A pyroclastic protolith for the most widespread carbonate- and serpentine-bearing ultramafic rock on the martian surface

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The origins of olivine-rich ultramafic rocks on the martian surface and the geologic context of their aqueous alteration to serpentine, Mg-carbonate, and other minerals remain poorly constrained. Previous origin hypotheses for these serpentinized ultramafic protoliths include emplacement as basement intrusions [1], melt from large impact events [2], and flood lavas [3]. We evaluate the protolith origin of the ~70,000 km^2 Circum-Isidis olivine-rich unit, which is ~3.7 Ga in age [2] and locally altered to Mg-carbonate (~10%) and serpentine [4], by synthesizing 1:50,000-scale geologic mapping and quantitative geomorphology of >100 unit outcrops with previous physical and orbital spectroscopic modeling. Our observations and measurements of the unit's stratigraphy, thickness, internal banding, and orientation indicate that the unit was likely an ash-fall deposit from Syrtis Major, consistent with previous modeling and spectroscopy.

The cold emplacement temperatures of martian distal tephra deposits rule out internally-sourced heat for serpentinization within the unit or the diverse alteration mineralogy observed in underlying rock units. The high permeability and porosity of clastic rocks, generally, and the high specific surface area of pyroclasts, specifically, suggests that lesser volumes of water may have been necessary to produce the serpentine and carbonate minerals detected spectroscopically from orbit. In conjunction with partially carbonated ultramafic pyroclasts observed in situ at Columbia Hills [5] and the absence of aqueous alteration minerals in massive olivine-rich ejecta of Argyre and Hellas, our work suggests that the protolith textures of clastic ultramafic rocks may be a primary control on the water-limited serpentinization and carbonation of the martian crust.

[1] Hoefen, T. M. et al. (2003) *Science*, *302*, 627–630.

[2] Mustard, J. F. et al. (2009) *J. Geophys. Res.*, *114*.

[3] Tornabene, L. L. et al. (2008) *J. Geophys. Res.*, *113*.

[4] Salvatore, M. R. et al. (2018) *Icarus*, *301*, 76–96.

[5] Ruff, S. W. et al. (2014) *Geology*, *42*, 359–362.