope records display the

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correlation between global ice volume and earth orbit, the latter directly regulating the solar insolation received by the earth's surface (Hays et al., 1976). Though there are problems with the Milankovitch hypothesis, such as the mechanism by which and the degree to which insolation plays a role in global and regional climate, it is widely accepted. Abundant evidence has also been provided in support of this hypothesis by Chinese loess records (Liu et al., 1999). For example, solar insolation might be a forcing factor on the East Asian winter monsoon variations by way of ice volume changes (Ding et al., 1995). Over the last 150 ka, precipitation in July on the Loess Plateau has shown close correlation with radiation in lower latitudes (Lu et al., 1996). The response of mollusk assemblages to orbital forcing in the last 250 ka has been reported from Luochuan loess section (Wu et al., 2000). However, arguments also exist that question the validity of this hypothesis (Winograd et al., 1992, 1997; Muller and MacDonald, 1997).

In China, loess layers were deposited during cold and arid glacial periods (during even-numbered marine isotope stages, MIS), and paleosols developed during warm-moist interglacials (during odd-numbered MIS; Liu et al., 1985), the loess–paleosol sequences thus recording the glacial–interglacial cycles. The boundary between a paleosol and its underlying loess layer reflects the transition from glacial to interglacial, although eolian sediment may be subjected to alteration by post-depositional leaching and pedogenic process to some degree, especially with a climatic shift from glacial to interglacial. This may cause some uncertainties at the paleosol–loess boundaries, since loess deposition is continuous between glacial and interglacial periods. In the western part of the Chinese Loess Plateau, the loess accumulation rate was high and the record provides a stratigraphy containing few disruptions. Therefore, loess records from this area are useful in discussing the transitions from glacial to interglacial periods, i.e., the terminations, including their amplitudes and phases. In this paper, information on terminations over the past 800 ka from a loess section in northwest China and their main characteristics are discussed. If the timing of terminations in loess deposit is correlated with solar insolation, then it can provide support to the Milankovitch hypothesis.

2. Stratigraphy and age dating

The Shagou loess section (37°33′ N, 102°49′ E) is situated on the northern flank of Qilian Mountains, Hexi (Gansu) Corridor, close to the Tengger Desert (Fig. 1). The total thickness of the Quaternary section of Shagou is about 230 m. The loess–paleosol sequences in the section compare well with those in the central Chinese Loess Plateau from L9 at the bottom to L1 at the top. The Holocene deposit is largely absent because of post-depositional denudation. Paleosols are less well developed compared to those in the central Loess Plateau with weak carbonate leaching and less clay material. Mean annual temperature and precipitation are about 5 °C and 300 mm, respectively. Disruption at contacts between paleosols and the underlying loess layers is quite rare because of minimal bioturbation, weak post-depositional pedogenesis, and weak runoff. The unusually high accumulation rate (about 230 m/820 ka) would have also served to minimize the extent and degree of post-depositional alteration. Thus, records of terminations (deglaciations) are well preserved.

Samples were taken at 10-cm intervals from L2 to the bottom of the Shagou section, at 5-cm intervals for the S2 paleosol and the L2 and L1 loess layers, and at 2.5-cm intervals for the S1 paleosol. Theoretically, the resolution is within ~1 ka below S1, and 0.1–0.2 ka for S1 and L1. Grain size is a sensitive proxy index of the winter monsoon and its response time to climatic changes in the Chinese loess deposit is very short (Derbyshire et al., 1997); here, it is the chosen climate proxy when discuss the terminations. Grain size measurements ranging from 0.02–2000 μm were completed using a Malvern Mastersizer 2000. Organic matter and carbonates were removed before grain measuring. The measurement precision (n=15) of the median grain size and the sand content for a sample from the lower part of the S1 paleosol is 1.115% and 2.727%, respectively.

A chronology for the Shagou section was established using paleogeomagnetic, radiocarbon dating, and TL dating. Previous work suggested that the age of the base of the Shagou section is about 0.83 Ma, i.e., older than the Brunhes/Matuyama boundary (Pan et al., 2001). All the TL dating results were completed at the State Key Laboratory of Loess and Quaternary Geology, Xi'an, while all the ^{14}C dating results were