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The high-temperature origin of hydrogen in enstatite chondrite chondrules and implications for the origin of terrestrial water

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Enstatite chondrites (ECs) are commonly proposed as Earth's main building blocks, due to their numerous isotopic similarities to terrestrial rocks. Water delivery to Earth is a long-standing issue that might be settled with the recent reevaluation of H content in ECs [1]. They thus contain sufficient H concentrations to account for the mass of Earth's oceans. However, the physicochemical process(es) by which H is incorporated in ECs remain largely unconstrained. ECs do not contain any hydrated minerals or traces of aqueous alteration [2] and are generally considered to be dry, i.e., without water and poor in volatile elements.

We combined secondary ion mass spectrometry analyses of volatile contents (H, C, F, Cl, S) and H isotopic compositions with Raman spectroscopy analyses of H speciation in the glassy chondrule mesostases of two paired unequilibrated ECs (Sahara 97097 and Sahara 97116). EC chondrule mesostases (68–830 wt. ppm H) contain much more H than chondrule silicates (5–25 wt. ppm H) and are characterized by H isotopic compositions of δD = −109 ± 27 ‰. Hydrogen and sulfur contents are positively correlated in EC chondrule mesostases, and well-resolved Raman peaks at 2580 cm^{-1} are commonly observed, corresponding to HS^- or H_2S bonding.

Based on these results, we propose that the high H abundances in EC chondrule mesostases do not result from secondary processes, such as terrestrial contamination or secondary asteroidal alteration, nor from a legacy of their chondrule precursors. Instead, they were likely established at high temperature during chondrule formation via interactions between Fe-poor melts and S-rich gas under extremely reducing conditions, in line with experimental results [3].

Our data confirm that ECs contain sufficient primordial hydrogen to explain the terrestrial water budget if no loss and likely contributed important amounts of other volatile elements such as carbon.

[1] Piani et al. (2020), *Science 369, 1110-1113.*

[2] Weisberg and Kimura (2012), *Geochemistry 72, 101-115.*

[3] Klimm and Botcharnikov (2010), *American Mineralogist 95, 1574-1579*