LEAD ISOTOPE SYSTEMATICS OF ACID RESIDUES FROM DEPLETED OLIVINE-PHYRIC SHERGOTTITES: IMPLICATIONS FOR HETEROGENEOUS DEPLETED SOURCE MANTLE. R. Moriwaki1, T. Usui2, T. Yokoyama1, 1Dept. of Earth and Planet. Sci., Tokyo Institute of Technology, 2-12-1 Ookayama, Meguro, Tokyo 152-8551, Japan (moriwaki.r.ab@m.titech.ac.jp). 2Earth Life Science Institute, Tokyo Institute of Technology. 2-12-1 Ookayama, Meguro, Tokyo 152-8551, Japan.

Introduction: Geochemical studies for Martian mantle are important in terms of comparative planetology, providing essential information for understanding the fundamental properties of terrestrial planet interior and their geochemical evolution [1, 2]. Shergottites, Martian basalts, have played key roles for understanding geochemical signatures of the Martian mantle. Previous studies have suggested that the shergottites are classified into three geochemical groups (enriched, intermediate, and depleted) based on their trace element abundances and radiogenic isotopic compositions [e.g., 2]. Whereas the origins of the enriched and intermediate shergottites are still unclear, it is generally accepted that parental magmas of depleted shergottites are originated from the depleted Martian mantle [2].

Recent studies have suggested that the depleted shergottites show variable initial Sr-Nd-Hf isotopic compositions [4], resulting from the formation of heterogeneous depleted source mantle via complicated planetary differentiation. To provide additional information for understanding the evolution of Martian interior, we investigate the Pb isotope systematics of the depleted Martian mantle based on the analyses of trace elements and Pb isotopes for two depleted olivine-phyrig shergottites, Tissint and Dar al Gani 476 (DaG 476).

Samples: Tissint and DaG 476 are olivine-phyrig shergottites and have olivine megacrysts in the groundmass that are mainly composed of pyroxene and plagioclase/maskelynite. Previous studies have suggested that these two meteorites show geochemically depleted signatures; e.g., Tissint and DaG 476 have initial ε143Nd of +44.4 [5] and + 36.6 [3], respectively, at the time of their crystallization. Tissint is a fresh witnessed fall meteorite, whereas DaG 476 has experienced significant terrestrial weathering on the hot desert as indicated by the trace element abundances [3].

Analytical Method: We prepared four Tissint whole-rock powders (Tissint-A, -B, -C, and -D) with a highly-pure quartz mortar and pestle. Five-step sequential acid leaching experiments (L1: H2O, L2: acetone, L3: 0.5 M HBr, L4: 1 M HF, L5: 5 M HCl) were conducted on these whole-rock powders following Moriwaki et al. (2015) [6]. One-tenth of each leachate and the final residue were used for trace element analyses with a quadrupole type ICP-MS (X series II, Thermo-Fisher Scientific) at Tokyo Tech. Lead isotope analyses were conducted using TIMS (Triton-plus, Thermo-Fisher Scientific) at Tokyo Tech. We followed the techniques of [7] for chemical purification and mass spectrometry with the normal 207Pb/204Pb double spike. We also prepared a DaG 476 whole-rock powder and conducted the acid leaching experiment for the trace element analysis. Because Pb isotopic analysis of our DaG 476 fractions has not been completed, this study used literature data for the acid leaches and residue from a DaG 476 whole-rock powder reported by Bouvier et al. (2005) [8].

Results:

Rare Earth Element (REE) Abundances: The residues from Tissint and DaG 476 show heavy REE enriched profiles with slightly positive Eu anomalies (Fig. 1). These signatures suggest that the acid residues are mainly composed of early crystallizing minerals (pyroxene and plagioclase), probably reflecting geochemical signatures of their parental magmas.

The acid residue of DaG 476 is more depleted in light REE (LREE) when compared with all the Tissint residues. It follows the argument that the parental magma of DaG 476 had more LREE-depleted signature than that of Tissint. The four residues from Tissint whole-rock powders show two distinct signatures in their LREE profiles; Tissint-C and -D have monotonically depleted LREE patterns, while Tissint-A and -B show slightly enriched in LREEs.

Lead Isotopic Compositions: Age-corrected initial Pb isotopic compositions were calculated based on their U/Pb ratios measured in this study and the assumption
that Tissint and DaG 476 have crystallization ages of 574 Ma [5] and 474 Ma [3], respectively.

Initial Pb isotopic compositions exhibit a linear trend in a 206Pb/204Pb-207Pb/204Pb diagram (Fig. 2). The acid residues from Tissint whole-rock powders show distinct initial Pb isotopic compositions; Tissint-C and -D are less radiogenic than those of Tissint-A and -B. Tissint-C shows the least radiogenic initial Pb isotopic composition (e.g., 206Pb/204Pb = 10.819) among the four Tissint whole-rock residues. DaG 476 has even less radiogenic initial Pb composition (e.g., 206Pb/204Pb = 9.978) at the time of its crystallization.

**Discussions:** Distinct initial Pb isotopic compositions in the four Tissint whole-rock powders is interpreted to result from incorporation of a secondary enriched component, rather than the radiogenic ingrowth of Pb in the Tissint lava, because Tissint-A and -B have more radiogenic Pb isotopic compositions along with the higher LREE abundances than those of Tissint-C and -D. This enriched component is interpreted to originate from an enriched mantle domain [9] and/or Martian surface [10]. Terrestrial contamination is also possible, but it is unlikely because the enriched component is observed in the highly-leached acid residues and because Tissint is a fresh witnessed fall meteorite.

Contrary to Tissint-A and -B, less radiogenic Pb isotopic compositions and LREE-depleted signatures of Tissint-C suggest that it contains a secondary enriched component less than Tissint-A and -B. Although we cannot completely exclude a possibility that even Tissint-C residue contains an undetectable amount of the enriched component, its Pb isotopic composition is likely undisturbed. This is further supported by the fact that acid leaches of L3 and L5 show similar initial Pb isotopic compositions to the final residue [6]. Because L3, L5, and the residue account for total ~95% of Pb in Tissint-C, their initial Pb isotopic compositions are representative of Tissint-C whole-rock powder and probably reflect the Tissint parental magma. On the other hand, the extremely unradiogenic signature of DaG 476 residue suggests that its Pb isotopic composition has avoided any secondary disturbance.

We calculated the 238U/204Pb ratios (μ-values) of the depleted source mantle based on these initial Pb isotopic compositions and the two-stage mantle evolution model. Our two-stage model assumed that depleted source mantle initially formed in silicate differentiation at 4.504 Ga [11], and then experienced partial melting to generate shergottite parental magmas. Lead isotopic evolution in the depleted source mantle is modeled assuming that bulk silicate Mars had the starting Pb isotopic composition of Canyon Diablo Troilite (CDT) at 4.567 Ga [12].

![Figure 2. Initial Pb isotopic compositions of the acid residues. Compositions of leachates (grey-square) and Canyon Diablo Troilite [12] are also shown.](image)

Our two-stage model calculation indicates that Tissint and DaG 476 source mantles have μ-values of 1.6 and 0.7, respectively. Distinct μ-values among these two shergottites are explained by heterogeneous depleted source mantle. However, our Pb isotopic data conflicts with Nd isotopes that presented more depleted signatures in Tissint source mantle (ε143Nd = +44.4 [5]) than that of DaG 476 source (+36.6 [3]). This contradiction suggests either that (1) uncoupled Nd-Pb isotopic heterogeneity of the mantle sources formed by complicated mineral fractionation during early stage silicate differentiation or that (2) just isotopic heterogeneity within the sample powders used in different labs. The latter sample heterogeneity might have formed by incorporation of the enriched component during its magmatism [9].

**Conclusions:** The Tissint and DaG 476 parental magmas have distinct initial Pb isotopic compositions. Our two-stage model calculation provides a significantly lower μ-value (0.7) of DaG 476 source mantle. The high initial Pb isotopic composition of Tissint indicates either the existence of heterogeneous depleted source mantle or incorporation of an enriched component during early stage of its magmatism.

**References:**