

RECORDS OF TWO ASTROGEOLOGIC EVENTS IN THE LOESS STRATA, LANTIAN, SHAANXI, CHINA*

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The thick loess strata in the Loess Plateau of China, which have not been essentially reformed by internal and external agents, are one of the optimum continental deposits preserving the extraterrestrial materials in the last 2.5 Ma. Thus, combining the records with the detailed data of the loess-paleosol sequence, the ages and environmental impacts of the astrogeologic events can be determined.

I. STUDY SECTION AND HORIZONS WITH MICROSPHERULES

Duanjiapo section on Bailu Yuan, which is located on the south margin of the Loess Plateau, lies about 0.5 km to the north of the Duanjia village ($34^{\circ}12'N$, $109^{\circ}12'E$, Fig. 1). The loess-paleosol sequence of the section is 134.5 m thick, and the top is about 760 m in altitude. According to the magnetostratigraphical study^[1], the Brunhes/Matuyama (B/M) and Matuyama/Gauss (M/G) boundaries are at the depth of 47.7 m and 133.5 m respectively. Based on the possible generation ages concerning the astrogeologic events at home and abroad, 24 samples (LD1—LD24) and 23 (LD25—LD47) were respectively collected from two segments at 44.5—46.9 m and 129.8—132.1 m depth. The sampling interval is 10 cm and the weight of samples is about 2 kg each.

After the samples were cleaned with water and dried in an oven, the particles of more than 100 μm in diameter have been sifted out and observed under a stereomicroscope. Fortunately, several dozen of microspherules have been discovered at the two segments mentioned above. 32 microspherules are found in 4 samples, LD3—LD5 of the S_6 base and

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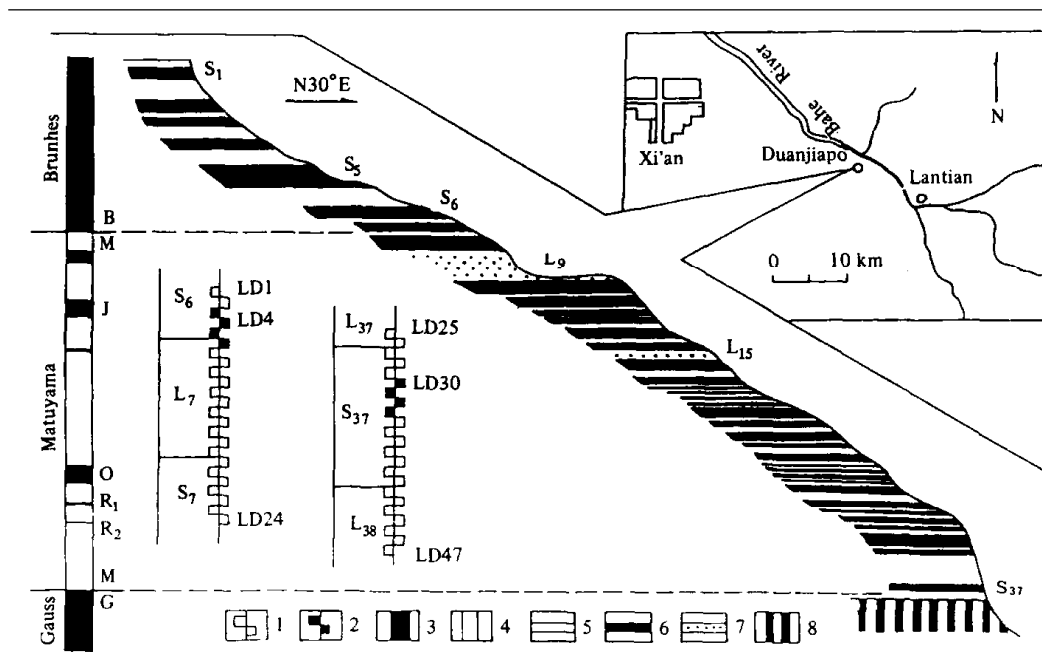


Fig. 1. Duanjiapo section and its position and sampling segments.

1. Sample points without microspherules; 2. sample points with microspherules; 3. normal polarity; 4. negative polarity; 5. loess layers; 6. paleosol layers; 7. silt layers; 8. red clay.

LD6 of the L_7 top, among which LD4 has more than the other 3, while 22 are discovered in samples LD30 — LD33 of the middle part of S_{37} , among which LD30 contains more microspherules compared with the other 3. With reference to the ages of B/M and M/G boundaries and the timescale of magnetic susceptibilities, the ages of the two segments with microspherules are respectively 0.66—0.68 MaBP and 2.42—2.44 MaBP.

II. APPEARANCES AND CHEMICAL CHARACTERISTICS OF THE MICROSPHERULES

The appearance of the microspherule assemblage found in S_6 and L_7 is extremely similar to that in S_{37} (Fig. 2). Stereomicroscope observation indicates that these microspherules, ranging from 135 to 300 μm in diameter, are chiefly in the form of hollow spherical and elliptical peloids, together with moniliform, dumbbell-like, mushroom, botryoidal aggregates and irregular shards, and in the colour of black, brown, yellow and colourless, especially black and dark brown. Most of the microspherules, usually brittle and accompanied with irregular fractures, have a shiny and smooth surface. SEM studies for 12 microspherules show various surface features, such as netlike, ring microfissure, gas cavity and gas print structures, and circular concavities, tumourlike projections and irregular micropore spaces, which are analogous to the surface features of cosmic dusts.

The major element data in Table 1 have been obtained from X-ray energy spectral analysis for 12 microspherules with different appearances, 4 grains from S_6 and 8 grains from S_{37} . Among them SiO_2 and Al_2O_3 in 91167 and 91169 are higher in content, which are close to the microtektite composition^[2, 3]. In addition, preliminary results of neutron activation analysis

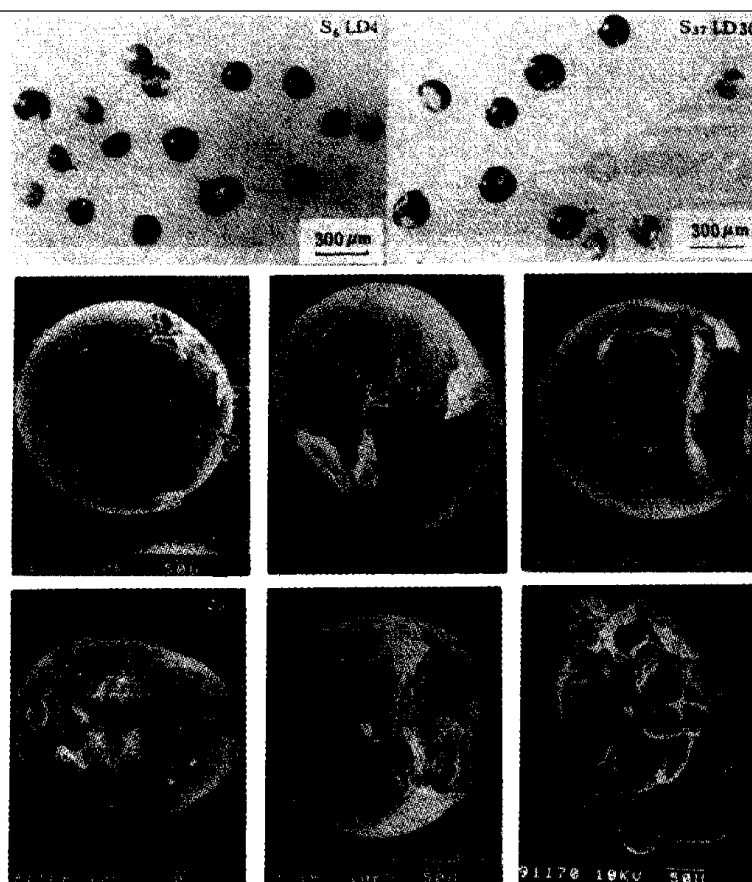


Fig. 2. Microspherule assemblages in LD4 and LD30 and the individual surface features.

LD4 and LD30, Stereomicroscope photo; 91162, ring microfissure, SEM micrograph, the same in the following; 91163, polygonal cracks; 91165, netlike structure and circular concavity; 91166, irregular cracks, gas cavities and netlike fissure; 91167, crumpled structure; 91170, botryoidal aggregate.

Table 1
Major Element Data of the Microspherules in S₆ and S₃₇ of Duanjiapo Section, Lantian

No. Compon. (%)	S ₆				S ₃₇							
	91163	91164	91165	91166	91162	91167	91168	91169	91170	91171	91173	91174
Na ₂ O		1.23				1.05	5.23		0.18		1.32	2.08
MgO	0.85	3.25	3.45		7.09	1.27	3.86	0.66	0.09	5.09	7.03	5.97
Al ₂ O ₃	5.90	10.27				14.18	9.49	14.79	0.69		12.90	6.90
SiO ₂	19.31	15.07			1.67	51.49	33.12	67.62	2.67	4.17	10.45	8.82
K ₂ O	3.05	2.35		1.23		8.26	9.85	2.80		0.73	4.49	0.53
CaO	61.20	54.06	86.99	94.13	82.33	13.72	22.71	5.18	2.25	82.22	51.07	70.69
TiO ₂		1.38						0.94			2.09	
Cr ₂ O ₃											2.00	
MnO	0.29	2.04			1.72	0.08	4.27			0.62		3.00
FeO	9.37	2.31			0.02	6.79	7.54	7.90	88.92	0.81	8.58	0.25
SO ₃		7.90	9.44	4.60	7.20	3.11	4.02		2.14	6.18		
Total	99.97	99.86	99.88	99.96	100.03	99.95	100.09	99.89	96.94	99.82	99.95	98.24

Note: X-ray energy spectral analysis was conducted by Chen Ke-qiao (Institute of Mineral Deposits, Ministry of Geology and Mineral Resources, PRC).

for each of 7 grains, whose appearances look like that of grains to be analysed with X-ray energy spectrum, illustrate (1) enrichment of siderophile elements including platinum group elements, (2) REE patterns similar to that of meteorites, and (3) the element correlations close to the solar abundance ratios of several trace elements, that is, there probably exist some chemical criteria for extraterrestrial origin in the horizons^[4-8]. Comparing the trace element data in the two horizons, platinum group element anomaly of the horizon in S_{37} is larger than that in S_6 . Roughly speaking, fewer grains of them are rich in FeO and belong to iron-rich extraterrestrial microspherules, such as brown and botryoidal aggregate, 91170, but most grains, black, brown and yellow in colour, have higher calcium. It is noticed that CaO content of 91162 black grain untreated with dilute hydrochloric acid is more than that of 91173 black grain immersed in it. However, these grains have been more or less overlapped by the secondary calcium coming from the loess strata, which are still the higher calcium extraterrestrial microspherules.

It can be seen that most of the microspherules in S_6 and S_{37} are of probably extraterrestrial origin except a little microtektite. Based on the phenomenon that the extraterrestrial microspherules were mixed with the microtektites in the same horizon, these microspherules belong to the fusion type of cosmic dusts, which were formed by pneumatolism, melting and explosion of the minor celestial bodies that come from the strong shock heating, when they passed through the atmosphere at great speed and altitudes before impacting the Earth.

III. DISCUSSION

1. Attention has been extensively paid to the polarity transitions of paleogeomagnetic field and global change characteristics in about 2.5 Ma BP by the Earth scientists. Discussing the geologic significance of the Quaternary lower line and M/G boundary, Liu Tungsheng et al.^[9] dealt with the layer of noble metal anomaly about 2.3 Ma BP in Core E_{13-3} of the Antarctic^[10]. The possibility of developing the Ice Age and paleoclimate cycles by the impact events of the extraterrestrial bodies has been discussed by Ouyang Zi-yuan et al.^[1] who quoted the impact event of the extraterrestrial body, 0.5—1 km in diameter, about 2.4 Ma BP. The super-microtektite record has been studied by Yuan Bao-yin et al.^[11] from the bottom of Wuchang Loess to the top of Red Clay in Heimugou section, Luochuan. Then, the exact horizon and age have been indicated on the basis of the extraterrestrial microspherules in S_{37} of Duanjiapo section, Lantian. It is reasonable to consider that the nutational phenomenon of global climate change and biotic evolution took place in about M/G boundary.

2. Another impact event of the extraterrestrial body, forming the microtektites widely in Asia-Australia area^[12], has been affirmed at about 0.7 Ma BP which is also an important

1) Ouyang Zi-yuan, Cheng Hong-de, Zhang Yan-hong & Quan Yun-bin, The possibility of developing the Ice Age and paleoclimate cycles by the impact events of the extraterrestrial bodies, Paper for the symposium on the fourth national meteoritics and space chemistry (in Chinese).

time of the climatic and environmental variation in the Pleistocene. The microtektites are predominant in the microspherules discovered by Li Chun-lai¹⁾ at L₈ over B/M boundary, but the microspherules found by us at S₆ over B/M boundary mainly come from extraterrestrial space. Moreover, the two records are divided by two layers, L₇ and S₇, and occupy the time interval of about 50 ka.

3. It can be shown that the quite close relationship existed in both of the nutational events in the climatic and environmental change sequence and the astrogeologic events in the late Neogene. In various terrestrial deposits, the red clay and loess widely distributed in the Loess Plateau, which is much thicker than the marine deposits in the same time, can be offered to study the Pliocene and Pleistocene astrogeologic events in detail. It will be helpful to carry out the further studies concerned, completely and perfectly, to understand the step development of the past global change, to solve the problems of the Quaternary lower line and the subdivision within the Pleistocene, and even beneficial to the study and discussion on the origin, mechanism and model of the long-term changes of global climate and environment.

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1) Li Chun-lai, Discovery of microtektites and glassy microspherules in the loess strata and its significance, Master's thesis, 1991 (in Chinese).