

Evidence from D/H and volatile abundances of impact melts for a surficial water reservoir on Mars

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Martian surface morphology implies that persistent liquid water once existed on its surface and played a significant role in the formation of weathered regolith. In order to study this surficial water we measured volatile abundances (H₂O, CO₂, S, Cl, F) and H isotopes of impact melts (IMs) and maskelynite (shocked plagioclase) in geochemically enriched (LAR 06319 [LAR06]) and intermediate (EETA79001 [EETA79]) shergottites by ion microprobe analysis. Early studies of inert gases contained in IMs from EETA79 match the relative abundances of modern Martian atmosphere.

IMs in LAR06 contain lower H₂O (~150ppm), CO₂ (~20ppm) and S (100-400ppm) but higher F (10-30ppm) and Cl (40-80ppm) than IMs in EETA79 (~300ppm H₂O, ~300ppm CO₂, 3200ppm S, <3ppm F, ~30ppm Cl). The major element compositions of IMs are probably derived by partial melting of primary plagioclase and pyroxene. Likewise, the halogen abundances could possibly reflect the incorporation of primary phosphates. On the other hand, the much higher H₂O/CO₂ ratios than that of the Martian atmosphere (<10⁻³) imply the presence of another water source.

In a previous study [1] based on olivine-hosted melt inclusions we showed that the primary magma of the geochemically depleted shergottite (Yamato 980459 [Y98]) had a chondritic low- δ D value of 275‰, whereas that of LAR06 had a very high- δ D value of 5079‰. In contrast with such extreme δ D differences, matrix phases in Y98 and LAR06 both have moderate δ D values. Groundmass glasses (GGs) in Y98 exhibit a slightly greater δ D variation of 200-1600‰, but still much less extreme than the range exhibited by the melt inclusions. The δ D values of the Y98 GGs rise with increasing water contents, implying mixing of two components: near-surface moderate- δ D and magmatic low- δ D components. On the other hand, IMs and maskelynites in LAR06 exhibit lower δ D values of ~1000-3000‰ than the primary LAR06 melt (5079‰), although mixing calculations suggest that these matrix δ D values could have been modified by contamination of <30ppm terrestrial water (δ D~-200‰). IMs in EETA79 also have a moderate δ D value of ~1600‰.

This study shows that the matrix phases (GG, IM and maskelynite) in all three shergottites have a relatively limited range of δ D values regardless of the distinct δ D of their magmatic sources. A [δ D vs. 1/H₂O] mixing diagram shows a convergence among the matrix δ D values, which could be attributable to the impact-induced addition of a common near-surface water with a moderate δ D value (~1200-2000‰). The origin of this surficial water reservoir remains unresolved: (1) it may be derived from the Martian atmosphere, but its moderate δ D values are distinctly lower than the widely-accepted atmospheric δ D value of ~4000-5000‰, and/or (2) it could originate from the addition of a weathered soil/dust component enriched in volatile elements. [1] Usui *et al.* (2012) *43rd LPSC*, #1341.

Natural variations of uranium isotopes in uranium ore minerals

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Introduction

Recent studies have shown significant variations in ²³⁵U/²³⁸U and ²³⁴U/²³⁸U ratios in geologic materials. We have investigated the uranium isotopic compositions of natural ores from various uranium deposit types with the use of MC-ICP-MS to better understand mechanisms and processes for fractionation of uranium isotopes in different geologic conditions.

Results

The $\delta^{235}\text{U}$ and $\delta^{234}\text{U}$ values of uranium minerals from various types of deposits worldwide show variations of 1.8 and 500‰, respectively, measured relative to NBL CRM 129-A. Higher $\delta^{235}\text{U}$ values are generally recorded by magmatic- or metasomatic-related U mineralization or deposits that have igneous rocks as a source of uranium (Fig. 1). High-grade unconformity type deposits have $\delta^{235}\text{U}$ values around -0.9‰. Vein-type, sandstone-hosted, most unconformity-type deposits, and uranium mineralization in the Beaverlodge area have lower $\delta^{235}\text{U}$ values (Fig. 1). $\delta^{234}\text{U}$ values for most samples analyzed are around 30‰ and record secular equilibrium. Some samples have $\delta^{234}\text{U}$ values much lower or higher than 30‰ associated with addition or removal of ²³⁴U during the past 500 Ka.

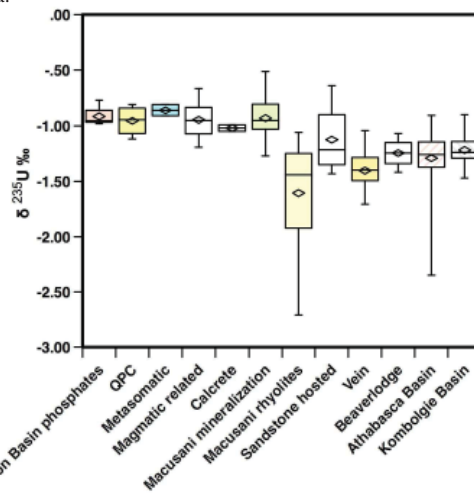


Figure 1: $\delta^{235}\text{U}$ values for studied samples

Discussion

The $\delta^{235}\text{U}$ and $\delta^{234}\text{U}$ values recorded in uranium ores from different types of deposits indicate that there are at least two different mechanisms responsible for ²³⁵U/²³⁸U and ²³⁴U/²³⁸U fractionation. ²³⁴U/²³⁸U disequilibria ratios indicate fluid alteration of the uranium minerals or rocks and postdepositional migration of ²³⁴U. Fractionation of ²³⁵U and ²³⁸U as a result of nuclear volume effects results in enrichment of the heavy isotope in reduced insoluble species relative to oxidized mobile species. Therefore, isotopic fractionation effects should be reflected in ²³⁵U/²³⁸U ratios in U ore minerals formed either by reduction of U⁶⁺ to UO₂ or chemical precipitation in the form of U⁶⁺ minerals. $\delta^{235}\text{U}$ values of uranium ore minerals from a variety of deposits are controlled by isotopic signature of the U source, the efficiency of U precipitation, and later fluid-produced alteration of the ore.