

Chemical composition of primitive achondrites: Clues for understanding the early differentiation processes of their parent bodies. Y. Hidaka^{1,2}, N. Shirai², A. Yamaguchi^{3,4}, M. Ebihara², and V. Debaille¹ ¹Laboratoire G-time, Université Libre de Bruxelles, 50 Av. F. D. Roosevelt, Brussels, Belgium, ²Department of chemistry, Tokyo Metropolitan University, 1-1 Minami-Osawa, Hachioji, Tokyo, Japan, ³National Institute of Polar Research, Tachikawa, Tokyo, Japan, ⁴Department of Polar Science, School of Multidisciplinary Science, Graduate University for Advanced Sciences, Tachikawa, Tokyo, Japan.

Introduction:

Primitive achondrites, acapulcoite-lodranites and winonaites, are the most suitable materials for understanding the early differentiation processes in the solar system bodies, because they preserve partially melted features in their textures and show primitive chemical compositions. Partial melting processes are believed to represent the early stages of differentiation of bodies and there are two types of processes proposed for chondritic materials: silicate partial melting and metallic partial melting [1]. Primitive achondrites have been well studied for their petrology [1, 2, 3, 4], but not enough for their bulk chemical composition, especially those for their metals. Therefore, in this study, we determined the chemical composition of a number of primitive achondrites to understand the partial melting processes that had occurred on their parent bodies.

Samples and analyses:

We have determined lithophile and siderophile element abundances of 13 primitive achondrites, including 9 acapulcoites (Dho 125, Dho 290, GRA 95209, MET 01195/01198/01244 Y-74063, Y 981505 and Y 981725), 2 lodranites (NWA 2235 and Y-791491) and 2 winonaites (NWA 725 and Y-8005). Among the analyzed meteorites, an acapulcoite Y-74063 and a winonaite NWA 725 have been reported as the relict chondrule-bearing primitive achondrites [5, 6]. Each meteorite was ground into powder in an agate mortar and was magnetically separated into the non-magnetic fraction and the magnetic fraction. The sample amount is ~200-300 mg for each meteorite. The non-magnetic fraction was analyzed by INAA and ICP-MS at Tokyo Metropolitan University (TMU). The magnetic fraction was analyzed by ICP-MS and ICP-AES at TMU. For Dho 125, Dho 290 and NWA 2235, we could not prepare the magnetic fraction, so they are unavailable for discussion of metallic partial melting.

Results:

The chemical composition of the non-magnetic fraction of each primitive achondrite is characterized in the abundances of light-rare earth elements (LREE), Eu and plagiophile elements (Na, Al and K). Acapulcoite Y-74063, winonaites NWA 725 and Y-8005 have nearly chondritic composition of REE and plagiophile elements. Acapulcoites Dho 125, Dho 290, GRA 95209 and MET 01195/01198/01244

have slightly depleted composition of LREE and plagiophile elements compared with chondrites. Acapulcoites Y 981505 and Y 981725 are more depleted in LREE but less depleted in plagiophile elements compared with Dho 125, Dho 290, GRA 95209 and MET 01195/01198/01244. Lodranites NWA 2235 and Y-791491 are severely depleted in plagiophile elements and Eu, but chondritic in LREE.

The chemical composition of the magnetic fraction of each primitive achondrite is characterized in the abundances of platinum group elements (PGE) and volatile elements (Cu, Ga, Sb, Ge and Sn). Among acapulcoite-lodranites, acapulcoite Y-74063 has chondritic composition of PGEs, while others are enriched in PGE except for an acapulcoite Y 981505. Lodranite Y-791491 has the highest PGE abundances among them. Y 981505 is clearly depleted in Re and Ir. Between winonaites, NWA 725 and Y-8005 have similar PGE abundances, but clearly different in volatile element abundances. The abundances of Ga, Sb, Ge, and Sn in Y-8005 are nearly chondritic. On the other hand, NWA 725 is depleted in Ga, Ge and Sn and slightly depleted in Sb relative to Y-8005.

Discussion:

In the non-magnetic fraction, primitive achondrites have wide variety of REE abundances that is difficult to explain by simple silicate partial melting process. The relationship between incompatible trace element (Th) and plagiophile elements is also difficult to explain by a single event (Fig. 1). Based on these observations, we assume the existence of different process(es) in addition to the silicate, basaltic partial melting on the parent body of acapulcoite-lodranites. From Fig. 1, we assume that phosphate must relate to the compositional transition of acapulcoite-lodranites. The phosphate mobilization process was proposed by [2] from their petrologic observations. They found the veins of phosphates and of metals with phosphates in meteorites they studied. We suggest that this phosphate mobilization process must have important role for the early differentiation processes and chemical compositional evolution on the acapulcoite-lodranite parent body.

The abundances of REE in winonaites NWA 725 and Y-8005 are nearly chondritic. This indicates that these winonaites are scarcely melted meteorites.

In the magnetic fraction, to explain the compositional variation of acapulcoite-lodranites, we

model the metallic partial melting in Fe-S and Fe-S-C systems. Partition coefficients are from [7, 8, 9]. The Fe-S system melting has been considered as the common process for primitive achondrite metals [1, 10]. On the other hand, it was suggested that if there were C in the system, Fe-S-C system melting had to occur [9, 11]. Acapulcoite GRA 95209 has been reported as having large amount of carbon in its metal [12]. Here, acapulcoite Y-74063 is used as the starting material of this calculation.

Modeling of Fe-S and Fe-S-C system melting can reproduce metals that have broadly similar chemical composition to those of measured primitive achondrites. In Ir/Ni vs. W/Re, model calculation results of the Fe-S system and Fe-S-C system melting are both mostly consistent with acapulcoites, but slightly inconsistent with lodranite and clearly different from winonaites (Fig. 2). However, we could not explain the reasons for low W/Re ratio in Y-791491 and difference in the abundances of some elements (Mo, Fe and Cu for Fe-S system, and Co, As and Cu for Fe-S-C system) between model and Y-791491. Therefore, it is difficult to conclude which type of partial melting process had occurred in the acapulcoite-lodranite parent body.

Compositional difference between two winonaites was difficult to explain by parent body processes. Considering that a winonaite parent body may have experienced several large impact events that caused secondary heating or the breakup-reassembly [4, 13], such a difference can be explained by the contribution of materials from different reservoirs.

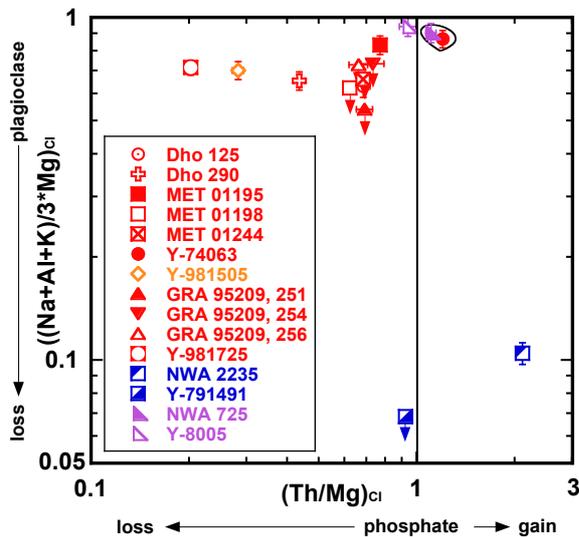


Fig. 1. CI-normalized plagiophile element abundances vs. Th abundances for the non-magnetic fraction of primitive achondrites. CI values are from [14].

References:

[1] McCoy T. J. et al. (1997) *GCA*, 61, 639-650. [2] McCoy T. J. et al. (1996) *GCA*, 60, 2681-2708. [3]

McCoy T. J. et al. (1997) *GCA*, 61, 623-637. [4] Benedix G. K. et al. (1998) *GCA*, 62, 2535-2553. [5] Yanai and Kojima, (1991) [6] Patzer A. et al. (2004) *Meteorit. Planet. Sci.*, 39, 61-85. [7] Chabot N. L. and Jones H. (2003) *Meteorit. Planet. Sci.*, 38, 1425-1436. [8] Chabot N. L. et al. (2009) *Meteorit. Planet. Sci.*, 44, 505-519. [9] Hayden L. A. et al. (2011) *GCA*, 75, 6570-6583. [10] Mittlefehldt D. W. et al. (1996) *GCA*, 60, 867-882. [11] Goodrich C. A. et al. (2013) *GCA*, 112, 340-373. [12] McCoy T. J. et al. (2006) *GCA*, 70, 516-531. [13] Schulz T. et al. (2009) *EPSL*, 280, 185-193. [14] Anders E. and Grevesse N. (1989) *GCA*, 53, 197-214.

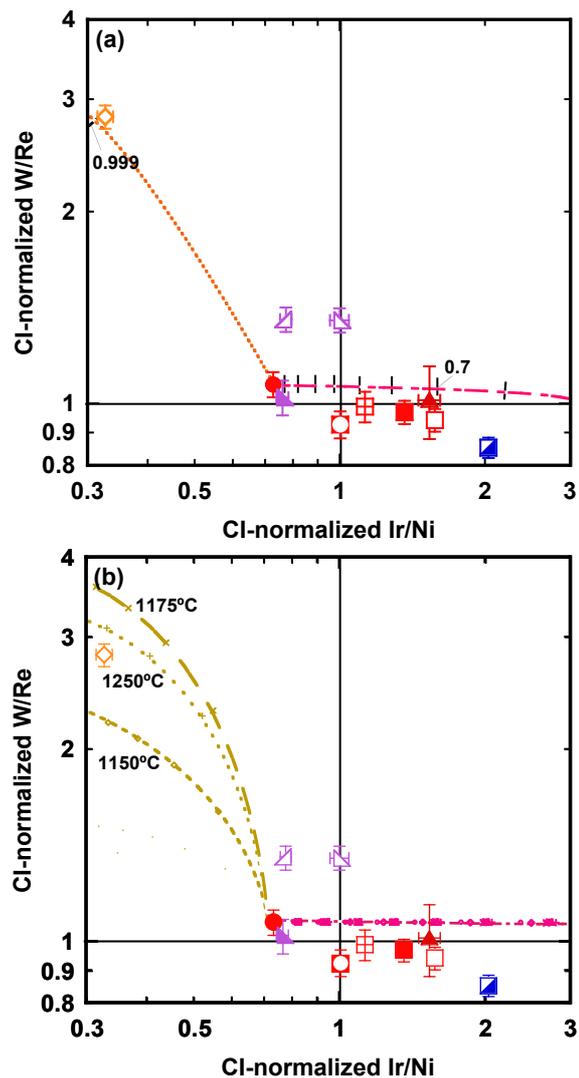


Fig. 2. CI-normalized W/Re vs. Ir/Ni ratios for the magnetic fraction of primitive achondrites. (a) Dotted lines show model calculation results of Fe-S eutectic melting. (b) Dotted lines show model calculation results of Fe-S-C melting. Legends are the same as shown in Fig. 1.