Sr AND Nd DATA FOR UPPER EOCENE SPHERULE LAYERS. Shaobin Liu[1], B. P. Glass[1], H. H. Ngo[2], D. A. Papanastassiou[2,3], and G. J. Wasserburg[2], [1]Department of Geology, University of Delaware, Newark, DE 19716, [2]Lunatic Asylum, Division Geological Planetary Sciences, Caltech 170-25, Pasadena, CA 91125, [3]Earth Space Science Division, JPL 183-335, Caltech, 4800 Oak Grove Dr., Pasadena, CA 91109-8099 (shaobin@udel.edu).

Introduction: The late Eocene was a time of major climatic cooling and biotic turnover [1,2]. This was also a time when several large impact craters were formed, including the 90 km diameter Chesapeake Bay structure and the 100 km diameter Popigai crater in Northern Siberia [3]. At least two spherule layers have been found in upper Eocene marine sediments: 1) the North American (N.A.) microtektite layer and 2) the slightly older clinopyroxene-bearing (cpx) spherule (microkrystite) layer associated with a positive Ir anomaly [4,5]. Keller et al. [5] concluded that the cpx spherules belong to two separate layers: 1) an older layer of more Ca-rich spherules in the Eastern equatorial Indian Ocean and Western equatorial Pacific, and 2) a younger layer found in the central equatorial Pacific Ocean, Gulf of Mexico, and Caribbean Sea. Glass and Burns [6] argued that there was probably only one cpx spherule layer, based on overlap in petrography and composition of cpx spherules from the various sites. Wei [7] reevaluated the biostratigraphy and agreed that there was only one cpx spherule layer. Support for a single cpx spherule layer was provided by Whitehead et al. [8] who found that the Sr and Nd isotopic data are consistent with a single source for the cpx spherules. Several authors have suggested that the N.A. microtektites were derived from the Chesapeake Bay structure [9,10]. This is consistent with the Sr and Nd data for the N.A. tektites and microtektites [11-13]. It has been suggested that the Popigai impact structure may be the source of the cpx spherules [2,14]. This is supported by Sr and Nd studies [8].

In 1993, an Ir anomaly was discovered in upper Eocene sediments from the Maud Rise in the Southern Ocean (ODP Hole 689B)[15]. Vonhof and Smit [16] found cpx spherules and microtektites associated with the Ir anomaly at this site [16]. They concluded that the cpx spherules are similar to those at other upper Eocene sites and that the microtektites may belong to the N.A. strewn field [16]. Glass and Koeberl [14] concluded that the cpx spherule layer is probably global in extent and found the peak abundance of the microtektites to be about 2 cm above the peak abundance of the cpx spherules. They also concluded that the microtektites at Site 689 are compositionally similar to the N.A. microtektites and, thus, probably belong to the N.A. strewn field. Glass and Koeberl [17] reported finding similar microtektites at DSDP Site 216 in the Eastern Indian Ocean which they suggested might also belong to the N.A. strewn field. However, at this site there was no evidence of stratigraphic separation between the microtektites and the cpx spherules. No separation was found between microtektites and cpx spherules in ODP Hole 689D (just 24 m from Hole 689B) and in Hole 1090B (~1600 km N-NE of Site 689) [18,19].

We have obtained Sr and Nd data for cpx spherules from DSDP Site 216 in the Eastern Indian Ocean, from ODP Hole 709C in the Western Indian Ocean, and from ODP Hole 1090B in the Western South Atlantic Ocean, and for microtektites from ODP Hole 689D on the Southern Ocean (Maud Rise). The objectives were to determine whether or not the Sr and Nd isotope compositions and systematics of cpx spherules from two new sites (709 and 1090) support the suggestion that they are from the same source (i.e., the same event) as the cpx spherules from other sites, and whether the microtektites from Site 689 in the Southern Ocean belong to the N.A. strewn field.

Results and Discussion: The DSDP/ODP samples were disaggregated in water, wet sieved, and dried. Cpx spherules were then handpicked and separated

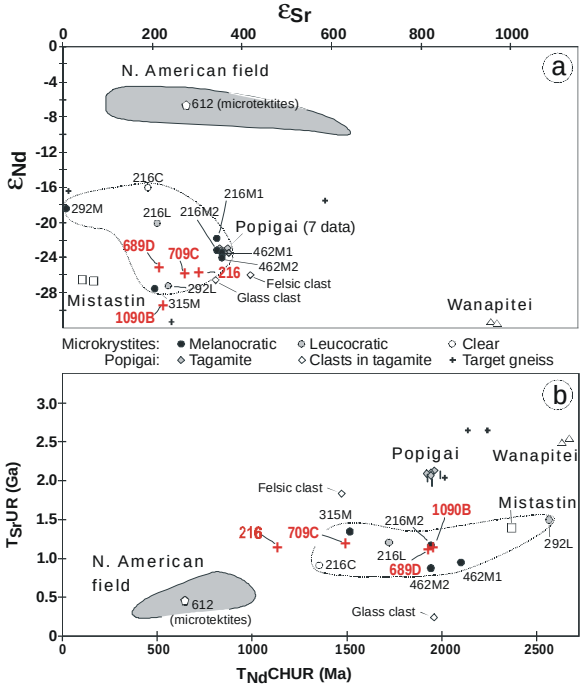

Fig. 1. (a) εNd vs. εSr. (b) $T_{Sr}UR$ vs $T_{Nd}CHUR$. Modified after [8]. Red plus signs are new data. Microkrystites = cpx spherules, clear = microtektites.

into dark- and light-colored spherules. The methods used in determining the Sr and Nd were recently described [8]. Sample weights ranged from 0.4 to 4 mg. See [8] for reference values. We calculated Sr model ages T(UR) (relative the Earth mantle evolution) and Nd T(CHUR) (relative to chondritic evolution). The Nd model age reflects the mean crustal age of the source of a sample, while the Sr model age reflects the time of sedimentation, associated with Rb/Sr enrichment. The dark (melanocratic) cpx spherules from sites 216, 709, and 1090 have similar $\varepsilon^{87}Sr/^{86}Sr$ and $\varepsilon^{143}Nd/^{144}Nd$ values and T(UR)Sr and T(CHUR)Nd model ages (Table 1). The microtektites from ODP Site 689 have similar $\varepsilon^{87}Sr/^{86}Sr$ and $\varepsilon^{143}Nd/144Nd$ values and similar model ages compared with the dark cpx spherules (Table 1). The dark cpx spherules from DSDP Site 216 have somewhat lower $\varepsilon^{87}Sr/^{86}Sr$ and $\varepsilon^{143}Nd/^{144}Nd$ values and lower T(UR)Sr model age (Table 1) than reported by Whitehead et al. [8] for dark cpx spherules from this site (i.e., 298.5 vs. 340.0 - 342.1 and -26 vs. 21.8 to -23.2, respectively) (Fig. 1: modified after Fig. 5 in [8]). The $\varepsilon^{87}Sr/^{86}Sr$ and $\varepsilon^{143}Nd/^{144}Nd$ values for dark cpx spherules in this study are all in the range of values obtained by Whitehead et al. [8], if we include the light colored (leucocratic) cpx spherules, in addition to the dark cpx spherules. Futhermore, the Sr and Nd model ages for the dark cpx spherules are all within the range reported by Whitehead et al. for the dark cpx spherules [8] (Fig. 1). Therefore, Sr-Nd data for two new ODP sites (709 and 1090) support the conclusion that there is a single cpx spherule layer, which is probably global in extent.

The $\varepsilon^{87}Sr/^{86}Sr$ and $\varepsilon^{143}Nd/^{144}Nd$ values that we obtained for the microtektites from Site 689 are somewhat different than the $\varepsilon^{87}Sr/^{86}Sr$ and $\varepsilon^{143}Nd/^{144}Nd$ values previously obtained [8] for microtektites at Site 216 (213.8 vs. 187.2 and -25.3 vs. -16.0, respectively). Likewise, the T(UR)Sr and T(CHUR)Nd model ages determined for the Site 689 microtektites are higher than the model ages previously found [8] for the Site 216 microtektites (1080 vs. 910 and 1900 vs. 1350, respectively). The Sr and Nd isotopic compositions and model ages for the microtektites at Site 689 are distinct from the values and fields (Fig. 1) defined by N. A. tektites and microtektites. Therefore, the Sr and Nd isotopic data do not support previous conclusions that the microtektites associated with the cpx spherule layer in the sites in the Southern Ocean (Site 689) and in the Eastern Indian Ocean (Site 216) belong to the N.A. strewn field. Instead, based on isotope systematics for Sr and Nd, they seem to have been derived from the same source material as the cpx spherules, in spite of difference in petrography and chemistry.

Conclusions: Sr and Nd isotopic data for the upper Eocene cpx spherules from two new sites support previous conclusions that the cpx spherules belong to a single layer and that the layer is probably global in geographic extent. The source crater may be the Popigai structure, but the new data do not support this hypothesis as well as the data published by Whitehead et al. [8]. The microtektites found associated with the cpx spherules in the Southern Ocean (Site 689) and in the Eastern Indian Ocean (Site 216) do not appear to belong to the N.A. strewn field, but seem to have the same source as the cpx spherules (i. e., they appear to belong the cpx spherule layer).

Table 1. Sr-Nd Analytical Results

Site	DSDP 216	ODP 1090B	ODP 709C	ODP 689D
	E. Indian	S. Atlantic	W. Indian	S. Atlantic
Sample	Dark cpx sphr.	Dark cpx sphr.	Dark cpx sphr.	Microtektites
$\varepsilon^{87}Sr/^{86}Sr$	298.5±1.4	218.7±1.1	269.3±1.0	213.8±0.8
$\varepsilon^{143}Nd/^{144}Nd$	-26.0±0.6	-29.7±0.8	-26.1±0.5	-25.3±0.6
f(Rb/Sr)	15.97	11.77	13.98	11.88
f(Sm/Nd)	-0.9144	-0.6056	-0.7025	-0.5291
T(UR)Sr (Ma)	1120±5	1110±6	1160±4	1080±4
T(CHUR)Nd (Ma)	1130±26	1950±53	1480±28	1900±45

Epsilon values relative to 0.7045 (Sr) and 0.511847 (Nd); 2σ uncertainties; Fractionation *f* relative to: $^{87}Rb/^{86}Sr$=0.0827 (Earth); $^{147}Sm/^{144}Nd$= 0.1967 (chondrites and Earth).

References: [1]Prothero D.R.(1994) *The Eocene-Oligocene Transition: Paradise Lost*, Columbia U. Press. [2]Poag C.W. (1997) *Palaios* 12, 582. [3]Grieve R.A.F. (1996) *Meteoritics & Planet. Sci.(MAPS)* 31, 166. [4]Glass B.P. et al. (1985) *LPSC 16, JGR* 90, D175. [5]Keller G. et al. (1987) *Meteoritics* 22, 25. [6]Glass B.P. & Burns C.A. (1987) *Meteoritics* 22, 265. [7]Wei, W. (1995) *Paleogeog. Paleoclim. Paleoecol.* 114, 101. [8]Whitehead J. et al. (2000) *EPSL* 181, 473. [9]Poag C.W. et al. (1994) *Geology* 22, 691. [10]Koeberl C. et al. (1996) *Science* 271, 1263. [11]Shaw H.F. & Wasserburg G.J. (1982) *EPSL* 60, 155. [12]Ngo H.H. et al. (1985) *GCA* 49, 1477. [13]Stecher O. et al. (1989) *Meteoritics* 24, 89. [14]Glass B.P. & Koeberl C. (1999) *MAPS* 34, 197. [15]Montanari A. et al. (1993) *Palaios* 8, 420. [16]Vonhof H.B. & Smit J. (1996) In *The Role of Impact Processes in the Geol. & Biol. Evol. of Planet Earth* (K. Drobne et al., eds.) Ljubljana. [17]Glass B.P. & Koeberl C. (1999) *MAPS* 34, A43. [18]Liu S. & Glass B.P. (2000) *LPSC XXXI*, #1846. [19]Liu, S. et al. (2000) *MAPS* 35, A98.

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