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A COMPARISON:PALAEOENVIRONMENTAL CHANGE RECORDS OF CHINESE LOESS AND ANTARCTIC ICE CORES OVER LAST 150,000 YEARS

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Abstract Studies on Chinese loess and a comparison with Antarctic ice cores provided a general pattern of global environmental change and the regional differentiation over last 150,000 years. Climatic change revealed by magnetic susceptibility of Linxia loess section in China was paralled with temperature variation revealed by δD of Vostok ice core over last 150,000 years, which indicates a pattern of climatic change tendencies on a long-scale (thousand years). However, the ranges of variation at the same phase, especially, during the last Interglacial age (80,000—140,000 a.B.P.) were more different between Chinese loess sections and Antarctic ice cores.
Key words Chinese loess, Antarctic ice cores, magnetic susceptibility, pollen, global change.

The environmental change over last 150,000 years, which included several large environmental fluctuations such as the Penultimate Glacial period, the last Interglacial age, the last Glaciation, the contemporary Interglacial age (Holocene), and a series of environmental change events, is one of the focuses of global change study at present. It involved several major cycles of environmental change about 100,000, 40,000, 20,000 years in period, which resulted from the change of astronomical orbit either.

Many studies indicated that the loess deposits in middle latitudes and polar ice cores recorded considerable information of terrestrial environmental change. In recent years, research on both loess deposits and ice cores has developed rapidly, which plays an important role in revealing the environmental change over last 150,000 years. How to synthesize the environmental change information derived from these two different types of records in different regions, so as to expound the general rules of global environmental change and regional differentiation, has become a popular topic in earth science. So far some work have been done in this area (Petit *et al.*, 1990, Li, *et al.*, 1990). This presents a further discussion by studing the Linxia loess section in China, and comparing it with Antarctic ice cores.

1. Environmental records of Chinese loess over last 150,000 years

Due to large thickness, continuous deposit, long covered period, more complete records of palaeoenvironmental change, Chinese loess is one of the best records of the environmental change (Heller and Liu, 1982, 1984; Burbank and Li, 1985; Liu *et al.*, 1985; Sasajima and Wang, 1984; Kukla, 1987, 1988, 1989). Research showes that the Linxia loess section in China can be taken as a standard stratigraphic section for recording environmental change since 150,000 a. B. P., Deposit rate in this area was as 4—5 times as the others, paleosol layers were also more than those in other places, therefore, this section reveals the environmental changes with high sensibility and good distinguishability.

Linxia section is located at north side of Linxia city, the second terrace of Daxia River (a first branch of Yellow River). Geographic coordinates: 35°35′ N, 103°11′E, 1900 a.s. l. (Fig. 1,2). Chronological study on Linxia loess section can convert the thickness sequence into the age sequence (Fig. 3).

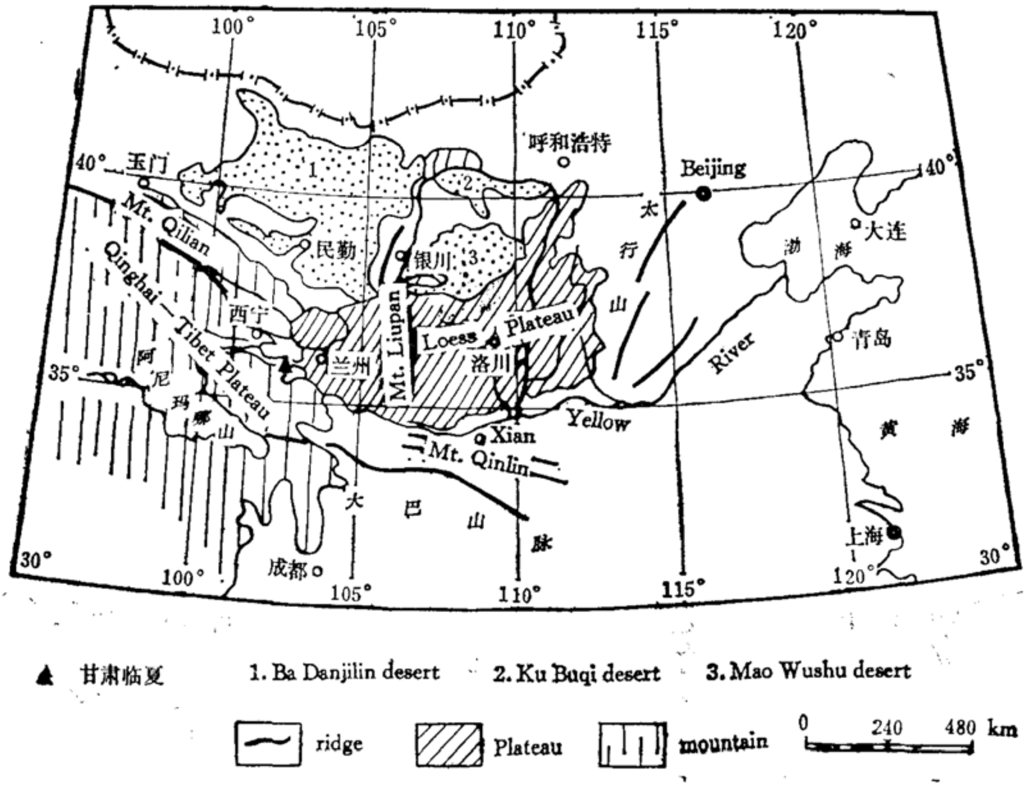

Fig. 1. The position of Linxia basin, China.

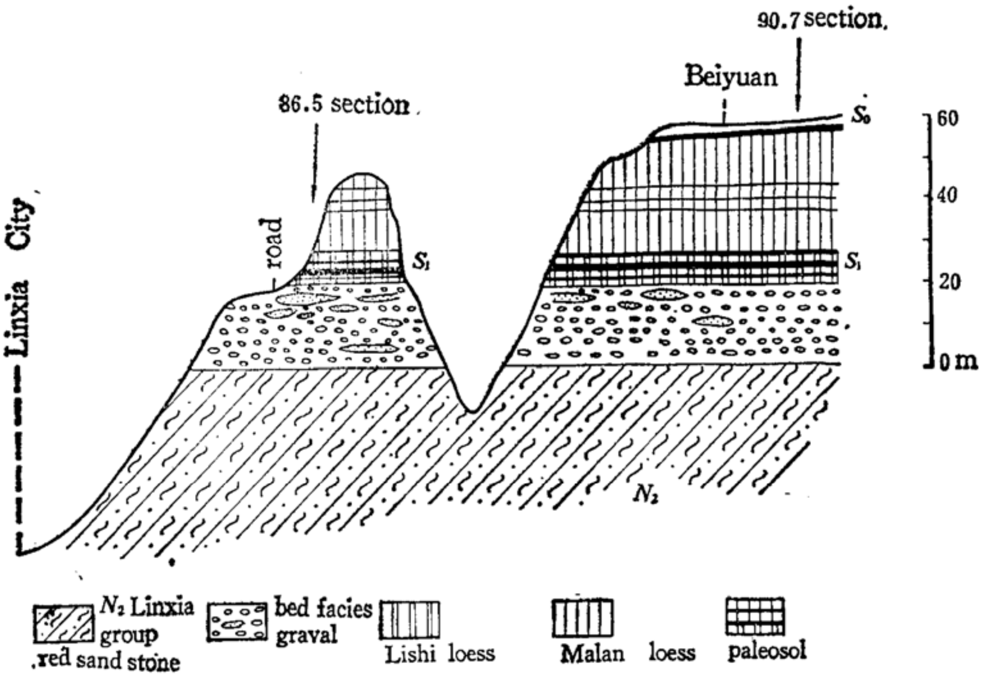

Fig. 2. Schematic diagram of Linxia terrace section.

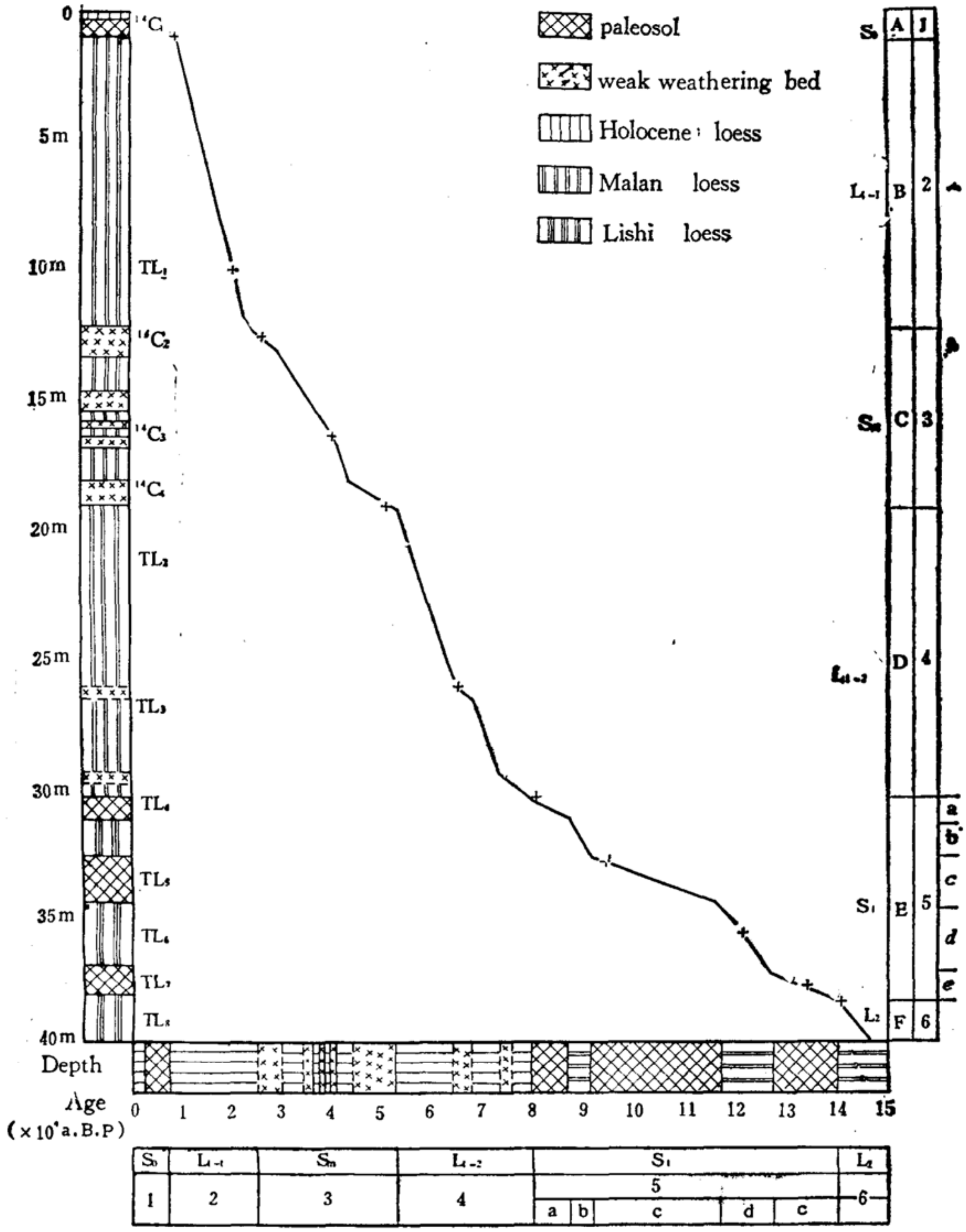

Fig. 3. The relation of the thick strata sequence with the age strata sequence at the Linxia loess section, China.

The alternated sequence of loess and paleosol deposits is the good indicator for the environmental change. According to the stratigraphy of loess and paleosols, Linxia loess section can be divided into several time intervals: $S_0 < 8{,}500$ a. B. P.; L_{1-1}, 25,000—8,500 a. B. P.; Sm, 53,000—25,000 a. B. P.; L_{1-2}, 80,000—53,000 a. B. P.; S_1, 140,000—80,000 a. B. P.; $L_2 > 140{,}000$ a. B. P. Among these, stage Sm was composed of three weak pedogenic paleosol layers with two loess between, stage S_1 included three paleosol layers of drab soil type and two loess layers, L_{1-2} contained two weak weathering layers.

The variation of the magnetic susceptibility among loess and paleosols, as substitutive index for environmental change, can be compared with $\delta^{18}O$ profile of deep sea cores (An Zhisheng *et al.*, 1990, Kukla *et al.*, 1988, Wang, 1987, Beget *et al.*, 1990). The magnetic susceptibility measurement were taken at 5cm intervals on linxia loess section by Bartington SM2 magnetic susceptibility system. The magnetic susceptibility of loess stage was about 20 C. G.S.; that of paleosol at stage Sm, 30 C.G.S.; and at S_0, S_1, about 60—90. That means the magnetic susceptibility of paleosol at stage Sm is as 1.5 times as that of loess stage, at stage S_0 and S_1, is 3—4 times more than loess stage. The magnetic stratigraphy is consistent with visual distinguishing of loess and palaeosol layers.

Pollen records from loess and paleosols can reveal paleovegetation features inferring the major climatic shifts. Fig. 4 shows the results of pollen analysis at Linxia section. The concentration of pollen was high in paleosols and low in loess. There was considerable amount of lignosa at paleosols, but in loess most of them was herb. The period from paleosol to loess, just as the early cold phase, was the developing time of dark coniferous forest major with pine, dragon spurce and fir.

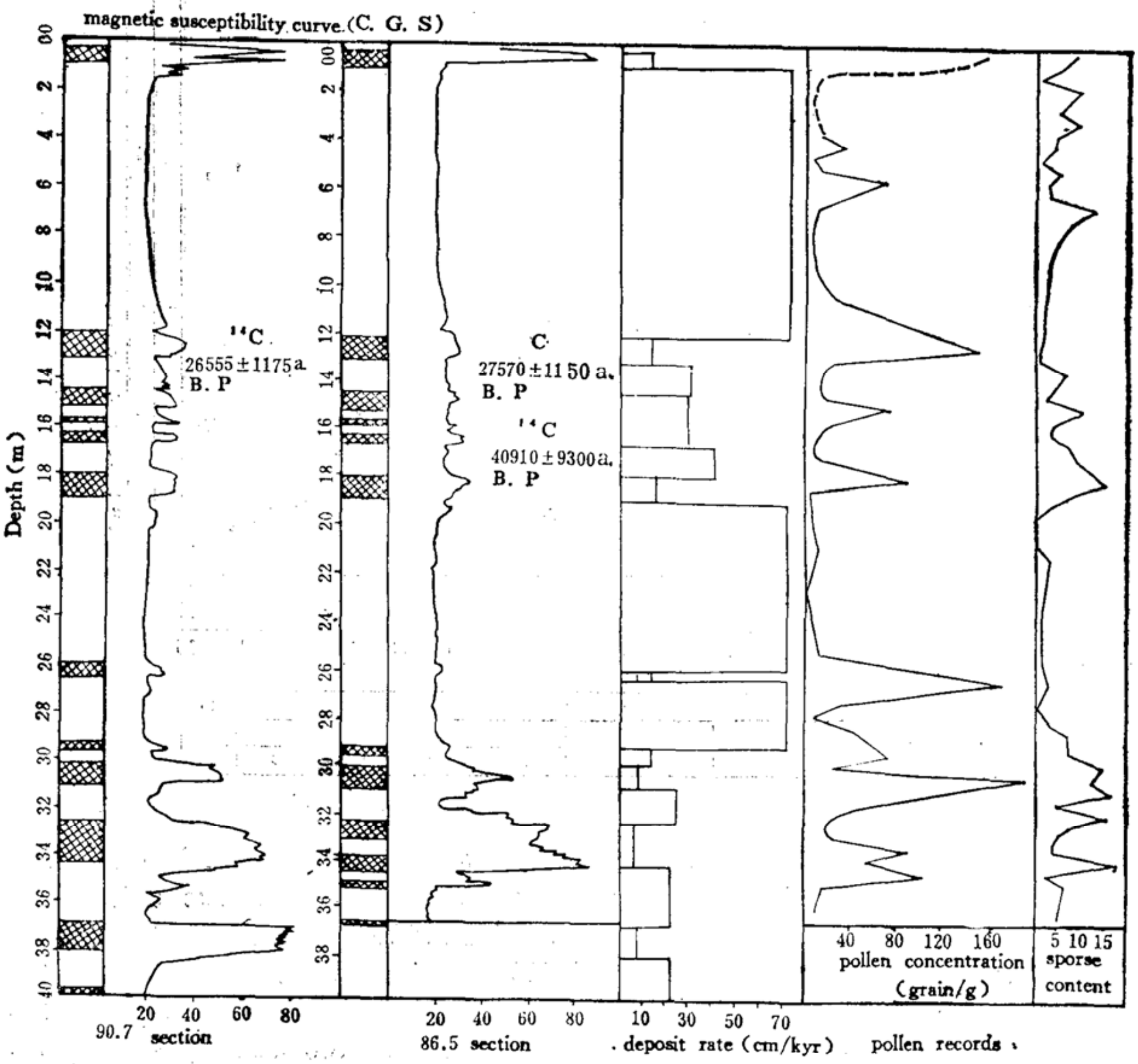

Fig. 4. Magnetic susceptibility, deposit rate and pollen records of Linxia section in China.

In middle of the cold phase as about 60,000 a. B. P. and 18,000 a. B. P., the major plants were sage, chenodiaceae, lompositae, just like vegetation of arid desert steppe.

According to pollen assemblages, we can conclude that the precipitaton in last Interglacial age was more than 200 mm, and the temperature was 3°C higher than that at present. In last Full Glacial age, the temperature was 7.8°C lower, and the precipitation (30% as much as today) was 350 mm less than that at present.

2. Records of Chinese loess compare with Antarctic ice cores

The environmental change revealed by Antarctic ice cores over last 150,000 years was divided into 8 stages as A-H (fig. 5) (Lorius *et al.*, 1985, Jouzel *et al.*, 1987). Among these, stage H was about the same to the sixth stage of deep sea core $\delta^{18}O$, or the Penultimate Glacial period, stage E, F and G matched the 5th stage of $\delta^{18}O$ stage D corresponded to the 4th $\delta^{18}O$, or early period of the last Glaciation; stage C, the 3th $\delta^{18}O$; stage B, the 2nd $\delta^{18}O$, or the main Wurm Glaciation; stage A was about the same to the 1st stage of $\delta^{18}O$, or Holocene. The variations of temperature revealed by ice core records as: At cold phases, stage B, D and H were about the same level. Stage F was about 2°C higher than stage B, D and H, the cold phase of middle stage E was warmer than stage F. At warm phases, temperature in Holocene was about 8°C higher than that in last Glaciation. The temperature of the warm term in the last Full Interglacial age (stage G) (equal to substage 5e of deep sea $\delta^{18}O$, but last for a longer time), was 3°C higher than that in Holocene. The highest temperature at stage E (about the same to 5a, 5c) was about 3°C lower than that in Holocene, and at interstadial of the last Glaciation (stage C) it was 5—6°C lower than in Holocene.

By comparing the results from loess section of Linxia in China with environmental change records from Vostok ice core over last 150,000 years, we know, these two records are derived from different semispheres, but both of them have remarkable similarities in revealing environmental change (Fig. 5). The similar points are that phase Le of Linxia loess section corresponded to phase H of Vostok ice core; S_1 corresponded to E, F and G; and L_{1-2}, Sm, L_{1-1}, S_0 corresponded respectively to D, C, B, A. There were two weak pedogenic layers at lower part of L_{1-2} of Linxia section, along with peak values of magnetic susceptibility, the short developing periods of dark coniferous forest, and the periods of precipitation increased. Correspondingly, at early phase D of Vostok, there were two terms that temperature rose a little. Four peak values of magnetic susceptibility were at Linxia section during 53,000 —25,000 a.B. P.. and also, within Vostok ice core and Byrd ice core, four relatively high temperature periods were at interstadial of the last Glaciation during 58,000—30,000 a. B. P. (Jouzel et al., 1987, 1989). In Linxia section, there were two short developing periods for herb at about 12,000 a.B.P. and 15.000 a. B.P., and at the same time in Byrd ice core, two periods of temperatural fluctuation were occurred. Therefore these two kinds of records have no difference in revealing climatic fluctuations on a long timescale (thousands years), which indicates the concordance and comparability of the global environmental change. Moreover, the environmental change is synchronous in south and north semisphere, this conclusion is obtained from deep sea records by Hays *et al.* (1976), and verified again from terrestrial records.

Through comparing with deep sea records, some significant differences can be found. First of all environmental charateristics revealed by Linxia section at early and late full stage of the last

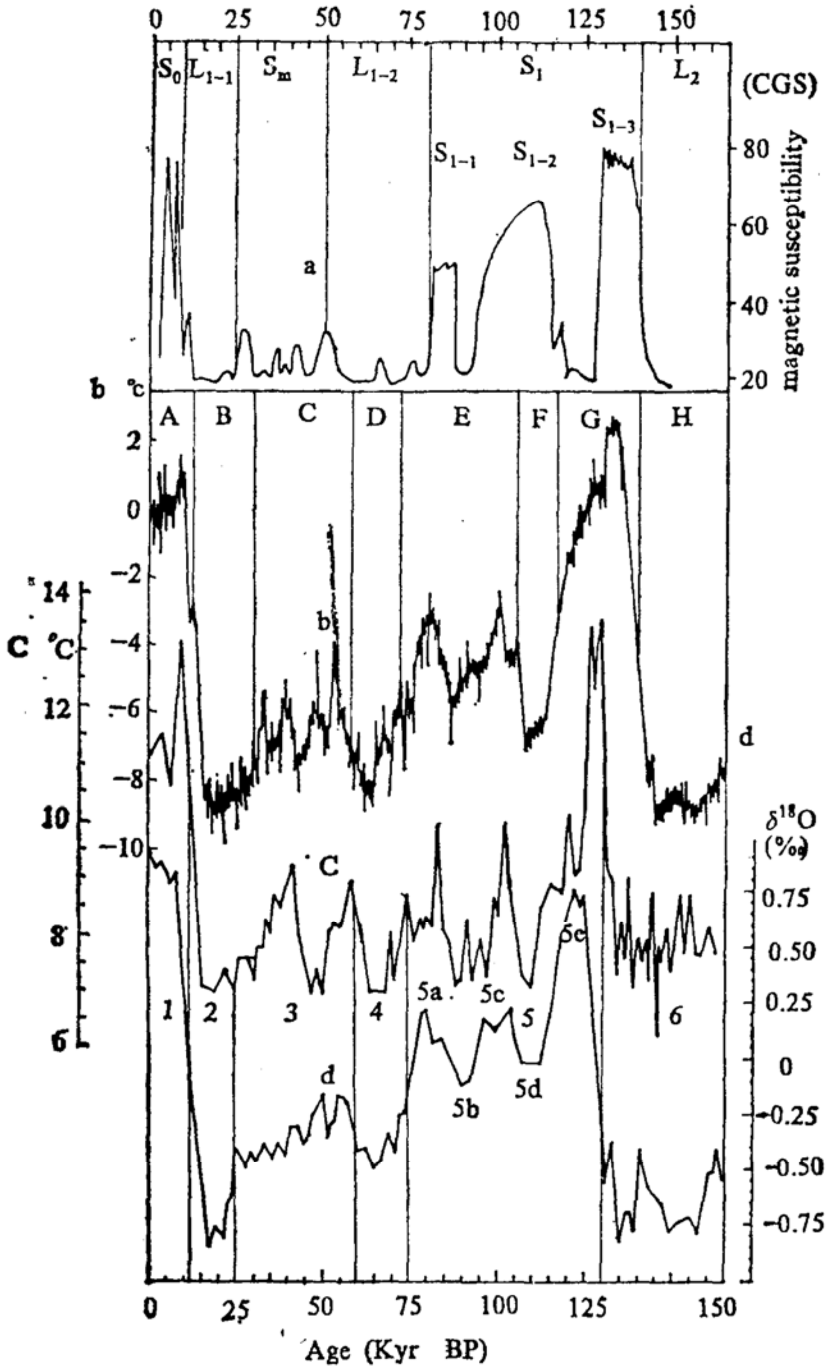

Fig. 5. A comparison of loess deposit with ice-core and deep-sea core.

Glaciation (about 60,000 a.B.P. and 18,000 a.B.P.) were remarkably similar, which were the same as Vostok ice core. However, among deep sea records (Hays et al., 1976. Shackleton and Opdyke, 1973, Martinson et al., 1987), these two stages, i. e., stage 2, 4 of $\delta^{18}O$, the decline value of sea level (expressed by $\delta^{18}O$) had greater difference. Secondly, at stage S_1 (140,000—80,000 a.B.P.) of Linxia section, two loess layers were in between three paleosol layers. The magnetic susceptibility of these loess substages corresponded to that of loess (L_{1-1E}, L_{1-2}) deposited in the last Full Glacial age. That means the climatic features of these two substages in S_1, were about the same to that in the last Full Glacial age, if magnetic susceptibility can be used as substitutive index to describe paleoclimate (Kulka, 1987, 1988). To use $\delta^{18}O$ as climatic index to explain Vostok ice core by Lorius *et al.* (1985), also revealed that the climate at stage F was on the same scale as that at B and D. However, there were some differences between them when used δD as index (Jouzel, 1987). Having studied paleoglaciation in Rocky Mountains, North America, Richmond (1972) pointed out that there were two periods of glacial advance at about 120,000 a. B. P. and 90, 000 a. B.P., glaciers reached the extent of the last Full Glacial age. Therefore, these differences are because of climatic differences, or the mistake from climatic index, which need further research. Thirdly, at Linxia section, the maturity of the three paleosol layers S_{1-1} S_{1-2}, S_{1-3} of stage S_1 were

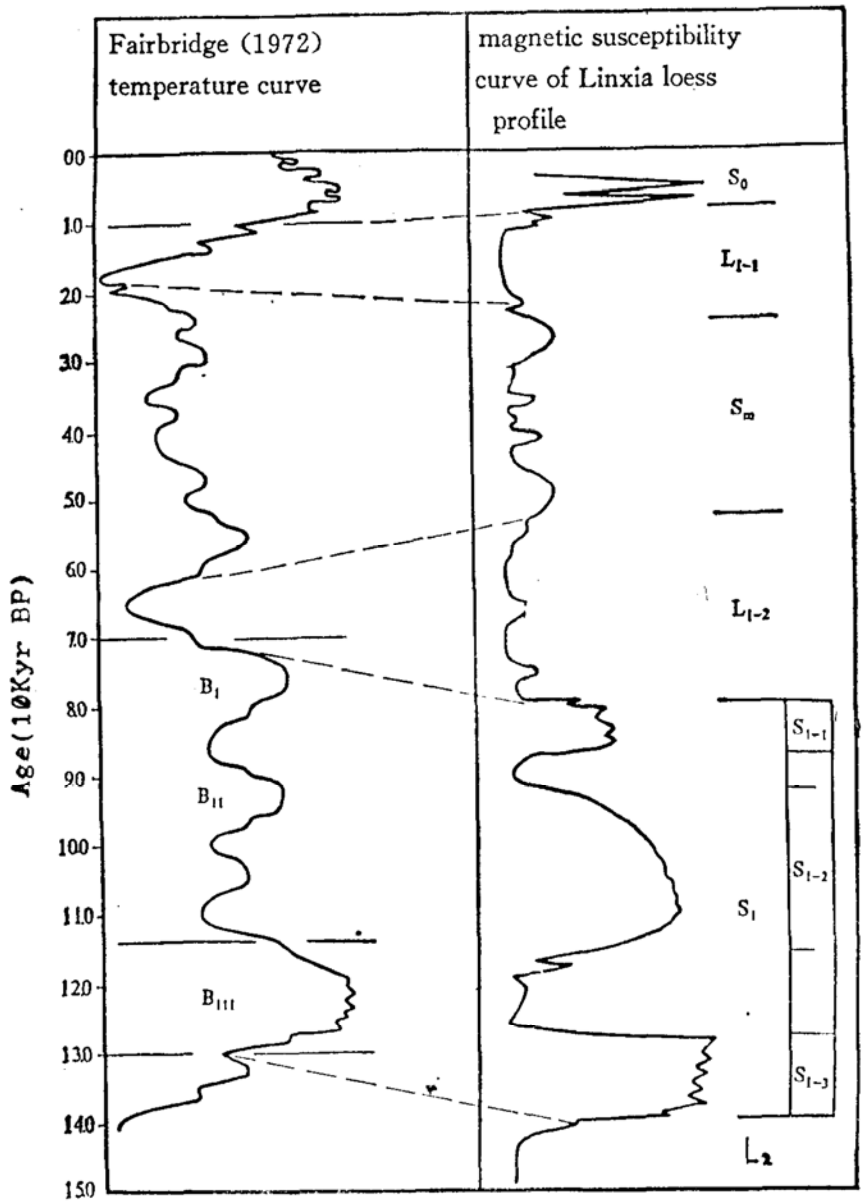

Fig. 6. A comparison of magnetic susceptibility curve of Linxia loess section with ideal temperature curve modeled by Fairbridge (1972) over last 150,000 years.

wakened from the oldest to the youngest. This result is different from Vostok ice core and deep sea records. At stage E of Vostok ice core, the two highest values of temperature were very approximate, but only a half of the value of stage G. Records of deep sea core RC11-120 in South Indian Ocean showed that, the substages 5a, 5c had the similar value and lower than 5e. Therefore, the record of loess at this point, is different to ice core and deep sea core. In 1972, Fairbridge modeled the ideal temperature curve for the late Quaternary, which is similar with the magnetic susceptibility curve of Linxia section (Fig. 6). From this, it can be got that the magnetic susceptibility of paleosol layer S_{1-2} at Linxia section was higher than that of S_{1-1}, lower than S_{1-3}, and the paleosol layer was thicker than that of S_{1-1} and S_{1-3}, the reason was that the period of S_{1-2} at Linxia section was equal to the developing time of the B_2 terrace and early-subterrace in Barbadose (Fig. 6). It means paleosol S_{1-2} developed longer, but climate condition in developing time is not as good as the forming time of paleosol S_{1-3}.

Comparative research shows that, fluctuation tendecies of environmental charateristics recorded by Chinese loess and Antarctic ice cores over last 150,000 years were concordant. The ranges of variation, during the last Interglacial age, have greater difference between these two records. When comparing with deep sea records, it shows that marine and terrestrial environmental records have a world of difference at early and late stage of the last Glaciation.

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