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Hydrogen isotopic composition of the water in CR chondrites

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Many chondrites experienced aqueous alteration, as revealed by the presence of phyllosilicates that are often associated with carbonates, magnetite, sulfides, and sulfates. The timing and duration of the alteration has been constrained by Mn-Cr dating of carbonates; physical constraints on the alteration (e.g. temperature) have been assessed through O isotopes of individual components [e.g., 1]. These data suggest that the alteration of chondrites took place over extended periods of time, and probably occurred almost entirely in asteroidal rather than nebular settings [e.g., 2]. However, our understanding of the conditions of alteration remains imperfect. For example, the origin, composition, and evolution of the fluids during alteration remain poorly constrained. The modification induced by the fluids on the pristine characteristics of the original constituents of the chondrites is only partially understood. In addition to allowing a better understanding of asteroidal alteration, the isotopic composition of asteroidal water is a key parameter to better understand the asteroid-comet continuum and is an important input in nebular models [e.g., 3].

Aqueously altered chondrites are composed of two main hydrogen (H) bearing phases: organics and hydrated minerals. Phyllosilicates and silicates in some aqueously meteorites are enriched in deuterium (D)relative to SMOW [e.g., 4,5], but the enrichments are smaller than in the respective organics [6]. An interstellar origin was attributed to the asteroidal water based on its D enrichment [4]. However, different hypothesis must be tested. Were the D enrichments in water inherited from the molecular cloud or nebula, or do they represent a later signature produced through some secondary reprocessing?

CR chondrites are considered to be the most primitive chondrites in our collections. The thermal and aqueous alteration experienced by QUE 99177, MET 00426, EET 92042, GRA 95229, Renazzo and Al Rais CR chondrites was assessed through multi-technique characterization (Raman, IR, EPMA, SIMS) of the carbonaceous matter and hydrated mineral phases in them. Each of the chondrites escaped long duration thermal metamorphism and experienced some fluid circulation [7, 8]. In particular, the extent of aqueous alteration experienced by QUE 99177 and MET 00426 may have been previously underestimated. The H isotopic compositions of the altering fluids were measured in situ, by SIMS, in fine-grained phyllosilicates and individual coarse-grained hydrated silicates. The main observations are that (i) the water is systematically enriched in D in each CR chondrite (up to dDwater = 1980permil); (ii) the isotopic composition of the water is characterized by highly variable D-enrichment at the micrometer scale; (iii) there is no clear trend observed in the isotopic composition of the water (maximum D-enrichment, range of variation) along the aqueous alteration sequence in the studied CR chondrites.

The high variability of the isotopic composition of the water/OH in CR chondrites is most easily reconciled with a secondary origin of the D-enrichments than with the presence of preserved pristine D-rich ices. Chondrites and comets may have sampled different water reservoirs. The water present in the CR chondrites probably formed in the inner Solar System [7, 8].

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