REE abundances and Sr isotopic compositions of diogenites

T. Saitou[1], K. Sera[2] and H. Hidaka[1]
[1]*Department of Earth and Planetary Sciences, Nagoya University, Nagoya 464-8601, Japan.*
[2]*Department of Earth and Planetary Systems Science, Hiroshima University, Higashi-Hiroshima 739-8526, Japan.*

Introduction: The howardite, eucrite and diogenite (HED) suite is the largest meteorite group of achondrites. These meteorites originate in the common differentiated asteroid's crust: the asteroid is thought to be asteroid 4 Vesta. Therefore HEDs provide us information of their parent body's crust, and we can improve our knowledge about early evolution of planetary crusts by analyzing them. Studies of HEDs have been regularly conducted and provide some models for genesis of HEDs, which can be roughly divided in two patterns: (a) HEDs were simply generated by magma ocean differentiation, single-stage model, (b) requiring additional process to (a) to generate HEDs, multi-stage model [1, 2]. In this study, we mainly discuss about whether model is more reliable by focusing on diogenites.

Diogenites are orthopyroxene-rich monomineralic cumurates. Since most diogenites show HREE-rich and LREE-poor REE patterns, they are thought to be generated by differentiation of chondritic melt (corresponding to the model (a)) or by more complicated process (corresponding to the model (b)). Some preceding studies (e.g., [1]; [2]) have indicated that the abundances of trace elements, especially REE, cannot be explained by the model (a), while those of major elements can be. Chronology can also provide valuable information to reveal the genesis of HEDs. However, chronological studies of diogenites are less developed than those of eucrites, because of their monomineralic compositions and low abundances of U, Th and Sm, including radiogenic isotopes. Here, we report REE abundances and Sr isotope compositions of 6 diogenites to discuss about their genesis.

Sample and Method: Bilanga, Tatahouine, NWA 5480, Y-002875, Y-74013 and Y-74097 were used in this study. Ultrasonic washed samples (about 200 mg) were crushed to powders, and then the sample powders were dissolved in HF and $HClO_4$ mixture. After dissolution, the sample solution was dissolved in 2M HCl ("mother solution"). A part of the solution was once evaporated to dryness, and redissolved in 2% HNO_3 of 5-10 ml to determine the elemental abundances of Rb, Sr and REE by ICP-MS (Agilent 7500cx). Other part of mother solution was used for Sr isotopic analysis after chemical separation by two-step of resin chemistry: the first step with cation exchange resin (Bio-Rad AG50WX8) and the second with Sr resin (Eichrom SR-B25-A). And then, the isotope compositions of the Sr fractions were measured by TIMS (Trion Plus).

Results and Discussion: REE patterns of analyzed diogenites are shown in Figure 1. They reveal depletions of lighter REE (LREE), enrichments of heavier REE (HREE) and negative Eu anomalies, which are often observed in typical diogenites [1, 2]. Parameters to characterize the REE patterns of diogenites are shown in Table 1. Most data in the parameters are consistent with previous data collected from typical diogenites [1].

The variation of LREE depletion degrees ($(La/Sm)_n$=0.45~2.37) cannot be easily explained by the model (a), because diogenites should be formed by differentiation of common parental melt in the model (a). Some of LREE depletion degrees may be explained from the presence of REE-rich accessory minerals such as phosphates. Because of high REE concentrations of phosphates (> 1000 × CI), LREE depletion trends in diogenites largely depend upon the amount of the phosphates included in diogenites [1, 2]. However, it is still disputable whether all patterns can be explained only by the contribution of phosphates. Eu anomaly degrees (Eu/Eu*) also can be varied by the phosphate effect, due to low Eu concentration of diogenites.

The variation of HREE enrichment degrees ($(Dy/Lu)_n$=0.18~0.73) is more difficult to explain by the model (a): value of $(Dy/Lu)_n$ is much less sensitive to phosphate effect than $(La/Sm)_n$ [1], because of high HREE concentrations of diogenotes relative to LREE (see Figure. 1). The results of REE data support the model (b) rather than the model (a) to explain the variation of REE patterns in diogenites.

Results of Sr isotopic analysis are shown in Figure 2. The data points of Bilanga, Y-002875 and NWA 5480 were plotted near the 4.367 Ga-old isochron, which represents the Rb-Sr formation age of ordinary eucrites [3]. The Rb-Sr ages of these three diogenites are probably close to those of eucrites. On the other hand, the data points of Y-74013 and Y-74097 were plotted around the 1.1 Ga-old isochron rather than the 4.367 Ga-old isochron. The age of 1.1 Ga is previously reported as the Ar-Ar formation age of Y-74097 [4]. Furthermore, the combination of the Rb-Sr data between this study and previous study [5] newly provides the ages of 1.8 Ga and 0.46 Ga for Y-74013 and Y-74097, respectively (see Figure. 2). Though these ages are not clearly consistent with the Ar-Ar age of Y-74097, these data suggest a significant disturbance of Rb-Sr systems by a thermal event on HED parent body in approximately 1 Ga, and the Rb-Sr formation ages of these two diogenites seem to have been erased by this event. To determine their formation ages, chronological applications of more heat-resistant systematics such as Lu-Hf and Sm-Nd decay systems are required.

References: [1] J. A. Barrat et al. (2010) Relative chronology of crust formation on asteroid Vesta: Insights from the geochemistry of diogenites. *Geochim. Cosmochim. Acta* 74, 6218-6231. [2] J. A. Barrat et al. (2008) Geochemistry of diogenites: Still more diversity in their parental melts. *Meteorit. Planet. Sci.* 43, 1759-1775. [3] M. I. Smoilar (1993) A survey of Rb-Sr systematics of eucrites. *Meteritics.* 28, 105-113. [4] I. Kaneoka et al. (1979) 40Ar-39Ar age studies of four Yamato-74 meteorites. *Mem. Natl Inst. Polar Res., Spec. Issue* 12, 186-208. [5] N. Nakamura (1979) A preliminary study on four Yamato diogenites –Sm-Nd and Rb-Sr systematics–. *Mem. Natl Inst. Polar Res., Spec. Issue* 15, 219-226.

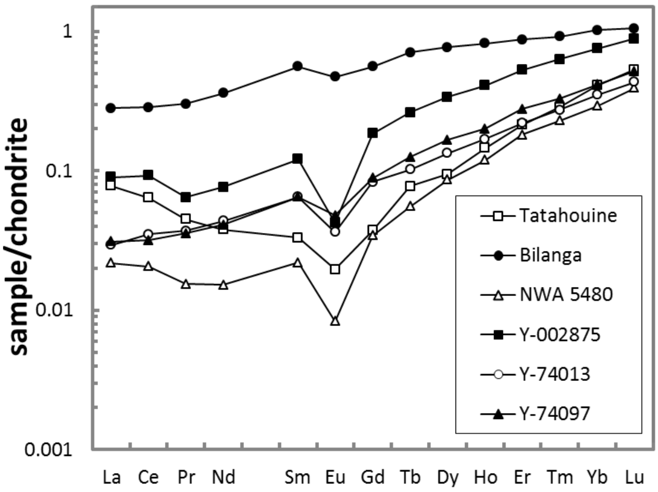

Figure 1. REE patterns of diogenites

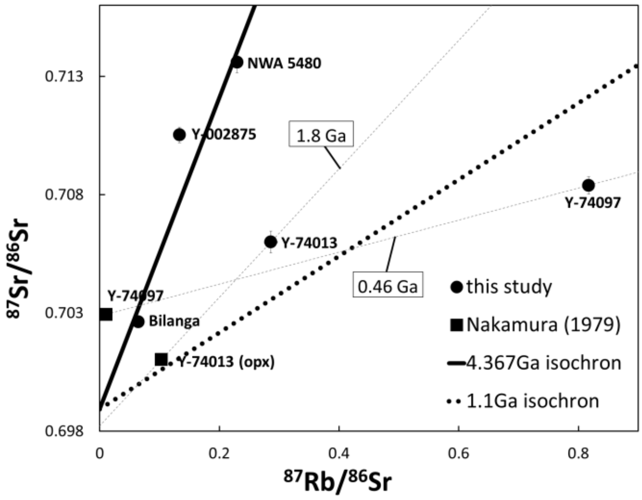

Figure 2. Rb-Sr diagram for diogenites

Table 1. Features of REE patterns

sample	Eu/Eu*	$(La/Sm)_n$	$(Dy/Lu)_n$
Tatahouine	0.56	2.37	0.18
Bilanga	0.84	0.50	0.73
NWA 5480	0.30	0.99	0.22
Y-002875	0.28	0.74	0.38
Y-74013	0.50	0.45	0.31
Y-74097	0.63	0.48	0.32
[1]	0.04~0.76	—	0.01~0.8