Paleoclimatic significance of grain size of loess-palaeosol deposit in Chinese Loess Plateau*

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Abstract Particle size analysis for samples from three last glacial cycle loess-palaeosol profiles along a northwest-southeast transection on the Chinese Loess Plateau has been carried out. The paleoclimatic significance of grain size indices has been obtained by analyzing the fraction content variations and their comparisons with global ice volume and solar radiation variations. The results show that (i) paleoclimatic significance of the grain size indices of loess-palaeosol deposit is different with grain size fraction content and sampling points in Chinese Loess Plateau; (ii) the sub-coarse grain fraction is a good proxy index of East Asia winter monsoon strength and therefore can be used to detect the global climate changes; (iii) the content of sub-fine and fine grain fractions is influenced by both the input of sub-coarse grain fraction and pedogenesis; (iv) the sub-coarse fraction exhibits a negative relationship with the sub-fine and fine fraction.

Keywords: paleoclimatic significance, loess-palaeosol, grain size, Chinese Loess Plateau.

Grain size variations of loess-palaeosol sequences on the Chinese Loess Plateau are indicators of wind-blown capacity and depositional environment of the Loess Plateau during the Quaternary, and probably the best proxy index of East Asia winter monsoon strength[1—6]. Grain size measurements of the loess deposit have been taken specially in the reconstruction of palaeomonsoon circulations. The 8-, 30- and 74-μm size fractions of the Luochuan section were used to document the palaeomonsoon strength[7,8]. The <8-μm grain fraction content is negatively related to the winter monsoon strength, while the 30—74-μm grain fraction content is positively related to the winter monsoon strength, and the >74-μm grain fraction content reflects the winter monsoon-strengthened events or/and dust storm events. However, it is unclear whether the above function can be used for loess deposits in other places, and we do not know which statistical index of grain size composite is sensitive to reflecting the monsoon change. In addition, both global and regional paleoclimatic signals could be preserved in the loess-palaeosol sequences, but there is no solid evidence to confirm this. Here we present detailed results of grain size measurements of three last glacial cycle loess-palaeosol profiles along a northwest-southeast transection on the Chinese Loess Plateau in Central China. The paleoclimatic significance of grain size distribution of the loess-palaeosol sequences will be discussed.

1 Sampling and measurement

The studied profiles are located in Huanxian, Xifeng and Xunyi, respectively (fig. 1), where deep gullies on the edge of the plateau reveal good exposures for the loess-palaeosol sequences.

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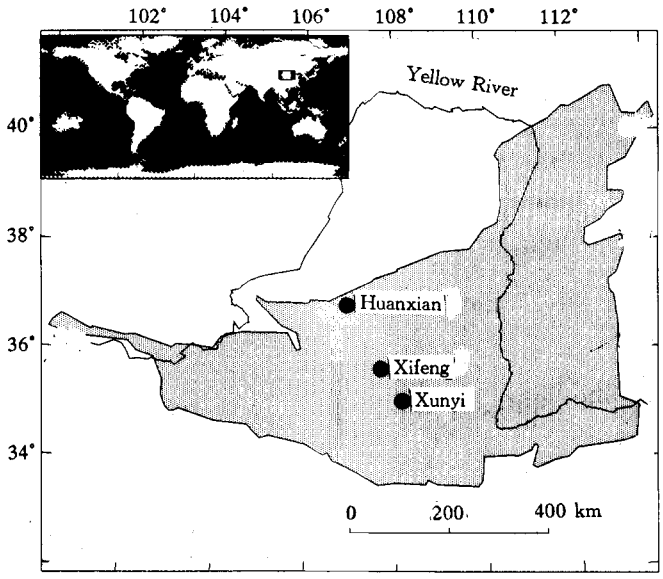

Fig. 1. Locations of sampling sites on the Loess Plateau in Central China. The shade area is the loess plateau.

The stratigraphy of loess-palaeosol sequence of the last glacial cycle in the region is easily recognizable in the field. Magnetic susceptibility measurements and their correlation with previously dated profiles[1],1) support the field stratigraphic identification. The Huanxian profile is situated in the transitional zone of desert to loess region, where sediments are coarser and sedimentation rate is higher, and the profile is thus thicker than the other two. Anthropogenic agriculture has disturbed the Holocene palaeosol (S0). The weakly developed palaeosol in the last glacial loess (L1) can also be identified in the field. Sediments of loess L1 are loose and coarse. The last interglacial palaeosol S1 is composed of three sub-palaeosols and intercalated with two loess layers. The Xifeng and Xunyi profiles can be correlated stratigraphically to the typical loess-palaeosol profile in Luochuan[1]. The Holocene soil (S0) at both sections is a black loam. A grayish-brown meadow cinnamon palaeosol complex (L1SS1) is developed in the middle part of loess L1. The S1 soil is a typical polygenetic leached argillic palaeosol. All the three profiles have been sampled for grain size and magnetic susceptibility measurements at sampling intervals of 5 cm. All the samples were pretreated with the method mentioned in ref. [7] before grain size analysis was carried out, except that, as an additional step the samples were oscillated in an ultrasonic machine for 10 min in order to further disperse. The measured error was not greater than 3%, and results are shown in fig. 2 (magnetic susceptibility not shown). From fig. 2 we can see that at the same sampling points particle size becomes finer with sampling site further from the northwest source area. The mean variations are in the same pattern with the global ice volume[9] and the solar radiation[10] variations.

2 Discussion

The grain size of the studied loess-palaeosol sequences ranges from 0 to 12.75 ϕ value,

1) Lai Zhongping, 1997, unpublished master degree thesis.

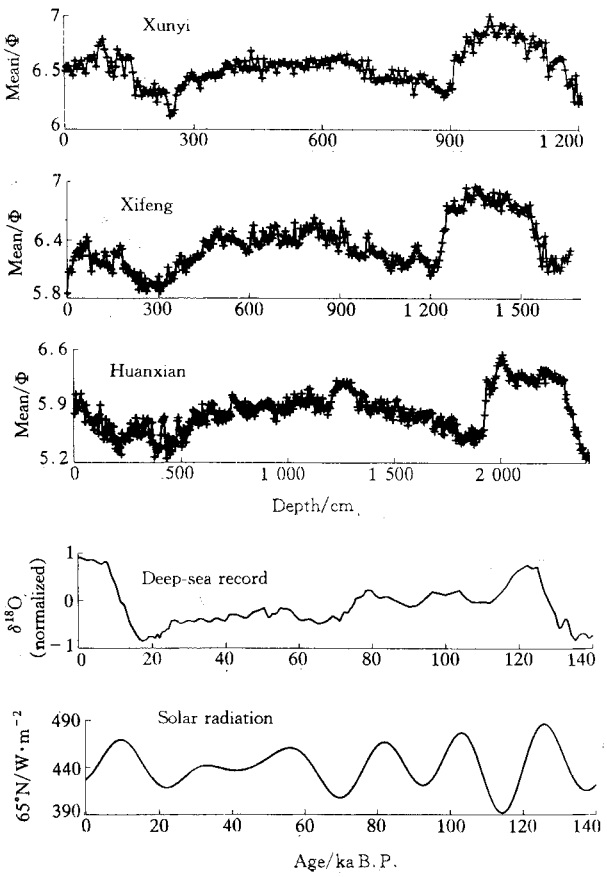

Fig. 2. Grain size variations of Huanxian, Xifeng and Xunyi loess-palaeosol deposit of the last glacial cycle and their correlation with the continental ice volume[9] and the solar radiation variations[10].

and is divided into 51 grades at intervals of 0.25 ϕ value. The content variations of each size fraction is plotted against depth, and a total of 153 curves are obtained. Some representative curves are presented in figure 3.

Previous research documented that the loess-palaeosol deposits on the Loess Plateau in Central China are transported by East Asia winter monsoon[11], and the grain size variations of these sediments can serve as good proxy indices of the winter monsoon strength[1—6]. We have preliminarily recognized the monsoon variations during the last glacial cycle through numerous geological records[11,12], and also known that the winter monsoon variations coincide with the global ice volume changes, which, in turn, influence the Mongolian high[13,14]. When the global ice volume expanded, the East Asia winter monsoon circulation was strengthened, the desert region in northwestern China moved southeastward and the dust over the Chinese Loess Plateau became coarser. Accordingly, we carefully analyzed all size fractions of the loess-palaeosol sequences and compared their variations with the winter monsoon strength variations and the global ice volume changes to determine what size fraction is sensitive to reflecting the monsoon circulation. The results show that the 44—63-μm grain fraction of Huanxian loess is an excellent indicator of the East Asia winter monsoon strength. The >63-μm grain fraction presents high-frequency, high-amplitude changing pattern, and can serve as an indicator of the intensified winter monsoon events or/and dust storm events. The 2—6-μm grain fraction presents negative relationship with the winter monsoon strength. This could be caused by the input of the coarse particles or/and strengthened pedogenesis when the winter monsoon was weakened. The paleoclimatic significance of the 6—44-μm fraction is still unclear. The <2-μm particle fraction is strongly influenced by the pedogenic process[15]. These particles can be transported over thousands of kilometers. Since there is only a small proportion deposited in the near source region, the <2-μm particle fraction is an indirect indicator of the East Asia summer monsoon strength. In summary, the particle fractions of <2, 2—6, 6—44, 44—63 and >63 μm preserve different paleoclimatic significance in reflecting the East Asia monsoon circulation changes. The corresponding fractions in Xifeng are <2, 2—8, 8—30, 30—53, >53 μm and in Xunyi are <2, 2—6, 6—26, 26—53, >53 μm, respectively. These particle fractions are termed fine, sub-fine, middle-sized, sub-coarse and coarse fraction,

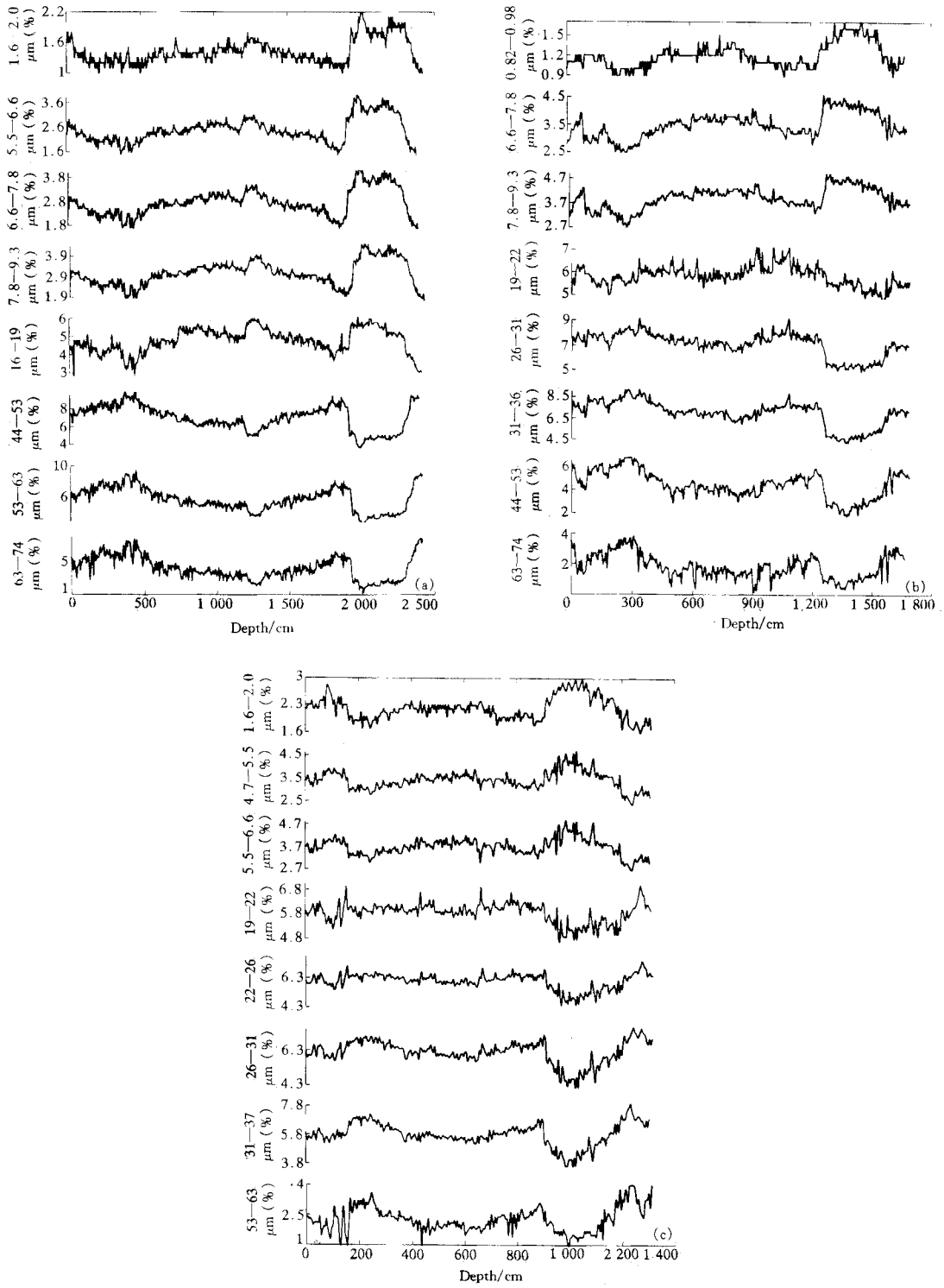

Fig.3. Grain size variations of some fractions content of the last glacial cycle deposit against the depth in Huanxian, Xifeng and Xunyi are shown in (a), (b) and (c), respectively.

respectively, in this paper.

In order to specifically compare the grain size variations with the global ice volume[9] and the solar radiation changes[10] (figs. 2 and 4), the grain size series is dated by correlating the magnetic susceptibility curves with the deep-sea oxygen isotope time series. The ages of rapid change points of the magnetic susceptibility curves can be obtained, and the ages interpolated by the model advanced by Porter and An[1] to assign an age for each sampling point. By detailed comparison, we found that the sub-coarse grain fraction is an excellent proxy index of the East Asia winter monsoon strength. Its close matching with the deep-sea oxygen isotope curve demonstrates its global paleoclimatic significance. The specific sub-coarse fractions in Huanxian, Xifeng and Xunyi are 44—63, 30—53 and 26—53 μm, respectively. The coarse fraction presents a high-frequency, high-amplitude changing pattern (compared with the Milankovitch cycle), which cannot be matched to the variations of ice volume. However, a good match among the three sampling sites suggests that they can serve as a proxy index of regional paleoclimatic changes. The coincident variations among three sequences may be caused by the winter monsoon-strengthened events or/and dust storm events. The coarse fraction in Huanxian, Xifeng and Xunyi are >63, >53 and >53 μm, respectively. The changes of the grain fraction content of 6—44 μm in Huanxian, 8—30 μm in Xifeng and 6—26 μm in Xunyi have no clearly defined relationship with the variations of the winter monsoon strength. It is also difficult to match the records among the three sampling sites. It may suggest that these particle fractions cannot be used as an indicator of monsoon climate changes, but an indicator of local climate. Further work is needed to test this conclusion.

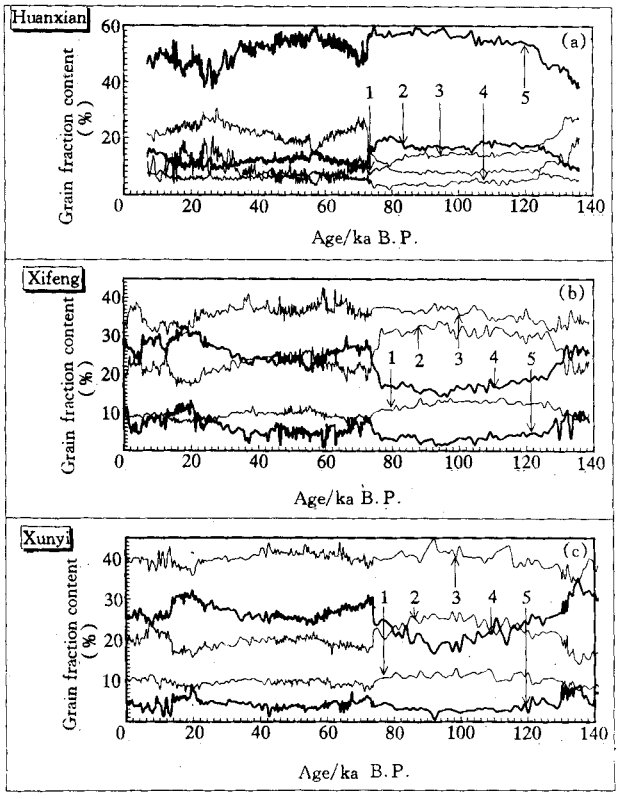

Fig. 4. Particle fraction variations of Huanxian, Xifeng and Xunyi with time.

An interesting thing is that the sub-coarse grain fraction has a negative relationship with the sub-fine and fine grain fractions, and a tentative explanation for this is that the sedimentation rates of the sub-fine and fine grain fractions are almost stable, and their relative content is largely influenced by the input flux of sub-coarse grain fraction. When the winter monsoon was strengthened, the windblown capacity was strengthened, more sub-coarse particles were transported to the Loess Plateau, and therefore the sub-fine and fine grain fractions became less. In addition, pedogenesis can produce finer particles. When summer monsoon is intensified during the interglacial period, the pedogenesis process is also intensified, thus produc-

ing more finer particles. The content of finer particles can thus serve as a proxy index of summer monsoon. However, it is not clear how much pedogenesis contributes to the content of fine particles.

3 Conclusion

1) Paleoclimatic significance of the grain size indices of the loess-palaeosol deposit is different with grain size fraction content and sampling points in Chinese Loess Plateau.

2) Both the global and regional paleoclimate signals are preserved in the loess-palaeosol deposits. The sub-coarse grain fraction is an excellent proxy index of the East Asia winter monsoon strength, and can also be used to detect the global climate changes. The content of sub-fine and fine grain fractions is influenced by the input of sub-coarse grain fraction and pedogenesis.

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