Identifying the host(s) of Martian water in the nakhlite meteorites

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The nakhlite meteorites are ~1.4 Ga old igneous rocks that were impact-ejected from Mars at ~11 Ma [1]. These olivine-clinopyroxenites contain upto 0.4 wt% water [2], which occurs mainly within narrow Si- and Fe-rich 'iddingsite' veins that cross-cut the olivine grains. Athough the nakhlites contain the largest amount of Martian water that available for analysis on Earth, the identity of its carrier(s) remain poorly understood. Previously described hydrous constituents of the olivine-hosted veins include smectite, amorphous gel, opaline silica, and iron (oxy)hydroxides [3-5]. We have sought to understand the composition and origin of the veins by analysis of the Northwest Africa (NWA) 817 meteorite, which has evidence for significant Martian aqueous alteration [6,7]. Our work has used high-resolution transmission electron microscopy (TEM) coupled with electron energy loss spectroscopy (EELS).

The veins comprise ~6-20 vol. % of NWA 817 olivine grains. Vein microstructures indicate an origin by centripetal replacement, with the iron-rich rims of the zoned olivine grains being most susceptible to alteration. High-resolution TEM shows that the veins are principally composed of nanocrystalline smectite intergrown with Fe-(oxy)hydroxides, in agreement with [6]. The smectite crystals were identified from their ~1 nm lattice fringe spacings, and individual crystals are typically 3-4 nm thick. The veins are locally cross-cut by aggregates of more coarsely crystalline smectite intergrown with Fe-(oxy)hydroxide, thus showing that the region of the Martian crust sampled by NWA 817 underwent multiple phases of water-rock interaction. By combining petrographic observations with high-precision argon isotope dating of nakhlite veins, we aim to understand better the source and longevity of water in the Martian crust at this relatively late stage in the planet's history.

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