

Loess Dating Progress in China

Loess is a sediment difficult to date. The loess sequences of the last climatic cycle in China are usually dated by radiocarbon and thermoluminescence (TL) measurements. Correlation with marine $\delta^{18}\text{O}$ records and orbital cycles is also frequently used for the construction of time-scales. In previous studies, soil S0 was correlated with the deep-sea oxygen isotope stage 1; loess L1 was correlated with isotope stages 2, 3 and 4, the weak soil complex within L1 with stage 3, and the S1 soil with stage 5.

Recently, the Weinan loess section was intensively dated for determining the ages of the major stratigraphic boundaries using TL and twenty-eight radiocarbon dates. The radiocarbon dating was carried out on the humin fraction of the organic matter in the samples using AMS. The results confirms the previous land-

sea correlation pattern except for the lower boundary of the soil complex in the Malan loess (Fig. 1): most of the TL dating yielded ages centered at ~50 ka, which is significantly younger than the age of stage 3 (~59 ka) according to Martinson *et al.* (1987). The TL age is, however, in good agreement with the oxygen isotope age of ~50 ka provided by the eolian dust record in the North Pacific (Hovan *et al.* 1989), which represents a direct link between the Chinese loess and marine $\delta^{18}\text{O}$ records. These dates provide an independent timescale for the loess-paleosol sequence of the last climatic cycle.

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Fig. 1: Depth-Age transformation of the Weinan loess section based on absolute dating compared with that obtained by correlating with the SPECMAP time scale (figure from Liu J.Q. *et al.*, 1994). SPECMAP data are from Imbrie *et al.*, 1984). 1. AMS ^{14}C age; 2. TL age; 3. stratigraphic boundary age obtained through correlation with SPECMAP $\delta^{18}\text{O}$ record; 4. Loess; 5. Paleosol

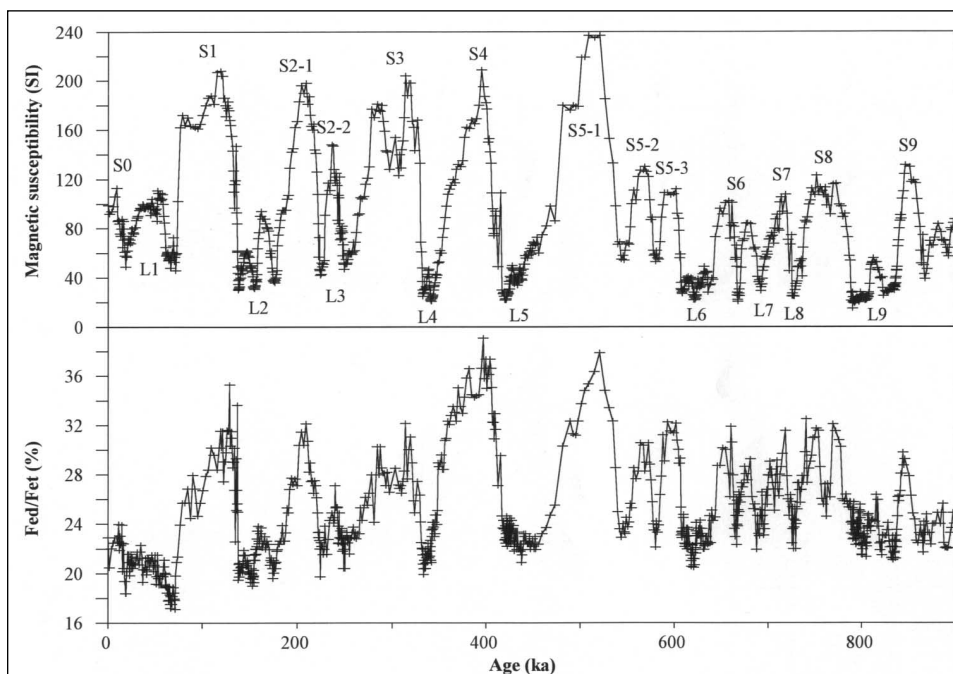
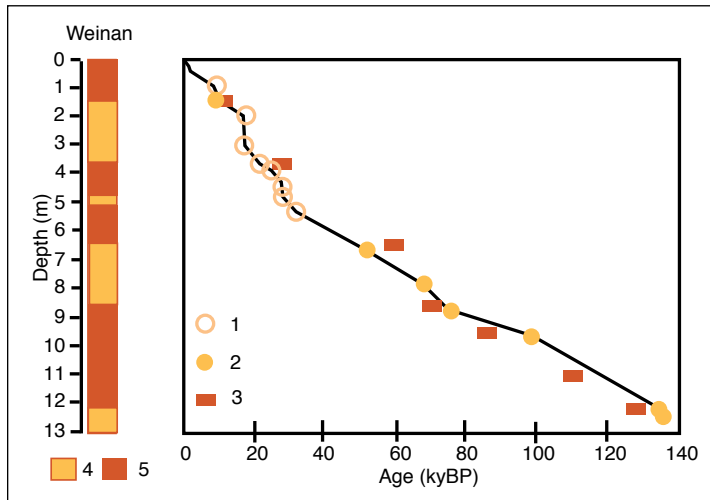


Fig. 2: Variations in the Fed/Fet ratio from the Changwu loess section compared with the magnetic susceptibility values. The timescale is obtained by correlating the susceptibility signals with that of Xifeng (see Kukla *et al.*, 1990, *Trans. Royal Society of Edinburgh: Earth Sciences*, 81:263-288)

A new Proxy of the East Asian Paleomonsoon

Magnetic susceptibility variations in Chinese loess-paleosol sequences are used by many authors as a proxy for the strength of East-Asian summer monsoon. Susceptibility values are higher in paleosols than in the overlying and underlying loess. Recently, we carried out a paleopedological study on three loess sections (Weinan, 34.33°N, 109.5°E; Changwu 35.2°N, 107.8°E and Xifeng 35.7°N, 107.6°E) for the last 900 ka using various pedological methods and found that the susceptibility value is not always consistent with the pedological indicators (Fig. 2). For example: (1) The S4, S5-1 and S5-3 soils represent the most developed soils while the susceptibility values for S4 and S5-3 are not higher than for the other soil units (in the case of S5-3 they are even lower). (2) For the three sub-units of S5, the intensity of pedogenesis shows an order of S5-1 (strongest), S5-3 and S5-2 (weakest) while the susceptibility shows an order of S5-1 (highest), S5-2 and S5-3 (lowest). (3) The soils S6, S7 and S8 are similar to S2 and S3 while the susceptibility values for the major soil units older than S5-1 are much lower than for the younger interglacial soils (S0 to S5-1), even lower than for some weakly developed interstadial soils in the loess units L1, L2 and L3. These results therefore provide a complex picture for the climatic significance of the magnetic susceptibility in paleosols. Understanding the basis of this complexity will require much additional work. The Loess Plateau is located in the East-Asian monsoon zone. Since the average soil temperatures in the region are below 0°C from late autumn to early spring under modern interglacial conditions, the chemical weathering of loess mainly depends upon summer temperatures and precipitation. Consequently, a chemical weathering index would be expected to reflect the paleomonsoon intensity: high weathering intensity can be interpreted as an indication of strengthened summer monsoon and lower weathering intensity indicates the reverse. Recently, we have generated a high-resolution paleo-weathering

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Reconstruction of Paleoclimate in the Loess Plateau using Non-Linear Mathematical Methods

In reconstructions of Quaternary climate, most researchers have made quantitative estimates of paleoclimate from linear relations between paleoclimatic proxy records and single climatic factors (e.g. temperature or precipitation), and established non-linear equations related to two climatic parameters such as temperature and precipitation by using response surface analysis. In this study, we use a non-linear inversion method to synthesize the data of three different proxy indicators and reconstruct paleoclimate. 63 records of Magnetic susceptibility (MS), 12 of the total Fe_2O_3 (Fet) and 28 of the mollusk species (*Vallonia cf. pulchella*) were taken from modern surface soils of the Loess Plateau and used as proxy indicators of physical, chemical and biological records. For stratigraphical study, we chose the Luochuan loess section, a standard section for Chinese loess. This section was sampled at

intervals of 10 cm from S1 to S0. A total of 120 samples for MS, Fet and mollusks have been studied. The data for annual mean temperature (AMT) and annual mean precipitation (AMP) at the modern surface soil sites were used to set up the multiple regression climatic functions. Fig. 3 shows temperature and precipitation variation in Luochuan over the past 11,000 ka based on the non-linear inversion method. From Fig. 3, we can see that there are some phase differences in the variations of the three proxy records. However, the AMT and AMP satisfy the non-linear relationship between the three climatic proxies and temperature and precipitation within acceptable limits, indicating a mutually consistent solution of the three climatic proxies.

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record (at 10 cm intervals) for the Changwu loess section using the ratio of free Fe_2O_3 (Fed) (extracted by dithionite-bicarbonate-citrate method) to total Fe_2O_3 widely used by pedologists for characterizing the soil weathering intensity. The new proxy is highly consistent with other indicators of the intensity of pedogenesis: (1) the most developed S4, S5-1 and S5-3 have the highest Fed/Fet ratio; (2) for the three sub-units of S5, the ratio is the highest for S5-1 and lowest for S5-2, thus in close agreement with the macro and micromorphological observations; (3) the ratios for the soil units S6, S7 and S8 are similar to those for S2 and S3; and (4) the susceptibility time-series shows a major shift in amplitude at ~ 600 ka BP while that for the new proxy is at ~ 800 ka, similar to that defined according to the paleosols. Therefore the Fed/Fet ratio seems to be a better indicator of the strength of the East Asian summer monsoon than do variations in magnetic susceptibility.

We believe that the strong development of the S4, S5-1 and S5-3 soils is not solely a function of a longer period of soil-formation, but of climate conditions. The data match well with the higher $\delta^{13}C$ values (marine oxygen isotope stages 11, 13 and 15) in the marine record (see Raymon *et al.*, 1990, *Earth and Planetary Science Letters*, 97:353-368; and Oppo *et al.*, 1990, *Palaeoceanography*, 5:43-54). These periods also correspond with the periods of greatest Atlantic-Pacific benthic $\delta^{13}C$ gradients, suggesting a link with the rate of the deep-water formation in the North Atlantic.

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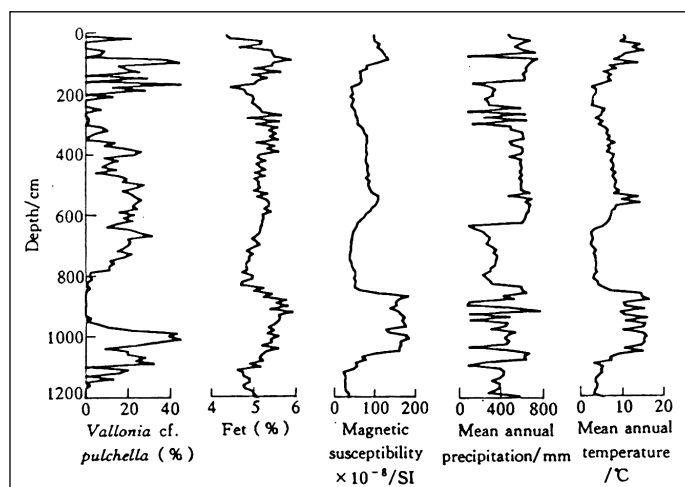


Fig. 3: Variations in the three proxy records of *Vallonia cf. pulchella*, Fet and MS in the Luochuan loess section since the last interglacial together with variations in AMT and AMP as derived from the non-linear inversion of these three proxy indicators.

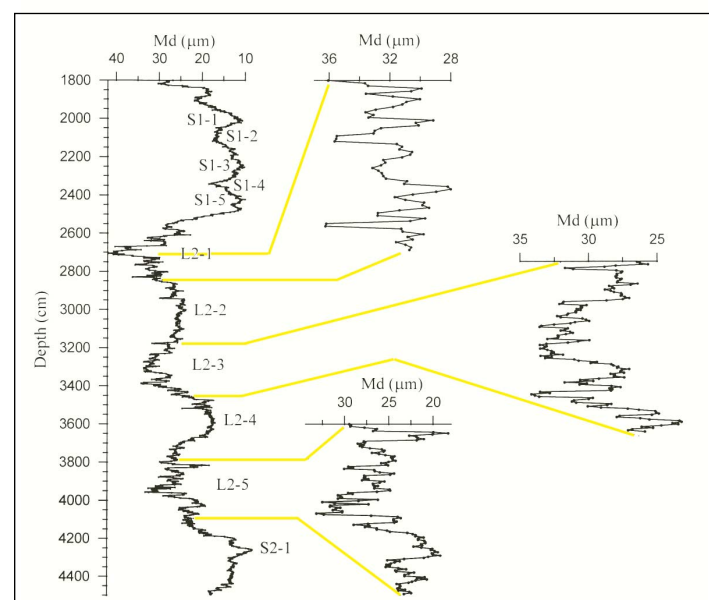


Fig. 4: Huining high resolution grain size record

Climatic Instability during the Penultimate Glaciation: Evidence from the Chinese Loess Deposits

Since the recognition of millennial-scale climatic oscillations in the Greenland ice cores, high-resolution records derived from various deposits all over the world have convincingly demonstrated that paleoclimatic variability of this kind is recorded in different parts of the global climate system, implying that climate instability during the last glacial period may be regarded as a global phenomenon. However, most of the high-resolution proxy records obtained hitherto only cover the last glaciation, and so climatic variability on sub-Milankovitch time scales in the older glacial periods is poorly known. Recently, we generated a high-resolution grain size record at Huining, the northwestern part of the Loess Plateau. The loess-soil sequence accumulated during the last two glacial-interglacial periods is about 45 m thick in the Huining section. We took samples of this part at 2 cm intervals. This sample spacing yields an average depositional time resolution of below a hundred years. Examination of the grain size record for the last

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