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Characterizing low-temperature aqueous alteration of Mars-analog basalts from Mauna Kea at multiple scales

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Abstract

We performed a multi-scale characterization of aqueous alteration of Mars analog basaltic rock from a Mauna Kea drill core using high-resolution visible and short-wave infrared (VIS-SWIR) spectral imaging, scanning electron microscopy, X-ray diffraction, and point VIS-SWIR spectra. Several types of smectites, zeolites, and primary minerals were identified. Mineral classes were mapped in cut sections extracted from the drill core and used to represent the range of alteration products seen in field data collected over 1000 m depth (Calvin et al. 2020). Ten distinct spectral end-members identified in the cut sections were used to map the field point spectra. Trioctahedral Fe- and Mg-rich smectites were present toward the top of the zone of analysis (972 m below the surface) and increased in abundance toward the bottom of the drill core (1763 m depth). The mineralogy demonstrates a general trend of discontinuous alteration that increases in intensity with depth, with less pervasive phyllosilicate alteration at the top, several zones of different mixtures of zeolites toward the center, followed by more abundant phyllosilicates in the lowest sections. Distinctly absent are Fe-Mg phyllosilicates other than smectites, as well as carbonates, sulfates, and Al phyllosilicates such as kaolinite or illite. Furthermore, hematite was only detected in two of 24 samples. The suite of assemblages points to aqueous alteration at low-to-moderate temperatures at neutral to basic pH in low-oxygen conditions, with little evidence of extensive surface interaction, presenting a possible analog for an early Mars subsurface environment. We also present a library of VIS-SWIR spectra of the analyzed cut sections, including both spatial averages (i.e., unweighted linear mixtures) of spectral images of each cut section and single point spectra of the cut sections. This will allow for consideration of nonlinear mixing effects in point spectra of these assemblages from natural surfaces in future terrestrial or planetary work.

Keywords: Visible to short-wave infrared spectroscopy, X-ray diffraction, scanning electron microscopy, Mars analog, natural zeolites, Mg/Fe smectites, aqueous alteration; Earth Analogs for Martian Geological Materials and Processes