Solar System Hygrometry with Nominally Anhydrous Minerals

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During the initial accretion of the terrestrial planets, it is commonly assumed that material accreted in the inner solar system was dry [1]; if correct, the presence of water on the Earth, the Moon, and Mars requires late delivery of water to the inner solar system. The source(s) of this water and the timing of its delivery are topics of debate [2].

Recent work has identified a compositional dichotomy among meteorites defined by isotopes of Cr, Ti, O, and Mo [3]. This dichotomy divides carbonaceous chondrites (CC) from the majority of non-carbonaceous chondrites (NC) and achondrites; however, a few anomalous achondrites have been found to possess isotopic signatures with CC affinities. The division of meteorites into CC and NC groups is suggestive of spatial segregation of their parent bodies in the early solar system. It has been proposed that NC meteorites came from parent bodies that accreted in the inner solar system, while CC meteorites were sourced from the outer solar system [4].

We have measured water in nominally anhydrous minerals in achondrite meteorites with both CC and NC affinities. We expected that achondrite parent bodies with CC affinities may be more water-rich than their NC counterparts, due to the fact that they likely accreted beyond the snowline. However, our preliminary results show that orthopyroxene-rich cumulates from CC achondrite NWA 10132 and NC achondrite NWA 8777 are both relatively dry, with orthopyroxenes containing $\leq$3 ppm H_2O. Several processes could account for the dry nature of the CC and NC achondrites studied thus far, including: (1) baking of shallow unmelted chondritic material during differentiation by internal heating, driven by decay of short-lived radionuclides; (2) efficient magma ocean degassing; and (3) intermittent remelting and degassing of near-surface material during impact events [5]. Insofar as NWA 10132 can be considered representative of CC achondrites, our results suggest that CC achondrite parent bodies are an unlikely vehicle for water delivery to the inner solar system.

[1] O'Brien et al. 2018; [2] Sarafian et al. 2017; [3] Warren 2011; [4] Scott et al. 2018; [5] Elkins-Tanton 2012