A New Interpretation of Pb Isotopic Variation of Shergottites: Evidence for Heterogeneous Mantle and Crustal Assimilation on Mars

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Geochemical studies of shergottites (Martian basalts) 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. 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. This study compiles and reassesses all the available Pb isotopic compositions of shergottites; the datasets include whole-rocks and mineral separates with acid leaching experiments.
Three geochemical groups of shergottites (enriched, intermediate, and depleted) have different Pb isotopic compositions, reflecting different μ(^{238}U-^{204}Pb) values of their sources. The enriched and depleted shergottites individually exhibit distinct linear arrays in the ^{206}Pb/^{204}Pb-^{207}Pb/^{204}Pb diagram, providing apparent isochron ages of ~4.1 Ga and ~4.3 Ga, respectively. These linear arrays in the Pb isotopic diagram are 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 variations in the Pb isotopic compositions of shergottites: (1a) Pb-Pb isochron representing a shergottite crystallization age, (1b) Pb-Pb isochron for the formation ages of the shergottite source reservoirs, (2a) mixing of a terrestrial Pb component, and (2b) mixing of Martian surficial Pb by alternation. However, these interpretations of the Pb isotopic variations are inconsistent with other isotopic systematics such as Rb-Sr, Sm-Nd, and Lu-Hf for shergottites.
We propose a new model for the shergottite Pb isotopic variations along with other geochemical evidence, in which the two linear arrays defined by the enriched and depleted shergottites represent assimilation of an ancient high-μ crustal component that has high ^{207}Pb/^{204}Pb and ^{206}Pb/^{204}Pb ratios. Differences in the other ends of the linear arrays are interpreted as reflecting the geochemical heterogeneity of the Martian mantle (i.e. enriched and depleted mantle sources). These interpretations of the Pb isotopic variations are consistent with two models proposed by other geochemical signatures of shergottites, “crustal assimilation” and “mantle heterogeneity”.

Keywords: Mars, Shergottite, Pb isotope

