Are there 100s of ppm water in nominally anhydrous minerals of non-carbonaceous asteroids?

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Non-carbonaceous (NC) asteroids of mainly the S type comprise a large fraction of objects in the main asteroid belt and among the near-Earth asteroid population. Materials represented by them have played significant roles in the accretion of the terrestrial planets, but generally NC materials have been considered essentially dry relative to carbonaceous chondrites (CC). In consequence, NC planetesimals were usually not considered as carriers of H_2O delivered to the early Earth. Recently, SIMS studies of regolith particles returned by JAXA's Hayabusa mission from S-type/LL-group asteroid 25143 Itokawa have reported 240 to 990 ppm H_2O in the nominally anhydrous minerals (NAMs) orthopyroxene, olivine, and albite [1,2]. Additional data has indicated similar contents in NAMs of equilibrated chondrites of the L and LL groups [1,3] and in NAMs of unequilibrated chondrites [4].

H_2O contents on the order of 100s of ppm in NAMs of ordinary chondrites would have substantial implications for the early accretion of H_2O to the proto-Earth and would also imply high lithostatic pressures during thermometamorphism within chondritic planetesimals not consistent with current size estimates. Moreover, high water-to-rock ratios during metamorphism could indicate much higher bulk H_2O contents of pristine equilibrated chondrites beyond the defect-bound hydroxyl component, e.g., in the form of fluid inclusions. This would have considerable implications for the targeting of S-type near-Earth asteroids for in-situ space resources utilization (ISRU).

In order to shed more light on the H_2O contents in asteroidal NAMs, we have conducted a survey of H_2O in equilibrated chondrites and achondrites using the NanoSIMS 50L at the Open University, UK [5]. This contribution serves to place these results in perspective with other recent findings. The NAMs studied comprise olivine and orthopyroxene from a set of equilibrated ordinary chondrites of the L and LL groups (Baszkówka, Bensour, Kheneg Ljouâd, and Tuxtuac) and several ultramafic achondrites (Zakłodzie, Dhofar 125, Northwest Africa [NWA] 4969, NWA 6693, and NWA 7317). For calibration we used terrestrial olivine and orthopyroxene with H_2O contents determined by Fourier transform infrared spectroscopy. Our 99.7% (~3SD) detection limits achieved were 3.6 to 5.4 ppm H_2O for olivine and 7.7 to 10.9 ppm H_2O for orthopyroxene.

Our survey did not identify any meteorite sample that consistently showed H_2O contents in NAMs above our detection limits. Other recent SIMS studies of H_2O in NAMs of ungrouped achondrites and acapulcoites/lodranites, including NWA 6704 (paired with our sample of NWA 6693) and Dhofar 125, did not detect H_2O above 2.1 ppm [6] and 6.6 ppm [7], respectively. SIMS analyses of NAMs in unequilibrated chondrites by have also indicated very low H_2O contents of 8 to 14 ppm in these materials [8].

Finding H_2O contents one to two orders of magnitude lower than previously reported suggests that the parent planetesimals of the highly metamorphic chondrites, primitive achondrites and ultramafic achondrites studied were efficiently degassed during metamorphism and melting, if they initially had held substantial amounts of volatiles [5,6]. The discrepancies between SIMS analyses of Itokawa samples/equilibrated chondrites showing 100s of ppm H_2O on the one hand and equilibrated chondrites showing hardly any detectable H_2O on the other hand may stem from two contributions: Systematic errors of the analyses and/or heterogeneity of the samples. Sample contamination leading to systematically biased H_2O contents is a major suspect. It appears more likely to occur than H_2O loss from the strongly bound hydroxyl defects in NAMs, which requires substantial or prolonged heating to diffusively remove H_2O. The studies available rarely analysed the same samples or meteorites, rendering it difficult to rule out sample heterogeneity. However, there is currently no other indication to support the hypothesis that common equilibrated chondrites underwent metamorphism under vastly different peak pressures and H_2O fugacities, leading to heterogeneous H_2O contents in NAMs among different meteorites.

Hence, the presence of 100s of ppm H_2O in samples of asteroid Itokawa and equilibrated non-carbonaceous chondrites is doubtful and the role of their parent bodies in delivering water to the terrestrial planets needs to be questioned.

References

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