IL NUOVO CIMENTO VOL. 21 C, N. 2 Marzo-Aprile 1998

Study of microspherules in the Permian-Triassic boundary of Wanmo section, Guizhou province, China, by PIXE analysis (*)

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(ricevuto il 17 Novembre 1997; approvato il 20 Marzo 1998)

Summary. — Many microspherules were extracted from the shale of the Permian-Triassic boundary of Wanmo section in the Guizhou province of China. Their number abruptly increased at one place leading to an interesting pattern similar to previous studies. The chemical patterns of these microsperules determined by PIXE analysis were compared with previous results from magnetic components of shale and meteorites. In contention with previous studies illustrating the intrusion of microspherules into the Solar System, it is postulated that the Solar System encountered the giant molecular clouds and the microspherules of the present study came from there.

PACS 96.50.Mt – Meteorites, micrometeorites, and tektites.
PACS 98.38.Cp – Interstellar dust grains.

1. – Introduction

Extraterrestrial materials always fall on the Earth and on average about 103-104 ton fall every year. It is important to pursuit the origin of these cosmic matter for cosmo-geophysical studies. Although many researchers have studied microspherules in sedimentary rocks, their origin has not yet been fully understood. It follows from previous studies on composition of microspherules, collected from the Paleozoic-Mesozoic and Permian-Triassic bedded chert in southwest Japan, with PIXE analysis, that they have an extraterrestrial origin and the Solar System encountered a giant molecular cloud in the past. In this paper, we provide new evidence from microspherules from the Permian-Triassic boundary of Wanmo section in the Guizhou province of China.

2. – Sampling methods and analytical techniques

Permian-Triassic (P/T) boundary is exposed at more than twenty locations in China. We collected samples from ten spots around Wanmo section (fig. 1). Using a hand magnet, the magnetic components were carefully separated from the crushed powder

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(*) The author of this paper has agreed to not receive the proofs for correction.

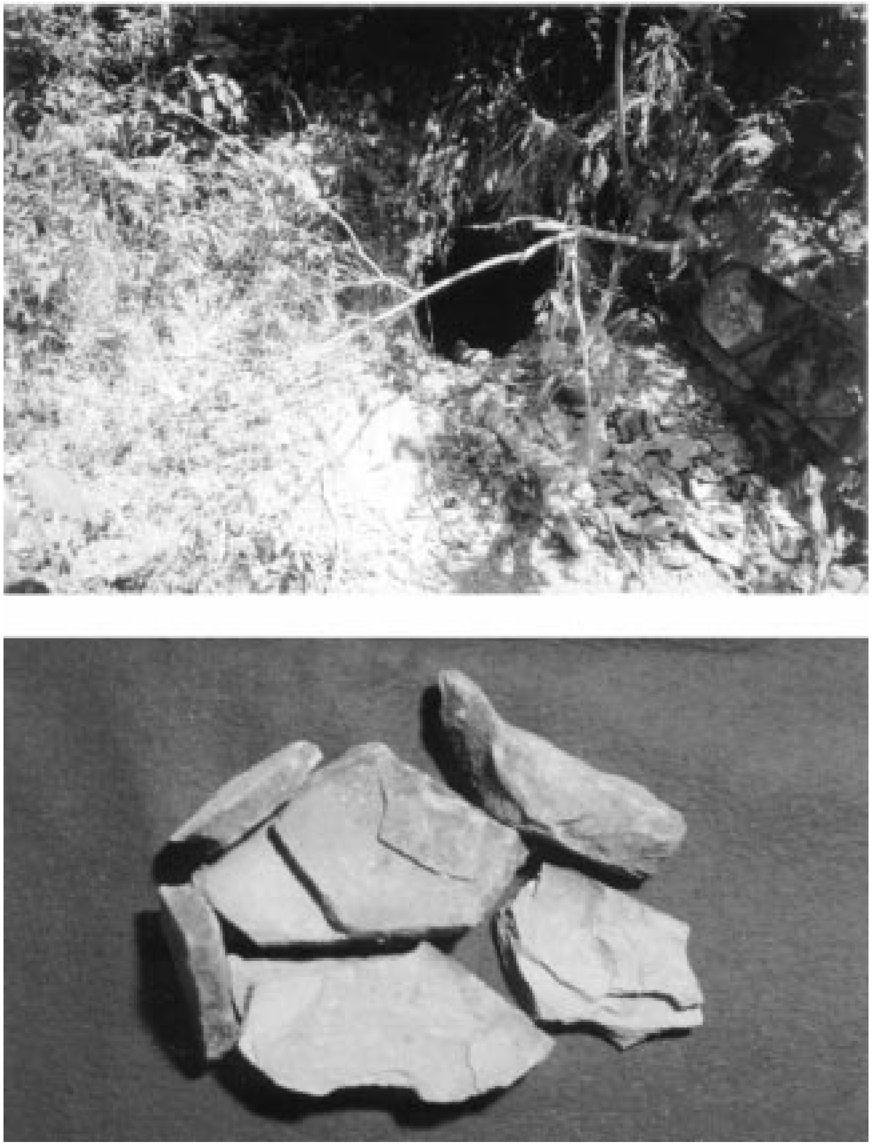

Fig. 1. – Top: photograph showing a sampling site from the Permian-Triassic boundary at the Wanmo section, Guizhou province, China. Most of the samples of the present study were collected in and around this site. Bottom: photograph showing a shale sample collected from the sampling site mentioned in the top figure.

and microspherules were picked up with a needle under stereomicroscope. The number of microspherules in unit mass from ten samples were counted under stereomicroscope. An interesting thing noticed is the sudden increase in the number of microspherules (about hundred times more) at one spot in comparison with the other spots (fig. 2), which is similar to the one observed at the P/T boundary of the Sasayama section, Southwest Japan [1].

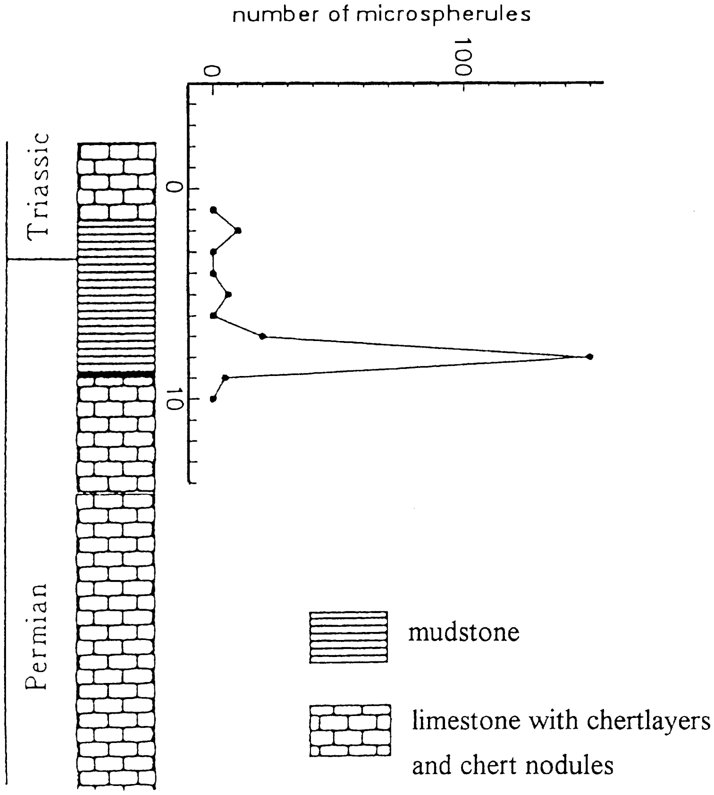

Fig. 2. – Figure showing the stratigraphic column of the Wanmo section. The variation in the number of microspherules per unit mass at the various sampling spots is also given. An interesting feature noticed is the sudden increase (about hundered times more) in the number of microspherules at one spot.

The surface features of these microspehrules were observed under scanning electron micrograph (fig. 3). Under the stereomicroscope, the microspherules were separated into two between the glass plates (fig. 4). In each section of the microspherule, one can see that it never contains a metallic nucleus, and is almost hollow.

Chemical patterns of the microspherules were obtained by PIXE analysis, and for comparison magnetic components of the shale were also analyzed. The important factor relating to the accuracy of PIXE analysis is the backing material. In order to minimize background, we have adopted highly pure and very thin carbon fibers as backing material as illustrated in previous works. The sample holder was improved to a circle shape. PIXE experiments were carried out using 1.5 MeV proton beam from accelerator (Compact Disktron, Physitec Co. Ltd., Tokyo, Japan) at Retsumeikan University, Japan. The intensity of the proton beam current was 10-20 nA on the target with an irradiation of 15-20 min in the vacuum state. The spectra were recorded, and were analyzed by an on-line computer system.

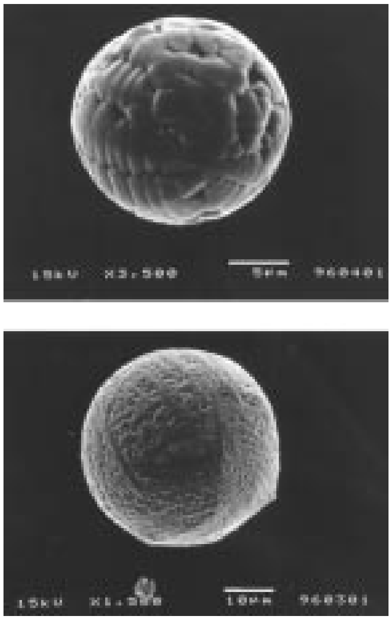

Fig. 3. – Scanning Electron Microphotographs of the surface of two organic microspherules.

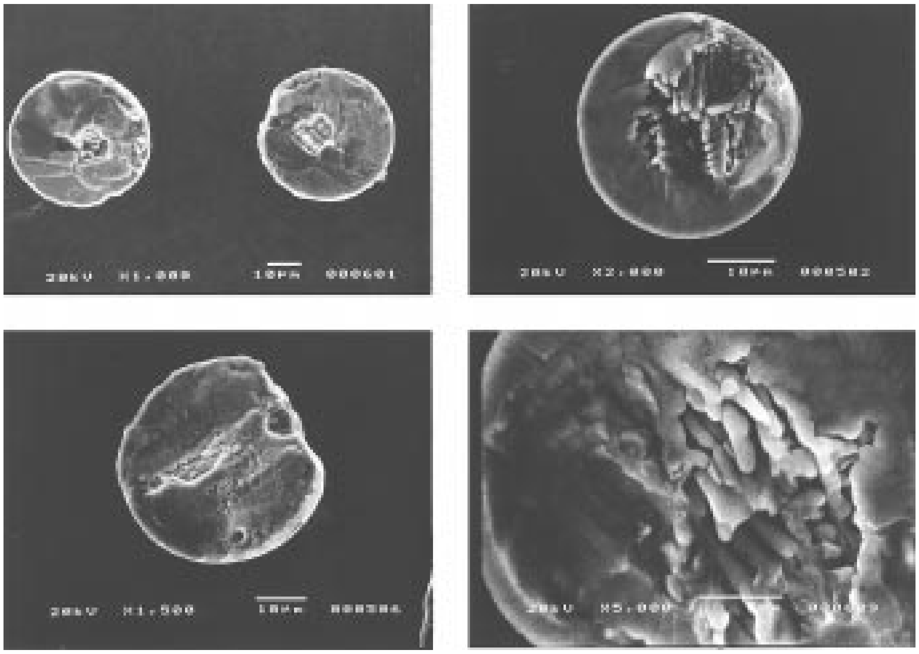

Fig. 4. – Scanning Electron Microphotographs showing the internal texture of microspherules. A close observation of these microspherules reveals that they never contain a metallic nucleus and are almost hollow.

3. – Results and discussion

The Ti/Fe, Cr/Fe, Mn/Fe, Co/Fe and Ni/Fe ratios of microspherules and the magnetic components of the shale are summarized in table I. The data of meteorites from previous studies are also quoted for comparison [2]. The ratio of Ti/Fe *vs.* Cr/Fe (fig. 5) and Mn/Fe *vs.* Ti/Fe (fig. 6), when plotted, indicate distinct groups for magnetic components of shale, and microspherules and meteorites, thus providing a useful index for distinguishing terrestrial and extraterrestrial sources. It is considered that titanium and chromium contents are more in terrestrial than in extraterrestrial sources, while cobalt and nickel contents are more in extraterrestrial sources. It follows from table I, figs. 5 and 6, that the microspherules clearly belong to the extraterrestrial group. Also Ti/Fe, Mn/Fe, Cr/Fe, Co/Fe and Ni/Fe ratios are closely similar to magnetite from carbonaceous chondrite from previous studies.

Astronomers estimate that since the Solar System was born, it encountered the giant molecular clouds about 15-20 times. Because of the effect of Lorentze force, they generally believed that it is not possible for the interplanetary dust to intrude into the Solar System. But the intrusion of the flow of interplanetary dust into the Solar System was discovered near Jupiter by Ulysses in 1993 [3]. S. Minami also showed the possibility that interstellar dust can enter the Solar System through an interesting simulation [4]. It follows from present and previous studies that microspherules were not only enhanced at the P/T boundary at Wanmo section, but also at Guanyunsu [5] section, Huanan section in China, and Sasayama section in Japan. It can thus be considered that when the Solar System traverses the giant molecular clouds, the microspherules flow into the Solar System, and hence enormous amounts of it will be accreted to the Earth and the Moon. As a result, the Earth environment was

TABLE I. – *Table showing the ratio of* Ti, Cr, Mn, Co, *and* Ni *to* Fe. “ND” *means not detected.* Sph—*microspherule,* Mag—*magnetic component of shale.*

Sample	$\mathrm{Ti/Fe}\cdot 10^{-2}$	$\mathrm{Cr/Fe}\cdot 10^{-2}$	$\mathrm{Mn/Fe}\cdot 10^{-2}$	$\mathrm{Co/Fe}\cdot 10^{-2}$	$\mathrm{Ni/Fe}\cdot 10^{-2}$
Sph (C1)	0.24 ± 0.04	0.21 ± 0.06	0.39 ± 0.04	4.16 ± 0.41	4.35 ± 0.38
Sph (C2)	0.16 ± 0.03	0.13 ± 0.04	0.57 ± 0.06	6.24 ± 0.45	7.39 ± 0.52
Sph (C3)	0.20 ± 0.05	0.12 ± 0.04	0.06 ± 0.03	1.36 ± 0.36	7.15 ± 0.40
Sph (C4)	0.09 ± 0.06	0.18 ± 0.05	0.04 ± 0.02	4.14 ± 0.39	6.35 ± 0.58
Sph (C5)	0.42 ± 0.05	0.22 ± 0.05	0.33 ± 0.05	3.02 ± 0.28	11.26 ± 0.53
Sph (C6)	0.49 ± 0.04	0.46 ± 0.05	0.19 ± 0.04	2.19 ± 0.23	5.39 ± 0.34
Sph (C7)	0.43 ± 0.06	0.23 ± 0.04	0.58 ± 0.07	5.95 ± 0.48	9.26 ± 0.52
Sph (C8)	0.53 ± 0.06	0.36 ± 0.05	0.57 ± 0.06	10.01 ± 0.61	11.74 ± 0.68
Sph (C9)	0.07 ± 0.03	0.31 ± 0.05	0.64 ± 0.07	18.13 ± 0.73	6.49 ± 0.05
Average	0.29 ± 0.05	0.25 ± 0.05	0.38 ± 0.05	6.13 ± 0.44	7.71 ± 0.49
Mag (C1)	68.58 ± 3.42	0.11 ± 0.04	0.81 ± 0.07	ND	ND
Mag (C2)	53.36 ± 2.73	0.13 ± 0.04	2.14 ± 0.11	ND	ND
Mag (C3)	21.38 ± 0.91	0.14 ± 0.03	0.93 ± 0.08	ND	ND
Mag (C4)	70.12 ± 3.40	0.23 ± 0.03	1.87 ± 0.08	ND	ND
Mag (C5)	17.36 ± 0.84	0.09 ± 0.02	0.81 ± 0.06	ND	ND
Mag (C6)	28.15 ± 1.56	0.38 ± 0.05	1.69 ± 0.08	ND	ND
Mag (C7)	9.15 ± 0.69	0.41 ± 0.05	0.42 ± 0.05	ND	ND
Mag (C8)	41.39 ± 2.34	0.15 ± 0.03	0.68 ± 0.04	ND	ND
Average	38.69 ± 1.98	0.21 ± 0.04	1.17 ± 0.07	ND	ND

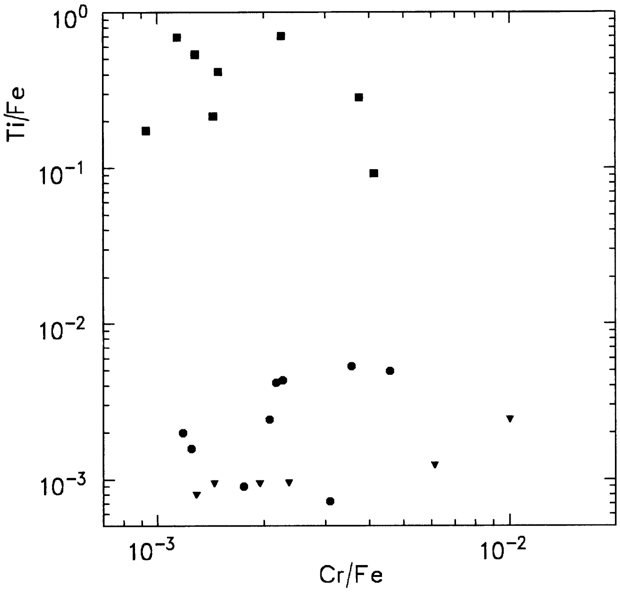

Fig. 5. – Figure showing a comparison of Cr/Fe and Ti/Fe ratios of microspherules (●), magnetic components of meteorites (▼), and magnetic components of shale (■), in a Cr/Fe *vs.* Ti/Fe plot. An important feature noticed is that microspherules and magnetic components of meteorites cluster together into a different group from the magnetic components of shale.

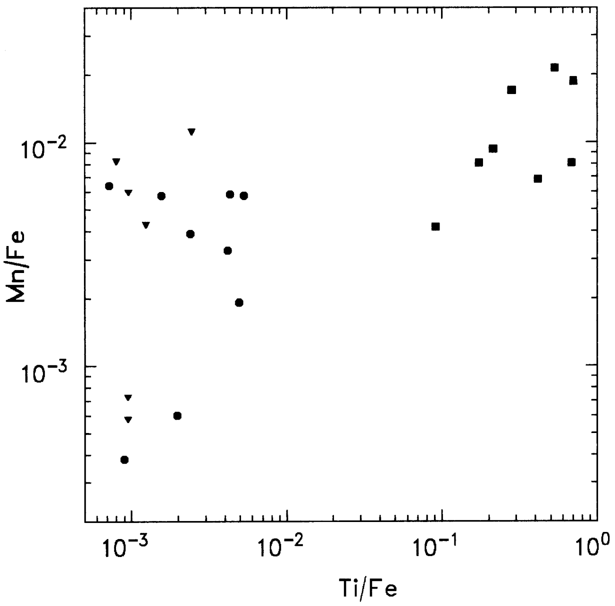

Fig. 6. – Figure showing a comparison of Ti/Fe and Mn/Fe ratios of microspherules (●), magnetic components of meteorites (▼), and magnetic components of shale (■), in a Ti/Fe *vs.* Mn/Fe plot. An important feature noticed is that microspherules and magnetic components of meteorites cluster together into a different group from the magnetic components of shale.

changed, resulting in mass extinction of living things. S. Yabushita supports giant molecular cloud modulation of extinction events with circumstantial evidence like amino acids and the oxygen depletion in the Cretaceous/Tertiary boundary [6]. Microspherules constitute an important evidence for the encounter of the Solar System with the giant molecular clouds.

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The author thanks Prof. S. MIONO, Osaka City University, Japan, for valuable discussions and advice. Thanks are due to Prof. Y. NAKAYAMA of Ritsumeikan University, Japan, for providing PIXE experiment equipment and Prof. K. SERA of Iwate Medicine University, Japan, for offering PIXE analysis program.

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