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Mineralogy and geochemistry of hot spring deposits at Námafjall, Iceland: Analog for sulfate soils at Gusev crater, Mars

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Abstract

Iceland's Námafjall geothermal area exhibits a range of alteration environments. Geochemical and mineralogical analyses of fumaroles and hot springs interacting with Holocene basaltic lavas at Hverir, and with Pleistocene hyaloclastites atop nearby Námaskarð hill, reveal different patterns of alteration depending on water-rock ratio, degree of oxidation, and substrate composition and age. The focus of this study is on the mineral deposits at and near hot springs at Hverir and Námaskarð. Surface samples, and samples collected from shallow pits in the alteration aprons adjacent to hot springs, were analyzed by X-ray diffraction (XRD) and X-ray fluorescence (XRF) to constrain the differences in composition with both distance and depth. Fluids were analyzed in the field for their environmental parameters and sampled for cation and anion analysis. Fluid analyses revealed uniformly acidic conditions but with site-to-site variation in other parameters such as temperature, salinity, and conductivity. Solid phases identified include amorphous silica, pyrite, elemental sulfur, and kaolinite in the muds, surrounded by Fe^{2+}-sulfate and then Fe^{3+}-sulfate efflorescence, following a redox gradient pattern involving the oxidation of sulfur and then iron with increasing distance. Shallow pits excavated near two Námaskarð hot springs reveal a shallow oxidation front, with sulfide-rich materials below a thin surface of sulfates and elemental sulfur. Silica phases include amorphous silica and quartz. Quartz likely reflects diagenetic maturation of earlier-formed amorphous silica, under surface hydrothermal conditions.

The high iron content of the substrate basalt and the prevalence of Fe-sulfates and Fe-oxides among the alteration products make this geothermal area an especially useful analog for potential martian hydrothermal environments. In particular, these sulfate-rich deposits adjacent to volcanic, acidic hot springs could provide a helpful comparison for sulfur-rich soils in the Columbia Hills on Mars, where some of the same minerals have been identified (e.g., ferricopiapite) or inferred (e.g., rhomboclase).

Keywords: Hydrothermal alteration, Mars analog, sulfate mineralogy; Earth Analogs for Martian Geological Materials and Processes