Millennial–Scale Oscillations of Loess Weathering over the Last Glacial Period

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The loess–soil sequence in the loess plateau region of northern China documents a continuous climate record showing past changes in the East–Asian summer and winter monsoon circulations. Grain–size data from the eastern and western Loess Plateau suggest that the winter monsoon experienced millennial–scale changes over the last climatic cycle correlated with those recorded in the icecores and ocean sediments from the circum-North Atlantic region. Here we report on a high–resolution paleoweathering record from the central loess plateau covering the last 73 ky using the ratio between the CBD (citrate–bicarbonate–dithionite) extractable free Fe_2O_3 (FeD) and total Fe_2O_3 (FeT). The ratio, which we express as a percentage, is a measurement of the quantity of iron liberated from iron–bearing silicate minerals by chemical weathering relative to the total iron available. Since chemical weathering in the region mainly depends upon summer precipitation and temperature, weathering intensity primarily reflects changes in the East-Asian summer monsoon.

Figure 1 shows the variations of the loess weathering intensity over the last 73 ky. Samples were analyzed at 2.5 cm intervals over a total thickness of 9.80 m. The time–scale is obtained by correlating the loess stratigraphic boundaries with the marine SPECMAP $\delta^{18}O$ record (Imbrie et al., 1984), then interpolating with Kukla's susceptibility age model (Kukla et al., 1990). The results show that glacial weathering intensity was much weaker before the Holocene. A series of millennial-scale FeD/FeT ratio oscillations overlies the slow glacial-interglacial trend. These changes are not necessarily recorded by magnetic susceptibility, which has been used as a proxy of the summer monsoon in earlier studies. This suggests that the FeD/FeT ratio is a more sensitive proxy for rapid climate variations than magnetic susceptibility. Over the last glacial period, general agreement

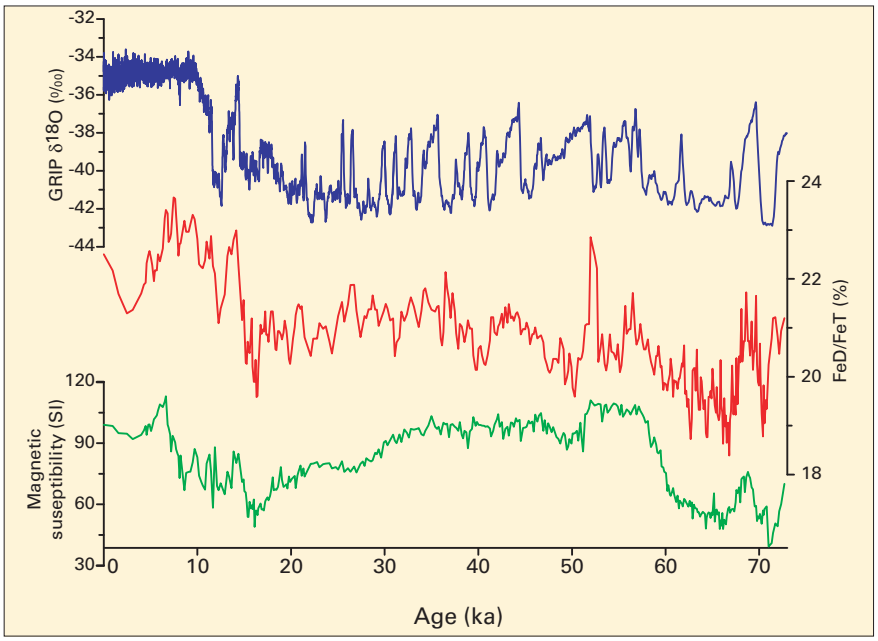

Fig. 1. Comparison of the GRIP $\delta^{18}O$ record with FeD/FeT ratios and magnetic susceptibility of the Changwu loess-soil sequence (The FeD/FeT timeseries is a 3–point moving average curve).

can be observed between the loess weathering record and the GRIP ice $\delta^{18}O$ record (Dansgaard et al., 1993). This method of dating by correlation is the current state of the art in loess reasearch. Radiocarbon has shown to be unreliable due to uncertain origin of carbon particles. Pollen and phytolith dating also give controversial results. The thermoluminescence method gives ages with potential errors of about 10–20 ky. Thus, we cannot make a cycle-by-cycle correlation between the loess weathering record and the ice-core records due to lack of absolute chronology in the loess record. However, we do believe that the loess record is accurately revealing the presence of millennial scale climate variability.

Our results indicate that millennial scale changes in the summer monsoon circulation occured during the last glacial period. The Younger Dryas event at 12.5 ky BP and the preceding warm period appear to have counterparts in the loess weathering timeseries. The dry–cold interval at 70.6 ky BP is clearly indicated by both the FeD/FeT timeseries and magnetic susceptibility. The conditions during this interval seem to have been particularly severe and to have influenced much of the loess plateau region. This dry-cold interval was immediately followed by a warm-humid interval centered at ~69 ky BP. Thus there appear to have been a two-step transition from the last interglacial stage (marine $\delta^{18}O$ stage 5) to the glacial period (marine $\delta^{18}O$ stage 4).

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