THE ESTHERVILLE MESOSIDERITE : A POLYMICT BRECCIA FORMED 4.42 TO 4.55 GA AGO : U-Pb, Rb-Sr, AND Sm-Nd ISOTOPIC EVIDENCE; M. Brouxel and M. Tatsumoto, U.S. Geological Survey, MS 963, Box 25046, Denver CO 80225.

The origin of mesosiderites is still a matter of intense debate. Their brecciated nature argues for an origin by meteoritic impacts at a planetary surface, while the mixing with metal in a molten stage appears to be hard to reconcile in a near surface environment. Very little chronological data have been published on mesosiderites and until recently most of the ages were rather young (3.6 to 4.24 Ga by Rb-Sr [1,2], and 3.23 to 4.25 Ga by K-Ar [3]) compared to the 4.55 Ga age of Juvinas [4]. A major heating event, likely a catastrophic collision between two asteroids, recorded by the Ar-Ar isotopes [5] around 3.5-3.9 Ga, may have affected some of the isotopic systems. A precise chronology of mesosiderites is therefore important to better understand their origin.

For that purpose, a U-Pb, Rb-Sr, and Sm-Nd isotopic study has been conducted on the Estherville mesosiderite. Five fractions separated by heavy liquids ($\rho<2.58$, $2.58<\rho<2.95$, $2.95<\rho<3.3$, $2.95<\rho<3.3$ magnetic, $\rho>3.3$) and a whole rock fraction were stepwise-leached in HBr (0.1N and 0.5N), HCl (2N), and HF (1N) + HNO_3 (2N), and analyzed for U-Pb, Rb-Sr, and Sm-Nd isotopes (the U-Pb data were previously reported [6]). Seven other fractions (two plagioclase, two olivine, two pigeonite, and a whole rock), separated by handpicking, were analyzed only for Rb-Sr and Sm-Nd isotopes. Twenty mg of troilite, separated by handpicking, was analyzed for Pb isotopes after leaching in very dilute HBr (0.01 N).

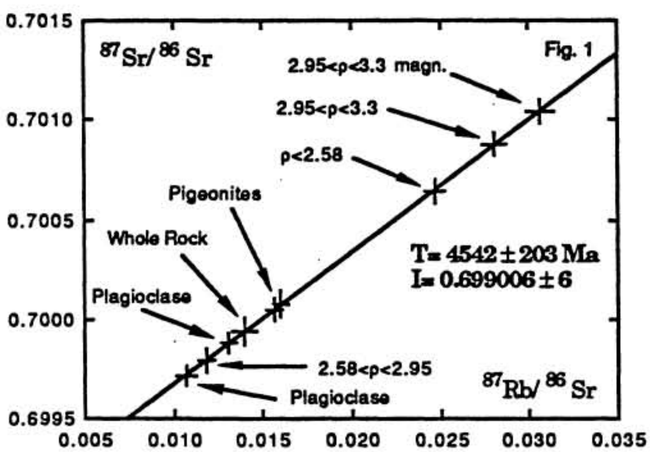
All the Pb isotopic data plot on a 4288 ± 85 Ma isochron which has been interpreted as a two or more component mixing line [6]. Two components were identified, with Pb-Pb and U-Pb ages respectively of 4556 ± 35 and 4557 ± 18 Ma for the first component, and 4422 ± 50 and 4437 ± 11 Ma for the second. The troilite sample presents a very low Pb concentration (37.7 ppb) with Pb isotopic compositions similar to the whole rock ($^{206}Pb/^{204}Pb = 18.885 \pm 0.23\%$, $^{207}Pb/^{204}Pb = 16.374 \pm 0.31\%$, $^{208}Pb/^{204}Pb = 38.945 \pm 0.26\%$). The U and Th concentrations are also very low (0.936 ppb and 3.90 ppb respectively). This troilite is more similar to those found in chondrites [7] than those found in iron meteorites [8].

The Rb-Sr data are given in Table 1 and shown in Fig. 1. The nine points define a linear array corresponding to an age of 4542 ± 203 Ma with an initial $^{87}Sr/^{86}Sr = 0.699006 \pm 0.000006$. The plagioclase fractions and the $2.58<\rho<2.95$ density fraction present the lowest $^{87}Sr/^{86}Sr$ and $^{87}Rb/^{86}Sr$ ratios. The $2.58<\rho<2.95$ density fraction, likely enriched in plagioclase, present also similar Sr concentration (≈ 60 ppm). The highest Sr concentration was measured in the light density fraction (≈ 80 ppm) which present also a more radiogenic Sr isotopic composition. The most radiogenic Sr isotopic ratios were measured in the heavy density fractions, likely enriched in OPX. They present low Sr concentrations (4 to 8 ppm). The pigeonites have also low Sr concentration (2 to 6 ppm), but intermediate Sr isotopic composition. The leaching procedure used in this study seems to have affected the Rb-Sr isotopic system. Highly variable $^{87}Rb/^{86}Sr$ ratios (0.0014 to 0.05) were measured in the leaches, probably due to Rb-Sr fractionation during the leaching procedure. Only a small amount of Rb and Sr were removed during the HBr leaching (≈ 1.2 and 1.5 % respectively) but much more during the HCl (≈ 0.8 and 4%) and the HF+HNO_3 (7.3 and 38 %) leaching. Only four samples that contained more than 1μg of Sr before leaching apparently had unaffected $^{87}Rb/^{86}Sr$ and $^{87}Sr/^{86}Sr$ ratios. The 4.54 Ga age obtained in this study compares very well with the 4.53 ± 0.26 Ga Rb-Sr age obtained by Murthy et al. [2] on the Estherville mesosiderite. The initial $^{87}Sr/^{86}Sr$ ratios are also similar within error (0.69903 ± 0.00003). We also analyzed the light density fraction ($\rho<2.58$), but did not get a mesostasis fraction which showed a high Rb/Sr ratio [2]. The small range of $^{87}Sr/^{86}Sr$ ratios (0.699790 to 0.70104) explain the rather imprecise Rb-Sr age.

The Sm-Nd data are given in Table 1 and shown in Fig. 2. Ten points define a linear array corresponding to an age of 4534 ± 96 Ma with an initial $^{143}Nd/^{144}Nd = 0.506836 \pm 0.000021$. The $2.58<\rho<2.95$ density fraction, likely enriched in plagioclase, present the lowest $^{143}Nd/^{144}Nd$ and $^{147}Sm/^{144}Nd$ ratios. Our plagioclase separate present similar Nd concentration (≈ 1.4 ppm) and a slightly higher $^{147}Sm/^{144}Nd$ ratio. The two olivine separates exhibit almost flat rare-earth element patterns ($^{147}Sm/^{144}Nd \approx 0.20$) and very low Nd concentration ($\approx$ 0.3 ppm). The highest $^{143}Nd/^{144}Nd$ and $^{147}Sm/^{144}Nd$ ratios were measured in the high density fractions (enriched in OPX) and in the pigeonite. The pigeonite present slightly higher Nd concentration ($\approx$ 0.14 ppm) compared to the OPX ($\approx$ 0.09 ppm). In contrast with the Rb-Sr isotopic system, our leaching procedure had very little effect on the Sm-Nd isotopes. Small amounts of rare-earth elements were leached and more importantly Sm and Nd apparently did not fractionate during the leaching procedure. The HBr leaches contain the most Sm and Nd ($\approx$ 9.9 and 8.8 % respectively), while very small amounts were measured in the HCl ($\approx$ 4.2 and 3.5 %) and $HF+HNO_3$ ($\approx$ 2.6 and 2.6 %) leaching. In these leaches, the amount of Nd measured was always extremely low ($\approx$ 0.98 ng in the HCl leaches and 0.76 ng in the $HF+HNO_3$ leaches).

The two components with Pb-Pb and U-Pb ages of 4.56 and 4.42 Ga were not distinguished with Rb-Sr and Sm-Nd isotopes. However, such heterogeneity may explain the large errors recorded (203 Ma for Sr and 96 Ma for Nd). It is also possible that these isotopic systems were slightly disturbed by a metamorphic event around 3.6 Ga [5]. However, the Rb-Sr and the Sm-Nd ages confirm that the silicate fraction of the Estherville mesosiderite was formed around 4.5 Ga. Such old ages, found also recently in Morristown (4.51 ± 0.12 Ga by Sm-Nd, [9]), are therefore likely for mesosiderites.

References : [1] Mittlefehldt D.W., Bansal B.M., Shih C.Y., Wiesmann H., and Nyquist L.E. (1986). Lunar and Planetary Science Conf. XVII, p. 553-554. [2] Murthy V.R., Coscio M.R., and Sabelin T. (1977). Proc. Lunar Sci. Conf. 8th, p. 177-186, 1977.[3] Begemann F., Weber H.W., Vilcsek E., and Hintenberger H. (1976). Geochim. Cosmochim. Acta, v. 40, p. 353-368. [4] Allègre C.J., Birck J.L., Fourcade S., and Semet M. (1975). Science, v. 187, p. 436-438, 1974. [5] Bogard D.D., Garrison D.H., J.L. Jordan, and D. Mittlefehldt (1990). Geochim. Cosmochim. Acta, submitted. [6] Brouxel M., and Tatsumoto M. (1990). Proc. Lunar Sci. Conf. XX, in press. [7] Unruh D.M. (1982). Earth Planet. Sci. Lett., v. 58, p. 75-94. [8} Tatsumoto M., Knight R.J., and Allègre C.J.. (1973). Science, v. 180, p. 1279-1283. [9] Prinzhofer A., Papanastassiou D.A., and Wasserburg G.J. (1989). Lunar and Planetary Science Conf. XX, p. 872-873.



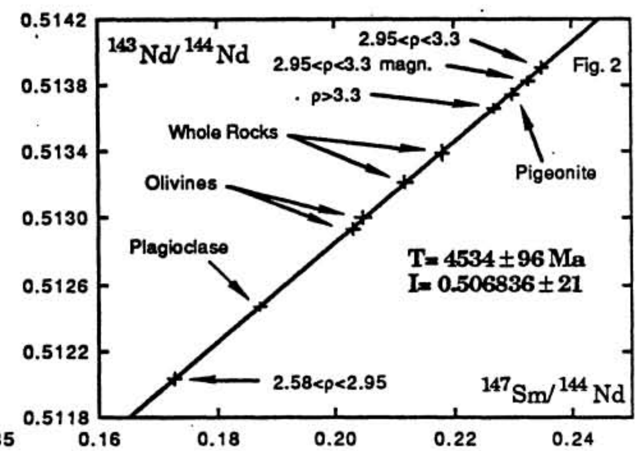


Table 1 : Sm-Nd and Rb-Sr analytical data of the Estherville mesosiderite residues.

Sample	Nd (ppm)	$^{147}Sm/^{144}Nd$	$^{143}Nd/^{144}Nd$	Initial	Sr (ppm)	$^{87}Rb/^{86}Sr$	$^{87}Sr/^{86}Sr$	Initial
PL-1	1.466	0.1873 ± 0.00101	0.512473 ± 0.000020	0.506837	58.200	0.01066 ± 0.00056	0.699710 ± 0.000040	0.699000
PL-2	---	--- --- ---	--- ---	---	65.470	0.01310 ± 0.00042	0.699880 ± 0.000050	0.699007
OL-1	0.274	0.2047 ± 0.00113	0.513007 ± 0.000032	0.506846	---	--- ---	--- ---	---
OL-2	0.391	0.2031 ± 0.00103	0.512941 ± 0.000029	0.506829	---	--- ---	--- ---	---
PI-1	---	--- --- ---	--- ---	---	2.310	0.01601 ± 0.00043	0.700080 ± 0,000060	0.699013
PI-2	0.141	0.2298 ± 0.00102	0.513747 ± 0.000026	0.506831	6.473	0.01562 ± 0.00038	0.700050 ± 0.000050	0.699009
ρ > 3.3	0.099	0.2269 ± 0.00100	0.513665 ± 0.000022	0.506836	---	--- ---	--- ---	---
2.95<ρ<3.3	0.083	0.2348 ± 0.00096	0.513904 ± 0.000035	0.506836	4.373	0.03065 ± 0.00074	0.701040 ± 0.000060	0.698998
2.95<ρ<3.3 magn.	0.131	0.2324 ± 0.00096	0.513830 ± 0.000023	0.506835	8.250	0.02801 ± 0.00057	0.700880 ± 0.000050	0.699014
2.58<ρ<2.95	1.271	0.1727 ± 0.00102	0.512029 ± 0.000031	0.506831	61.800	0.01181 ± 0.00041	0.699790 ± 0.000060	0.699003
ρ < 2.58	---	--- --- ---	--- ---	---	80.960	0.02465 ± 0.00051	0.700640 ± 0.000055	0.698998
WR-1	0.561	0.2182 ± 0.00103	0.513397 ± 0.000039	0.506829	---	--- ---	--- ---	---
WR-2	0.639	0.2118 ± 0.00113	0.513221 ± 0.000032	0.506847	6.956	0.01394 ± 0.00068	0.699940 ± 0.000070	0.699011