

火星表層水の水素同位体組成

A moderate hydrogen isotope composition of the surficial water reservoir on Mars

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Martian surface morphology implies that Mars was once warm enough to maintain persistent liquid water on its surface and that water played a significant role in the formation of weathered/alterred terrains. This study characterizes Martian surficial volatile reservoirs based on in situ ion microprobe analyses of volatile abundances and H-isotopes of glassy phases (groundmass glass [GG] and impact melt [IM]) in Martian basalts (shergottites). Although these meteorites are of igneous origin, some glassy phases underwent impact-induced modification that trapped surficial and atmospheric volatile components. Analyses of these glassy phases demonstrate that surficial volatile reservoirs have distinct D/H ratios from their magmatic volatiles.

Hydrogen isotope compositions and the abundances of volatile elements (H₂O, CO₂, S, Cl, F) of IMs and GGs have been measured using an ion microprobe (Cameca ims-6f) at DTM-CIW. This study employs three olivine-phyric shergottites: Y-980459 (Y98), LAR 06319 (LAR06), and Lithology-A of EETA79001 (EETA79). These meteorites are petrographically similar, but are geochemically distinct in terms of their radiogenic isotopes and incompatible trace elements. The composition of Y98 closely approximates a Martian primary melt that was directly derived from a geochemically depleted mantle reservoir. In contrast, LAR06 represents a melt that has assimilated a geochemically enriched Martian crust. EETA79 shows an intermediate geochemical signature, which is interpreted to reflect mixing of the depleted and enriched sources represented by Y98 and LAR06, respectively.

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 and high-P₂O₅ contents in the LAR 06 IMs could possibly reflect the incorporation of primary phosphates. Y98 GGs contain low H₂O (20-50 ppm) contents relative to F (15-30 ppm) and Cl (30-50 ppm). The high halogen/H₂O ratios in Y98 GGs, compared to those of Y98 primary magma [1], indicates degassing of magmatic water during eruption.

In our previous study [1] based on olivine-hosted melt inclusions we showed that the primary magma of Y98 had a chondritic low-dD (delta-D) value of 275 permil, whereas that of LAR06 had a very high-dD value of 5079 permil. In contrast with such extreme dD differences, matrix phases in Y98 and LAR06 both have moderate dD values. GGs in Y98 exhibit a slightly greater dD variation of 200-1600 permil, but still much less extreme than the range exhibited by the melt inclusions. The dD values of the Y98 GGs rise with increasing water contents, implying mixing of two components: near-surface moderate-dD and magmatic low-dD components. On the other hand, IMs in LAR06 exhibit lower dD values of ~1000-3000 permil than the primary LAR06 melt (5079 permil). IMs in EETA79 also have a moderate dD value of ~1600 permil.

This study shows that the matrix phases (GG and IM) in all three shergottites have a relatively limited range of dD values regardless of the distinct dD of their magmatic sources. A dD-1/H₂O mixing diagram shows a convergence among the matrix dD values, which could be attributable to the impact-induced addition of a common near-surface water with a moderate dD value (~1500-2000 permil). The origin of this surficial water reservoir remains unresolved: (1) it may be derived from the Martian atmosphere, but its moderate dD values are distinctly lower than the widely-accepted atmospheric dD value of ~4000-5000 permil, and/or (2) it could originate from the addition of a weathered soil/dust component enriched in volatile elements.

[1] Usui, T., et al. (2012) EPSL, 357-358, 119-129.

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