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Subaerial Carbonate Formation on Mars

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Carbonate on the Martian surface has been interpreted as evidence for liquid water [1-3]. Spectral evidence suggests Martian carbonates are associated with olivine and/or phyllosilicate minerals [4,5], and measured Mg-Fe ratios in the Martian magnesite-siderite carbonates match that of the co-occurring olivine [6,7]. Combined, these data have been interpreted as evidence of hydrothermal alteration of mafic/ultramafic rocks [e.g., 4,7]. However, rover analysis of rocks in both the Jezero and Gustev craters indicate olivine-carbonate-silica assemblages, absent of hydrated silicate minerals [3,8]. These assemblages are uncommon in terrestrial hydrothermal analogues where the alteration of ultramafic host rocks yield carbonate veins alongside talc, serpentine, and/or brucite [9,10].

Direct gas-rock reactions provide an alternative mechanism for the formation of carbonate minerals. Evidence for gas-rock reactions has been observed in natural and experimental settings, accelerated by either elevated temperatures and/or hydration [11-13]. Given the long timescales over which the Martian crust has been exposed to a CO_2-rich atmosphere, with relative humidity often greater than 50% [14], olivine carbonation could accumulate slowly in regions without tectonic overturning. Using Gibbs' free energy minimisation, we find magnesite-siderite carbonate is stable across a range of possible CO_2, O_2, and H_2O conditions at ambient pressure and temperature. With increased humidity, we predict minor abundances of talc, serpentine, and/or goethite, all below the spectral detection limit. If formed through gas-rock reactions, carbonate minerals are decoupled from aqueous environments, further highlighting the need for textural and geochemical palaeoenvironmental proxies.

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