Microtektites in the Middle Pleistocene deep-sea sediments of the South China Sea*

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Abstract This is a preliminary study on the microtektites that were found in large numbers from the interval between 7.80 and 8.10 m depth of core SO95-17957-2 (10°53.9′N, 115°18.3′E, water depth 2 195 m), northern Nansha area of the South China Sea. The microtektites vary in shape, with spherules predominating, and are commonly less than 1 mm in diameter, transparent or semitransparent, brownish in color, with bubbles inside. Based on coarse fraction stratigraphy and foraminifera/nanofossil biostratigraphical events the microtektite layer was assigned to nearly the Brunhes/Matuyama magnetic reversal boundary (some 0.78 MaBP). Obviously, the present microtektites, and those found from the middle Pleistocene of the Indian Ocean, Australia and loess of northern China, were products of the same impact event and therefore, are useful as a reliable mark in Quaternary stratigraphy, as well as in paleoclimatic studies.

Keywords: microtektites, coarse fraction, geological age, South China Sea.

During May and June, 1994, the R/V Sonne carried out its SO95 cruise under the Sino-Germany cooperative project "Monitor Monsoon" on the South China Sea, and collected a large number of deep-sea cores[1]. A preliminary study on core SO95-17957-2 has revealed that this core recorded a depositional history of more than one million years, and particularly, large numbers of microtektites are found from this core, that is the first time in the South China Sea.

1 Location and material

Core 17957-2 was taken from the northern Nansha area of the South China Sea (10°53.9′N, 115°18.3′E, water depth 2195 m and core length 13.84 m), and lithologically it consists of gray foraminiferal mud throughout. Generally, samples of 3 mL sediment were collected at 10-cm intervals for micropaleontological analysis, and at 5-cm intervals in the section containing microtektites. The microtektites are found mainly from between 7.80 to 8.15 m in core depth. Altogether 759 microtektites are picked out, of which 590 are complete in form while the rest are broken. The microtektites are most abundant in the two samples at depth 8.05 and 8.10 m, from which 323 and 309 microtektites are obtained respectively, and their number decreases markedly up- and downwards. For instance, 49 microtektites were found downwards in the sample at depth 8.15 m, and 41, 15 and 8 microtektites upwards in the samples at depth 8.00, 7.90 and 7.80 m respectively. Very few

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microtektites were encountered in the depth of 6.60—7.60 m.

2 Physical and chemical features of microtektites

2.1 Morphology

Microtektites vary in shape. Spherical microtektites (fig. 1-1. 2) are very common, making up 44% of the complete microtektites. Disk-shaped microtektites rank second in abundance (17.2 %), followed by flat ellipsoids (14.5%) (fig. 1-3), droplets (12%) (fig. 1-4—6) and elongate cylinders (9%). Dumbbells, winged bodies (fig. 1-7, 8) and other irregular forms occur occasionally.

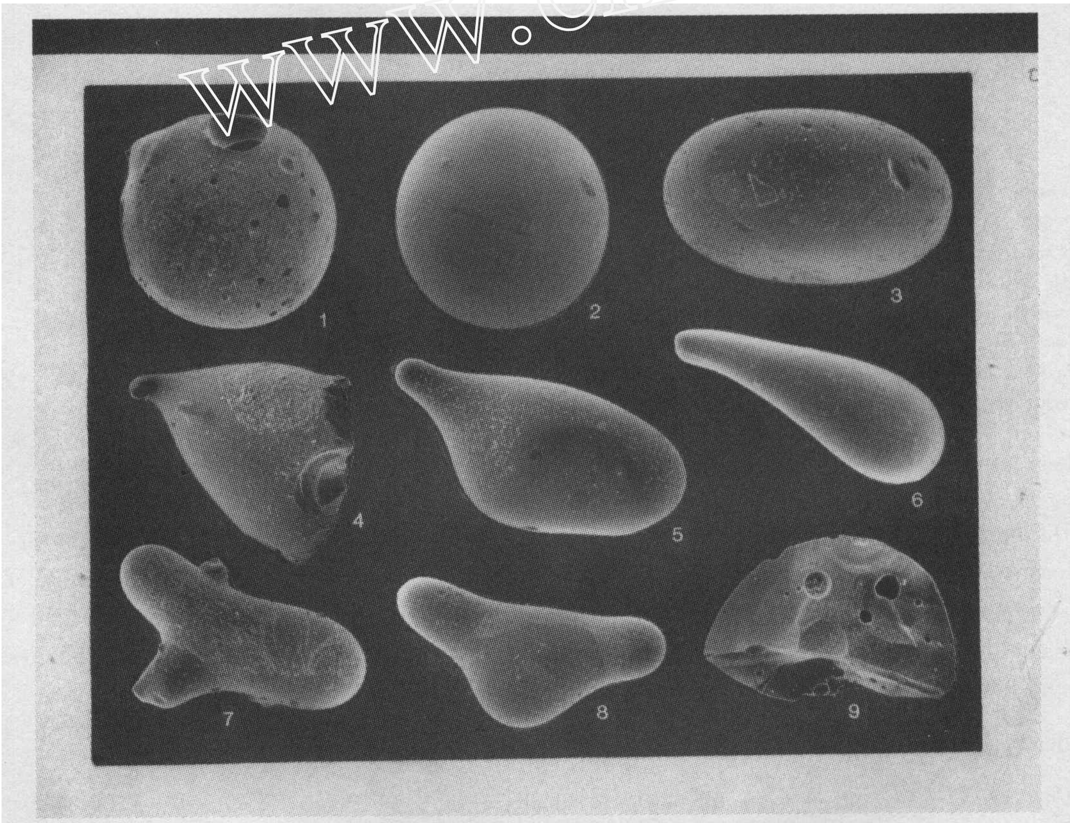

Fig. 1. SEM plate of microtektites from depth 8.05 m of core 17957-2. 1, Spherule, 0.22 mm in size, with rough surface and rounded pits; 2, Spherule, 0.20 mm in size, surface smooth; 3, ellipsoid, 0.21 mm long, with irregular pits; 4, droplet (broken), 0.39 mm long, with small attachment; 5, droplet, 0.41 mm long, with an impression (smooth area); 6, droplet, 0.46 mm long, surface smooth; 7, winged body, 0.42 mm long, with fine flowing lines; 8, winged body, 0.44 mm long; 9, debris, 0.37 mm long, showing smooth broken surface, bubble cavities and conchoid fracture.

2.2 Color

Under a bi-ocular stereomicroscope the microtektites are glassily transparent or semitransparent. About half of the microtektites are brown in color, and 43% light brown or very light brown. The rest are colorless (3.8%), dark brown (2.3%) or light yellow (0.5%).

2.3 Size

Microtektites exhibit a wide variety in size, but most are less than 1 mm in length or diameter with 85% being less than 0.45 mm. The average size measures 0.35 mm for the spherules and disks. The maximum size reaches 1.12 mm in diameter for spherules, and 1.30 mm in length for elongate forms.

2.4 Surface structure and bubble cavity

The surface of most microtektites is smooth, but some are mat. Rounded or irregular pits (fig. 1-1,3), impressions (fig. 1-5), fine flowing lines (fig. 1-7) and attachments (fig. 1-4,7) are occasionally present on the surface of some microtektites. The broken surface of the microtektites is usually plane and smooth with sharp margins, and in some cases with conchoid fractures (fig. 1-4,9). Most microtektites contain bubble cavities of various sizes (figure 1-9).

2.5 Chemical composition

The chemical composition of microtektites is shown in table 1, based on the X-ray energy spectral analysis of 5 microtektite samples.

Table 1 Chemical composition (mass fraction) of microtektites from core 17957-2

Sample	A (center)	A (edge)	B (center)	B (edge)	C (center)	C (edge)	D (center)	D (edge)	E (center)	E (edge)	Average
SiO_2	62.35	61.17	57.72	63.03	47.79	54.82	58.41	58.94	54.60	63.53	58.54
Al_2O_3	23.48	25.77	24.89	20.88	27.93	26.50	26.82	26.53	28.51	24.64	25.60
FeO	3.02	2.22	5.02	5.37	3.58	1.63	2.63	1.61	1.92	0.91	2.79
MgO	4.06	4.98	4.50	3.55	10.13	9.09	4.39	5.26	5.45	4.63	5.60
CaO	1.65	0.27	2.68	2.45	0.00	0.58	2.41	1.70	0.00	0.88	1.26
NaO	2.67	4.58	2.14	1.31	10.28	6.05	1.80	3.62	9.49	3.33	4.53
K_2O	2.06	0.97	2.25	2.60	0.27	0.53	2.57	1.92	0.00	1.55	1.47
TiO_2	0.68	0.00	0.76	0.78	0.00	0.76	0.94	0.39	0.00	0.48	0.48

A—E denote analyzed samples.

3 The age of microtektites

Bassinot et al. (1994) studied the coarse fraction of the ODP site 758 of the Indian Ocean and concluded that the fluctuations of coarse fraction correspond well to the glacial-interglacial cycles since the Middle Pleistocene (fig. 2 (a)). This provides a new tool for Quaternary stratigraphy and age determination. The contents of the coarse fraction (> 63 μm) in core 17957-2 vary from 15.9% to 76.1%. A comparison of fig. 2 (a) and (b) shows that the coarse fraction curve of core 17957-2 is similar to that of the ODP site 758 as well as to the $\delta^{18}O$ curve. Particularly, above 9 m of the core depth the curve is marked by a lower frequency and higher amplitude of fluctuations that corresponds to both the curves of coarse fraction and $\delta^{18}O$ of the ODP site 758 since 900 kaBP. Additionally, some biostratigraphical events provide more detailed age assignments. The last appearances of planktonic foraminifera *Globigerinoides ruber* (pink) and calcareous nannofossil *Pseudoemiliania lacunosa* are found at core depth of 1.4 and 5.6 m, indicating their age of 120 and 460 kaBP, or of the oxygen isotopic 5th stage and 12th stage, respectively[3,4]. Thus the position of the CF5 and CF12 stages can be determined in the curve of the coarse fraction of core 17957-2. The last appearances of both benthic foraminifera *Stilostomella* and *Pleurostomella* are found at core depth 6.8 m. According to the study of the extinction events of *Stilostomella* by Schönfeld (1996), these benthic foraminifers had disappeared gradually before 620 kaBP[5]. Judging from the comparison with ODP site 758 and the biostratigraphic events, the coarse fraction stratigraphy is applied to core 17957-2 with the CF stages corresponding to $\delta^{18}O$ stages (fig. 2(b)). The layer (8.05—8.10 m) with the maximum abundance of microtektites occurs near the boundary of stages CF19/20, corresponding to $\delta^{18}O$ stages 19/20, which in turn coincides with the Brunhes/Matuyama (B/M) pleomagnetic boundary. The age of the B/M boundary was commonly considered as 730 kaBP, but recent studies using radiometric determination and astronomical method have re-estimated the age at about 780 kaBP[6—8].

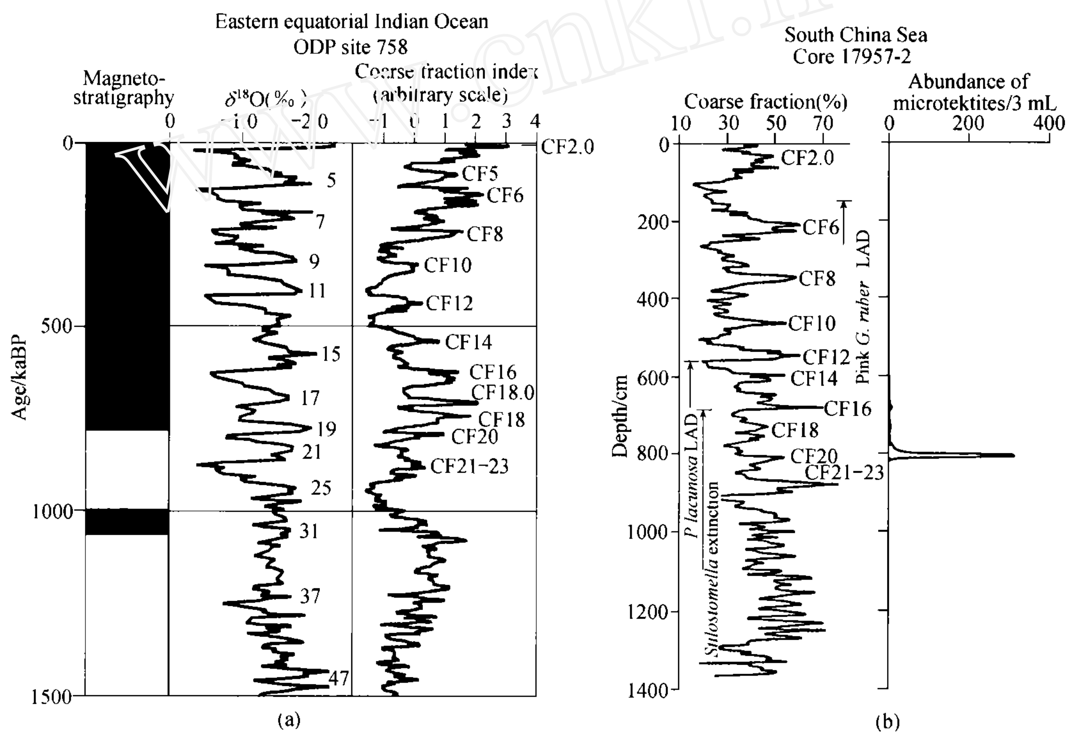

Fig. 2. A comparison of the coarse fraction curves and the $\delta^{18}O$ curve between ODP site 758 (a) and core SO17957-2 (b).

As early as the 1960s microtektites were reported existing in some deep-sea cores of the Indian Ocean near the B/M boundary[9,10]. Recently a few microtektites were discovered in loess of northern China[11,12]. The newly found microtektites from the South China Sea and tektites the so-called "Leigongmo", "Indo-China stone" and "Australian stone" are all undoubtedly products of one and the same impact event which occurred close to the B/M magnetic reversal (around 780 kaBP). The wide distribution area of the microtektites and tektites was called the Australasian strewn field.

4 Comparison and discussion

The simultaneous microtektites from the South China Sea, the Indian Ocean and loess display similar physical and chemical features, but they also show some differences. For examples, the mean diameter of microtektites of the Indian Ocean is 0.15 mm with the maximum 0.60 mm for the spherules[13]. The average size is 0.35 mm in the South China Sea with the maximum more than 1 mm. The microtektites in loess are smaller with its maximum size of 0.22 mm[11]. In the morphological aspect the spherules represent 84% of the microtektites in the Indian Ocean, but only 44% in the

South China Sea. The difference in form was probably artificial, associated with the finer mesh (38—40 μm) applied to washing samples from the Indian Ocean. A few dozen microtektites were found from hundreds of grams of loess sediments, and their abundance is considerably lower than that in the deep-sea samples. Chemically, the SiO_2 content is lower in the microtektites from the South China Sea than those from the Indian Ocean (Smith et al., 1991), but the Na_2O content is a little higher. Microtektites from loess are frequently rich in aluminum ($Al_2O_3 > 30\%$) and in magnesium ($MgO > 40\%$), which have not been encountered in the Indian Ocean and South China Sea. Some authors[11,12,14] ascribed the difference in the chemical composition of microtektites to the different composition of target rocks.

The depositional synchroneity and the wide distribution of the Australasian microtektites can be applied to the Quaternary stratigraphy study, providing a reliable mark in age determination, particularly due to the well-preservedness of the microtektites in the deep-sea sediments. Moreover, the environmental impact occurring around the B/M magnetic reversal (780 kaBP) has been attracting growing interest since the recent years[14—16].

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