Half-life and initial Solar System abundance of 146Sm determined from the oldest andesitic meteorite
Linru Fang1, Paul Frossard2, Maud Boyet3, Audrey Bouvier3, Jean-Alix Barrat3, 5, Marc Chaussidon1 and Frederic Mounier1, 1 Université de Paris, Institut de physique du globe de Paris, CNRS, F-75005 Paris, France (movrier@ipgp.fr; lfang@ipgp.fr), 2 Université Clermont Auvergne, CNRS, IRD, OPGC, Laboratoire Magmas et Volcans, F-63000 Clermont-Ferrand, France, 3 Bayerisches Geoinstitut, Universität Bayreuth, 95447 Bayreuth, Germany, 4 Univ Brest, CNRS, IRD, Ifremer, LEMAR, F-29280 Plouzané, France, 5 Institut Universitaire de France

Introduction: 146Sm–142Nd radioactive systematics can provide constraints on the timing of early differentiation processes on Earth, Moon, and Mars. However, the uncertainties related to the initial abundance and half-life (103 [1,2] or 68 Ma [3]) of the extinct isotope 146Sm impede the interpretation of the 146Sm–142Nd systematics. Here, we apply the short-lived 26Al–26Mg, 144Sm–142Nd, and long-lived 147Sm–143Nd chronometers to the oldest known andesitic meteorite and volcanic rock, Erg Chech 002 (EC 002). A robust crystallization age for EC 002 is constrained by 26Al–26Mg and 147Sm–143Nd mineral isochrons. Literature 146Sm/144Sm data of CAIs and asteroidal and planetary bodies are then combined with the 146Sm/143Nd value of EC 002 to obtain the best fit value for the half-life of 146Sm. Finally, the 146Sm–143Nd isochron of EC 002 is used to deduce a precise and best estimate for the initial 146Sm/144Sm ratio of the Solar System.

Material and Methods: A mass of ~ 4 g of EC 002 was crushed in an agate mortar and several mineral and bulk-rock fractions were separated from that. All the fractions have been passed through columns with ion exchange and specific resins in several steps to discard the matrix and purify solutions for Sm, Nd and Mg. Stable Sm, Nd and radiogenic Nd isotopic ratios were measured using TIMS. The 26Al/24Mg and Mg isotopic compositions were measured using ICP-MS and MC-ICP-MS, respectively.

Results and Discussion: The linear correlation between δ26Mg* and 26Al/24Mg defines an initial 26/24Mg ratio (δ26Mg*) of -0.009±0.005 %oo (2σ) and a slope corresponding to a 26Al/27Al of (8.89±0.09)×10^-6 which translates to an age of 1.8±0.01 Myr after CAIs formation. This age is ~450,000 years older than the in-situ ion microprobe Al-Mg age from Barrat et al. [5]. The two isochrons most likely date two different events since Mg in plagioclase diffused much faster than in pyroxene and the core of the plagioclase crystal analyzed by ion microprobe is probably not a closed system for Mg diffusion. If this hypothesis is correct, the MC-ICP-MS 26Al age would be closer to the crystallization age. EC 002 displays a μ143Nd nucleosynthetic composition of 12.0±3.2 (2σ) parts per million (ppm) which is distinctly lower than any Carbonaceous meteorites and falls within the Non-carbonaceous (NC) region, suggesting that the parent body of EC 002 is likely derived from the NC meteorite reservoir, in agreement with its negative Tm anomaly [5]. The 147Sm–144Nd isochron returns an initial 143Nd/144Nd ratio of 0.50679±0.00018 and defines a 147Sm–143Nd age of 4521±152 Ma. All 144Sm/144Nd and 142Nd/144Nd ratios of EC 002 define a regression line with an initial 146Sm/144Sm ratio of 0.00830±0.00032. Using the coupled fit lines of crystallization ages from other robust dating systems (147Sm–143Nd, Pu-Xe, Pb-Pb, and 26Al–26Mg) and 146Sm/144Sm ratios of CAIs, asteroidal and planetary samples, the half-life of 146Sm is modeled to be 102±9 Ma [4]. This modelling with natural samples provides robust support for the experimentally-determined 146Sm half-life value of 103 Ma, which is 35 Myr longer than the most recent determination [3]. The 103 Ma half-life confirmed here eliminates a large source of uncertainty on age determinations of the differentiation of the early mantle and lunar magma ocean. By combining the 26Al–26Mg crystallization age of EC 002 with the 146Sm/144Sm abundance recorded by the same mineral fractions, we deduced an initial 146Sm/144Sm for the Solar System of 0.00840±0.00032, which is the most reliable and precise estimate to use for 146Sm–142Nd chronology [4].

Conclusion: The Al-Mg systematics confirm that EC 002 is the oldest known andesitic meteorite as well as the oldest volcanic rock, with a formation age of 1.8±0.01 Myr after the Solar System formation. Stable Nd isotopic anomalies indicate that the parent body of EC 002 formed within the NC Reservoir. The most consistent half-life of 146Sm is 103 Ma from which we derive an initial 146Sm/144Sm ratio of the Solar System of 0.0084±0.00032. In association with its large recovered mass (~32 kg), abundant coarse mineral grains, and trace element-enriched composition, EC 002 represents the best anchor for 146Sm–142Nd systematics in planetary materials, and possibly for other short-lived radioactive decay systems.