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Olivine - Phyllosilicate replacement through an amorphous intermediate by interface - coupled dissolution precipitation.

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During the Noachian period on Mars, the interaction of water with olivine-pyroxene assemblages led to the widespread formation of hydrated phyllosilicates like clay, chlorites, and serpentines. This study investigates how olivine, a common mineral on Mars, alters when it comes into contact with aluminium-bearing aqueous solutions under hydrothermal conditions by elemental dissolution and redistribution. This research aims to improve our understanding of past water activity and the evolution of minerals on Mars.

In sealed hydrothermal bombs maintained at a temperature of 100 - 150 °C, finely powdered olivine was reacted with Al-, NH_4-, and Na-bearing chloride solutions. The resulting products were characterized using X-ray diffraction, scanning electron microscopy, and transmission electron microscopy with selected area electron diffraction imaging. The observed colour changes reflect the varying reactions: fresh olivine appeared grey-white, transitioned to white upon contact with water alone, exhibited a light-yellow hue in the presence of $AlCl_3$, and displayed the deepest yellow colour when combined with a mixture of $AlCl_3$ and NH_4Cl.

X-ray diffraction patterns showed decreased olivine peak intensity and broad humps, indicating the formation of amorphous products, and sharper peaks indicating well-crystallised minerals. SEM images revealed severe surface modification, including grain rounding, crack formation, surface erosion, and growth of amorphous material, which were absent in unreacted olivine. TEM observations further confirmed structural breakdown, showing loss of crystal boundaries and partial amorphization in altered samples. EDX analysis demonstrated a significant increase in Al content from 0.16 wt% in fresh olivine to 18.93 wt% in the most altered product, indicating Aluminium inclusion in mineral structures. Time was also a controlling factor, as longer experiments produced stronger alteration signals.

The textural and compositional observations, combined with reaction path modelling under different water-rock ratios, pH conditions and fluid compositions, were studied for a better understanding of the alteration process. Collectively, these results demonstrate that aluminium-rich mixed aqueous solutions significantly accelerate the breakdown of olivine and promote the formation of amorphous clay-like materials under hydrothermal conditions relevant to early Martian environments.

[1] Zhang et al. (2026). Applied Clay Science, 283, p.108120. [2] Besselink et al. (2020). Crystal Growth & Design, 20(5), pp.3365-3373.