H isotope signatures of minerals, melt inclusions, and impact glasses in SNC meteorites

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Introduction

Measurements of H isotope signatures of nominally anhydrous minerals, magmatic melt inclusions and impact glasses would provide clues to the sources of water in SNC meteorites and possibly on the initial D/H ratios of their parent magmas.

Experimental

H isotope compositions and abundances of phases in seven shergottites, two nakhlites, Chassigny, and ALH 84001 were determined by ion probe. The phases studied are phosphates, carbonates, olivine, clinopyroxene, feldspathic and mafic glasses, and post-stishovite silica. H in melt inclusions in the nakhlites, ALHA 77005, and Chassigny was also measured.

Results

All the phases analysed show evidence of an extraterrestrial, D-rich component. Feldspathic glass and post-stishovite silica in Zagami, Shergotty, and SaU 005 show a positive correlation between δD and water abundance; feldspathic and mafic glass in ALH 84001, ALHA 77005, and EETA 79001 show a negative correlation. Most melt inclusions contain a low δD magmatic glass (δD=–18 to 361‰), but two inclusions in Chassigny and Nakhla are much more D-rich (δD=1754 and 1408 ‰). Clinopyroxene in the nakhlites (δD=142-874 ‰) exhibit more fractionated compositions than olivine (δD=-93 to 210 ‰).

Discussion

All the phases analysed may contain a primary H component, but their compositions were modified by their interaction with a fractionated exchangeable Martian reservoir, by H devolatilization during impact, and by terrestrial contamination. The nakhlites though least altered or shocked among SNCs appear to have reacted with the fractionated Martian reservoir. The low δD values of most melt inclusions suggest that if they preserve the initial H isotope signatures of their parent magmas, the initial D/H ratios of Martian magmas may not be significantly different from those on Earth. The very D-rich inclusion in Chassigny was probably shock remelted.

Nb/Ta geochemical reservoirs

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The aim of this study is to picture the distribution of Nb and Ta between the main terrestrial units. We performed 485 analyses of Nb, Ta, Th and La by ICP-MS in a large variety of crustal and mantle rocks, as well as in mantle volcanics. In addition, we selected 1970 precise analyses from literature and from ongoing studies on mantle rocks.

The results confirm the sub-chondritic Nb/Ta value (< 17.5) of most Silicate-Earth components. Only a thin lithospheric layer including the lower continental crust and the upper lithospheric mantle is distinguished by super-chondritic Nb/Ta (20-25), ascribed to the evolution of volatile-rich and/or carbonatitic small melt fractions. This is supported, for instance, by very high Nb/Ta values in carbonatites (20 to > 2000). However, this layer is too thin and too depleted in Nb-Ta to counterbalance the sub-chondritic Nb/Ta ratio of the other Silicate-Earth units.

Data on oceanic basalts suggest concentric Nb/Ta zoning in the convective mantle, with a variation from 14.5 ± 1.5 in the MORB source to ≥ 16 in deeper mantle (16.0 ± 0.5 for French Polynesian OIBs and 16.3 ± 1.0 for the Ontong-Java Oceanic Plateau). Moreover, the Ontong-Java sampling includes 10 % of basalts with super-chondritic Nb/Ta, which may indicate the existence of an Nb-rich reservoir at the Core-Mantle Boundary (CMB).

However, our study does not support the idea that the subchondritic Nb/Ta ratios observed in most Silicate-Earth components is balanced by a super-chondritic reservoir hidden in deep-seated mantle and filled by recycled, subduction-related material: (1) Nb/Ta in oceanic arc volcanism (15.8 ± 3.4) is not significantly lower than in oceanic basalts; (2) the low Nb/Ta value of continental crust (12.8 ± 3.9 for the upper crust) is not inherited from subduction, but merely the reflection of within-crust differentiation processes; (3) in contrast with Nb/Th and Ta/La, Nb/Ta in OIBs is not correlated with isotopic variations attributed to recycling.

Whole-Earth inversion of Nb, Ta, Th and La data indicates that the sub-chondritic Nb/Ta signature of the Silicate Earth may be accounted for by substantial Nb partitioning in the Core, with a core/mantle distribution coefficient of 0.25 ± 0.08 consistent with experimental data (Wade and Wood, 2001). The super-chondritic Nb/Ta values in some oceanic plateau lavas may be the reflection of chemical interaction across the CMB, as previously suggested on the basis of PGE data (e.g., Jain et al., 1996).

Jain J. C. et al. (1996). *A.G.U., Eos* 77/46, suppl., 714.

Wade J. and Wood B. J. (2001). *Nature* 409, 75-78.