NEW CONSTRAINS ON THE SHERGOTTITE PETROGENESIS BY ANALYSIS OF PB ISOTOPIC COMPOSITIONAL SPACE: EVIDENCE FOR MANTLE HETEROGENEITY AND CRUSTAL ASSIMILATION ON MARS. M. Tobita[1], T. Usui[1], R. Moriwaki[1], and T. Yokoyama[1] [1]Dept. of Earth and Planet. Sci., Tokyo Institute of Technology, 2-12-1 Ookayama, Meguro-ku, Tokyo, Japan (tobita.m.aa@m.titech.ac.jp).

Introduction: Introduction: Geochemical studies of shergottite (Martian basalt) based on the Rb-Sr, Sm-Nd, and Lu-Hf isotopic systems have provided clues to understanding of the geochemical evolution of Martian mantle and identification of the source reservoirs [e.g. 14]. On the other hand, the U-Pb isotopic systematics has been used to a limited extend for the shergottite petrogenesis, because it is generally difficult to discriminate the indigenous magmatic Pb component from secondary Martian near-surface components and terrestrial contamination [2]. In this study, we compile and reassess all the available Pb isotopic compositions of shergottites (9 papers including conference proceedings); the datasets include whole-rocks and mineral separates with acid leaching experiments. Our analysis of the Pb-isotopic space for shergottites implies the existence of heterogeneous mantle and a geochemically enriched (high-μ: $^{238}U/^{204}Pb$) crustal reservoir.

Lead isotopic variation in shergottites: The Pb isotopic compositions of enriched shergottites exhibit a linear array in a $^{206}Pb/^{204}Pb$-$^{207}Pb/^{204}Pb$ diagram (Fig. 1), providing an apparent isochron age of ~4.1 Ga [5]. This linear array is dominantly defined by the acid leached residues of whole-rocks and plagioclases, whereas the contribution from the pyroxenes is minor.

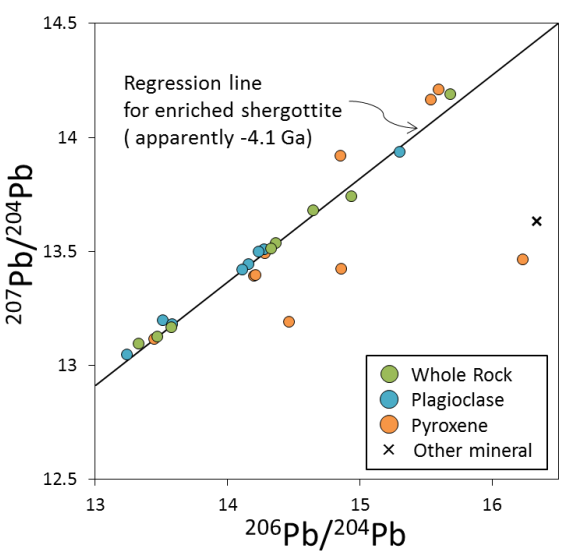

Fig. 1 *$^{206}Pb/^{204}Pb$ vs. $^{207}Pb/^{204}Pb$ diagram for acid residues of whole-rocks and mineral separates from enriched shergottites. The regression line obtained from the whore-rocks and plagioclases represents a Pb-Pb isochron age of ~4.1 Ga. Data sets from [2-6].*

This linear array in the Pb isotopic diagram is interpreted as reflecting either (1) a Pb-Pb isochron or (2) a mixing of two components with distinct Pb isotopic compositions. Four possibilities have been suggested to explain the linear variation in Pb isotopic compositions of shergottites: (1a) Pb-Pb isochron representing a shergottite crystallization age [3-6], (1b) Pb-Pb isochron signifying a formation age of the shergottite source reservoir(s) [13], (2a) mixing of a terrestrial Pb component [9, 10], and (2b) mixing relationship with incorporated Martian surficial Pb by alternation [1].

Reassessment of Pb-Pb isochron age: The linear array in the Pb isotopic diagram suggests a possibility that U-Pb fractionation occurred at ~4.1 Ga. However, this Pb-Pb isochron age conflicts with the other radiometric ages. The Sr-Nd-Hf isotopic systematics have proposed two major melting events for the shergottite petrogenesis: formation of the shergottite source mantle during the Martian magma ocean (~4.5 Ga) and partial melting of shergottite source mantle (150-600 Ma). The former age is derived from short-lived chronometers such as ^{146}Sm-^{142}Nd [11], while the latter is obtained from mineral isochrons of Rb-Sr, Sm-Nd, and Lu-Hf systems for shergottite [10]. These two ages (~4.5 Ga and 150-600 Ma) are inconsistent with the Pb-Pb isochron age of ~4.1 Ga. Moreover, the U-Pb discordia diagram for shergottites shows the intersections at ~200 Ma and ~4.5 Ga, corresponding to the crystallization age and the formation age of the source, respectively [2, 6, 12]. Thus, the 'pseudo' Pb-Pb isochron line turns out to reflect two-component mixing.

Reassessment of two-component mixing: Pb isotopic compositions of original shergottite magmas are easily altered by incorporating secondary components such as terrestrial contaminants and Martian surface materials. Previous studies performed stepwise acid leaching experiments in order to remove the effect of secondary contaminant Pb. Figure 2 shows the Pb isotopic compositions of acid leached residues and their first leachates from whore-rocks and plagioclase separates. The first leachates randomly scatter in the Pb isotopic diagram, while their residues define a linear array. The Pb isotopic compositions of first leachates are thought to be affected by the contamination of secondary Pb, because these contaminants are mainly dis-

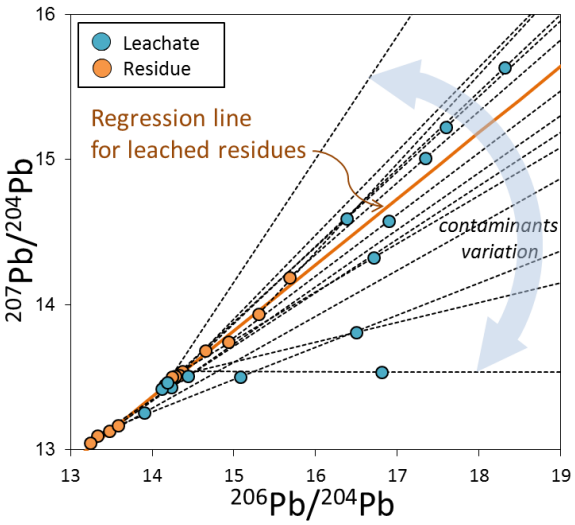

Fig. 2 *$^{206}Pb/^{204}Pb$ vs. $^{207}Pb/^{204}Pb$ diagram for the acid residues of whole-rock and plagioclase separate with their first leachates. Each dotted line connects a residue and its first leachate. Data sets from [2-6].*

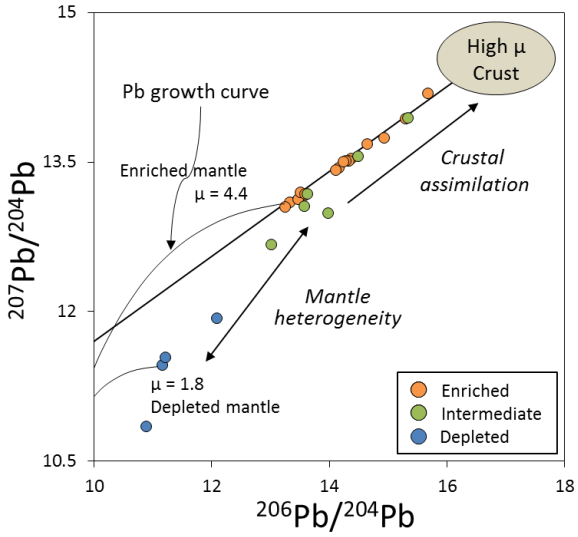

Fig. 3 *$^{206}Pb/^{204}Pb$ vs. $^{207}Pb/^{204}Pb$ diagram for acid residues of whole-rock and plagioclase. The single-stage Pb growth curves and a conceibable crustal high-μ source are also shown. Data sets from [2-9,12].*

tribute into grain boundaries which are easily eluted into a weak acid. The randomly-scattered Pb variation of the first leachates reflects Pb isotopic diversity of secondary contaminants. This observation indicates that the incorporation of secondary contaminants with a variety of Pb isotopic compositions unlikely produces the single linear array defined by the acid leached residues.

The Pb isotopic compositions of the acid leached residues are mostly derived from the shergottite magma sources, because crystalline lattice of original igneous phases are generally resistant to the acid leaching. Additionally, the linear array is represented by the plagioclase acid residues that have low-U/Pb ratios. This suggests that the linear array does not reflect either an age-effect or secondary contamination but represents mixing during the shergottite magmatism.

Mixing process during Martian magmatic activity and implications for the shergottite petrogenesis: Geochemical variability in the shergottite suite has been interpreted as reflecting the mixture of two distinct source reservoirs. However, the mixing process and the origin of the reservoirs have not been identified. Two scenarios have been proposed: (1) mixing between mantle derived magma and crustal component (crustal assimilation [10]), and (2) distinct magmas derived from individual mantle sources (mantle heterogeneity [14]).

The compilation and reassessment of Pb isotopic compositions of shergottites provide a new constraint on the shergottite source reservoirs and petrogenesis (Fig. 3). The acid residues of whole-rocks and plagioclase separates from the geochemically enriched and depleted shergottite have distinct μ-values. Furthermore, the enriched and depleted shergottites do not define a common linear trend in the Pb isotope space. This observation suggests that the previously proposed two-component mixing between the enriched and depleted reservoirs cannot produce the Pb isotopic variation in the shergottite suite. Alternatively, we propose a three-component model that involves the existence of heterogeneous mantle and assimilation of a high-μ crust. The distinct μ-values of shergottite sources (4.4 for enriched, and 1.8 for depleted source) reflect the geochemical heterogeneity in the Martian mantle, which formed during mantle differentiation at ~4.5 Ga. On the other hand, the linear array defined by the enriched shergottites represents assimilation of an ancient high-μ crustal component that has high $^{207}Pb/^{204}Pb$ and $^{206}Pb/^{204}Pb$ ratios.

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