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Title: Basalt weathering in a cold and icy climate: Three Sisters, Oregon as an analog for early Mars

Authors: E. B. Rampe, B. Horgan, R. J. Smith, N. A. Scudder, A. M. Rutledge, E. Bamber, R. V. Morris

There is abundant evidence for liquid water on early Mars, but the debate remains whether early Mars was warm and wet or cold and icy with punctuated periods of melting. To further investigate the hypothesis of a cold and icy early Mars, we collected rocks and sediments from the Collier and Diller glacial valleys in the Three Sisters volcanic complex in Oregon. We analyzed rocks and sediments with X-ray diffraction (XRD), scanning and transmission electron microscopies with energy dispersive spectroscopy (SEM, TEM, EDS), and visible, short-wave infrared (VSWIR) and thermal-IR (TIR) spectroscopies to characterize chemical weathering and sediment transport through the valleys. Here, we focus on the composition and mineralogy of the weathering products and how they compare to those identified on the martian surface. Phyllosilicates (smectite), zeolites, and poorly crystalline phases were discovered in pro- and supra-glacial sediments, whereas Si-rich regelation films were found on hand samples and boulders in the proglacial valleys. Most phyllosilicates and zeolites are likely detrital, originating from hydrothermally altered units on North Sister. TEM-EDS analyses of the <2 um size fraction of glacial flour samples demonstrate a variety of poorly crystalline (i.e., no long-range crystallographic order) phases: iron oxides, devitrified volcanic glass, and Fe-Si-Al phases. The CheMin XRD on the Curiosity rover in Gale crater has identified significant amounts of X-ray amorphous materials in all samples measured to date. The amorphous component is likely a combination of silicates, iron oxides, and sulfates. Although we have not yet observed amorphous sulfate in the samples from Three Sisters, the variety of poorly crystalline weathering products found at this site is consistent with the variable composition of the X-ray amorphous component identified by CheMin. We suggest that these amorphous phases on Mars could have formed in a similarly cold and icy environment.