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Secondary minerals associated with Lassen fumaroles and hot springs: Implications for martian hydrothermal deposits

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Abstract

The active hot springs, fumaroles, and mud pots of the southwestern Lassen hydrothermal system include various alteration environments, which produce a range of hydrothermal mineral assemblages. Analysis of water, mineral precipitates, altered sediment, and rock samples collected at and near these features at Sulphur Works, Bumpass Hell, Little Hot Springs Valley, and Growler and Morgan Hot Springs reveals conditions ranging from ~100 °C acid-sulfate fumaroles (e.g., Sulphur Works and Bumpass Hell) to near-neutral hot springs (e.g., Growler and Morgan), and includes both oxidizing and reducing conditions. Resulting hydrothermal minerals include a wide variety of sulfates (dominated by Al-sulfates, but also including Fe^{2+}, Fe^{3+}, Ca, Mg, and mixed-cation sulfates), sulfides (pyrite and marcasite), elemental sulfur, and smectite and kaolinite clays. Most altered samples contain at least one silica phase, most commonly quartz, but also including cristobalite, tridymite, and/or amorphous silica. Quartz and other silica phases are not as abundant in the less altered rock samples, thus their abundance in some hydrothermally altered sediment samples suggests a detrital origin, or formation by hydrothermal alteration (either modern or Pleistocene); this requires a high degree of diagenetic (or epigenetic) maturation. These results support a previously identified model that the Lassen hydrothermal system involves the de-coupling of a vapor phase (which becomes acidic as it oxidizes near the surface, producing acid-sulfate fumaroles at higher elevations at Sulphur Works and Bumpass Hell) from the residual near neutral thermal waters that emerge as hot springs at lower elevations (Growler and Morgan). Because both acid-sulfate fumarole and near-neutral sinter-producing hot springs have been invoked to explain the silica-rich deposits observed by the Mars Exploration Rover Spirit near Home Plate in the Columbia Hills on Mars, Lassen can serve as a useful terrestrial analog for comparison.

Keywords: Mars, hydrothermal alteration, sulfate minerals, element mobility