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Merrillite-apatite disequilibrium textures in martian meteorites record late-stage crustal processes

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The phosphate minerals merrillite and Cl±F±OH-bearing apatite are common accessory phases in martian meteorites, reflecting the order of magnitude higher bulk P contents of Mars relative to the bulk silicate Earth [1]. Phosphates are important reservoirs of rare earth elements [2] and apatite chemistry monitors variations in late-stage magmatic halogen and volatile fugacities. Furthermore, measurements of S^{6+}/S^{2-} in martian apatites record variable oxygen fugacity levels [3,4], with evidence for late-stage oxidation of Nakhla related to low-pressure interactions with the martian crust and atmosphere [3]. Here, we document evidence for disequilibrium at merrillite-apatite phase boundaries in martian meteorites that records changing conditions during or after apatite crystallization.

The merrillite-apatite phase boundaries are characterized by a symplectic intergrowth of Fe-oxide and phosphate that emanate into the merrillite side of the boundary and which are absent from the adjacent apatite. We used a variety of analytical techniques to measure compositional gradients across the symplectite region to assess possible formation mechanisms. Previously, similar features have been attributed to shock-melt processes [5], however in the occurrences we describe there is no evidence for direct influence of shock re-equilibration such as those documented in Apollo samples [6]. Instead, we explore whether the symplectites formed as a result of subsolidus reaction between merrillite and apatite, cryptic fluid metasomatism, or by oxidative breakdown of high Fe/Mg merrillite into low Fe/Mg merrillite and Fe-oxide. Because such textures appear in several martian meteorite types, they provide evidence for a widespread process influencing martian magmas that could reflect interactions with oxidized crustal or deuteric fluids.

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