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AQUEOUS ALTERATION PROCESSES ON ASTEROID RYUGU: NEW INSIGHTS FROM ABERRATION CORRECT SCANNNING TRANSMISSION ELECTRON MICROSCOPY OF PYRRHOTITE AND MAGNETITE

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The Hayabusa2 spacecraft successfully returned samples of the regolith of asteroid Ryugu to Earth in November 2022. Studies of these pristine samples demonstrate that they have characteristics consistent with CI chondrites [1-4], but are more pristine. Here we report FIB/TEM observations of pyrrhotite and magnetite from sample C0076-01 that provide new insights into aqueous alteration processes on asteroid Ryugu.

An elongate pyrrhotite grain oriented parallel to the *c*-axis was selected for FIB-TEM analysis. The grain is a single crystal that contains irregularly-shaped voids ~50 nm to 1 μm in size at its rim. Discontinuous, crystallographically oriented lamellae are present, <50 nm to 200 nm in length and <10 nm in thickness. HRTEM imaging shows that they consist of a phase with a basal spacing of ~ 0.7 nm and are enriched in Mg, Si, and O, consistent with serpentine, The pyrrhotite contains magnetite inclusions, <0.5 μm in size, that are facetted and contain myriad nanopores (<3 nm). Atomic resolution STEM imaging shows that the magnetite has a nanodomain structure, with irregularly shaped domains ~ 5 nm in size, distinguished by slight misorientations between the domains.

To our knowledge, this is the first reported example of coherent serpentine lamellae intergrown with pyrrhotite in an extraterrestrial sample. The serpentine is strong evidence that the two phases formed simultaneously, indicating that growth from an aqueous solution is most likely. The coherent nature of the intergrowth suggests that serpentine nucleated topotaxially on the surface of pyrrhotite grains and was overgrown by the sulfide. The complex domain structure of the magnetite and the presence of nanopores also supports growth from a solution. This domain structure may be the result of incorporation of Si into the magnetite structure, resulting in localized strain that is accommodated by distortion of the lattice.

References: [1] Kitazato, K., et al. (2019). Science 364, 272-275. [2] Nakamura, T. et al. (2022) Science 369 DOI: 10.1126/science.abn8671. [3] Ito, M. et al. (2023) Nature Astronomy doi.org/10.1038/s41550-022-01745-5. [4] Noguchi, T. et al. (2023) MAPS doi: 10.1111/maps.14093. [5] Dobrica, E. et al. (2023) GCA 346, doi.org/10.1016/j.gca.2023.02.003

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