EVIDENCE FOR AN ALKALI CHLORIDE HYDROTHERMAL SYSTEM IN THE COLUMBIA HILLS, MARS. S. W. Ruff[1] and J. D. Farmer[1], [1]School of Earth and Space Exploration, Arizona State University, Tempe, AZ 85287, steve.ruff@asu.edu.

Introduction: The Spirit rover encountered opaline silica outcrops (amorphous $SiO_2 \bullet nH_2O$) and soil adjacent to the Home Plate feature in the Columbia Hills of Gusev crater that were interpreted to be the products of a volcanic hydrothermal system [1]. An origin for the silica via acid-sulfate leaching of basaltic precursor materials by fumarolic steam condensates was the favored hypothesis in the initial analysis, based largely on geochemical arguments including a Ti enrichment in the soil. Nodular and digitate structures among the outcrops initially were attributed to aeolian erosion rather than to primary features of the former hydrothermal environment [2]. Now we recognize remarkably similar opaline silica structures forming in discharge channels of hot springs and geysers in the northern Chile geothermal field known as El Tatio (Fig. 1). These are primary sedimentary structures rather than erosional artifacts. Halite (NaCl) encrusts the silica at El Tatio, producing infrared spectral characteristics that match those of infrared spectra from Spirit's Miniature Thermal Emission Spectrometer (Mini-TES), consistent with an alkali chloride hydrothermal system at both sites.

El Tatio Analog: The hot springs and geysers of El Tatio are part of a high elevation (~4300 m) geothermal field in the Atacama Desert where precipitation is <100 mm/yr, mean annual evaporation rate is 132 mm, diurnal freeze-thaw is common [3], and UV irradiance is extremely high [4]. Such conditions provide a better analog to Mars than those of Yellowstone National Park and other well-known geothermal sites on Earth. One of the distinctive attributes of El Tatio is the common presence of halite on subaerial exposures of silica sinter (Fig. 2), which has an unanticipated effect on their thermal infrared spectra as shown below.

Results: Mini-TES spectra commonly display a prominent absorption feature near 1260 cm^{-1} that typically is weak or absent in terrestrial opaline silica. Previous work demonstrated that this feature is sensitive to viewing geometry and that opaline silica measured at the high emission angles (>40°) typical of Mini-TES observations results in a feature with depth sufficient to match that seen in some Mini-TES spectra [1; 2] (Fig. 3A). We now find that thin (10s of micrometers), patchy crusts of halite on silica sinter samples from El Tatio have a similar effect, independent of emission angle (Fig. 3B). Attribution of this spectral effect to halite comes from measuring the same sample before and after scrubbing and rinsing with a brush and deionized water. This action effectively removes halite from the surface without disturbing the silica. Spectra obtained after halite removal have a diminished and shifted feature near 1260 cm^{-1}, producing a spectrum much more similar to that of typical silica sinter, for example, from the hot springs of Yellowstone National Park, (Fig. 4).

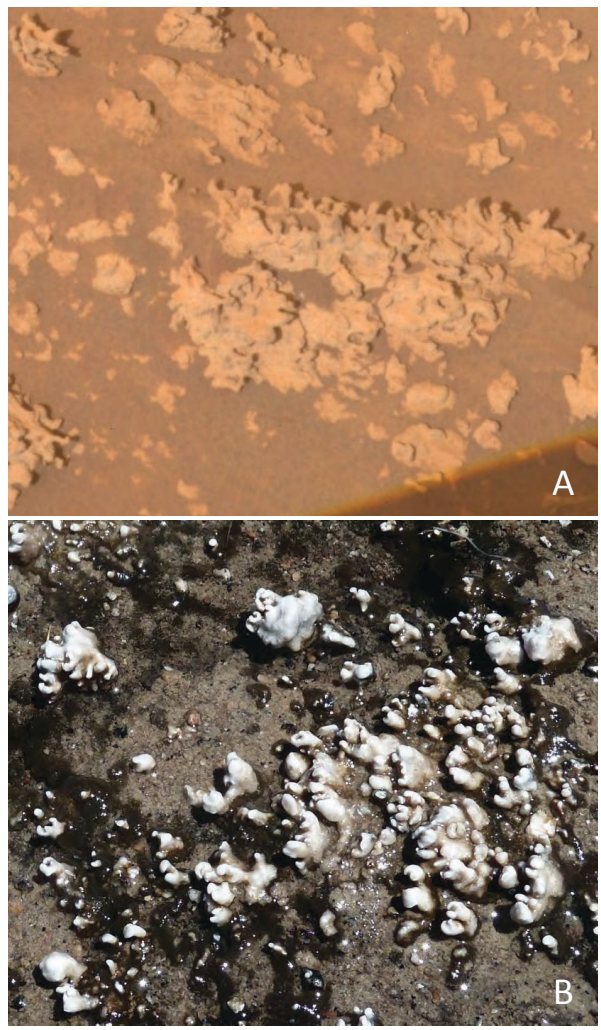

Figure 1. Digitate silica structures adjacent to Home Plate (A) and in a hot spring discharge channel at El Tatio, Chile (B) at the same scale. Each scene spans ~17 cm. Mars scene is a Pancam approximate true color image (sol 1160, P2582); reddish hues are due to dust cover.

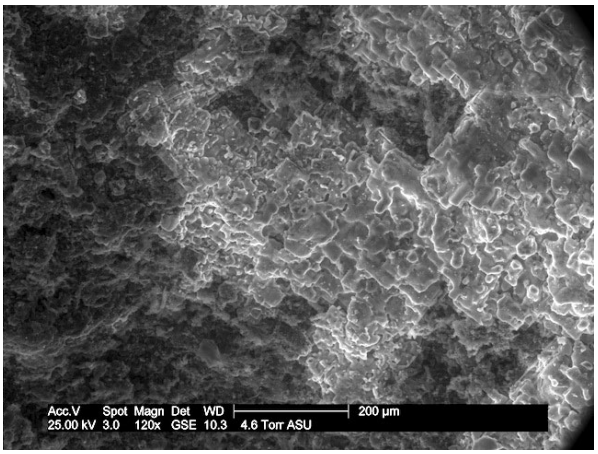

Figure 2. Scanning electron microscope image of El Tatio sample showing halite crust (lighter tone) over opaline silica (darker tone).

Discussion: Although viewing geometry affects the spectral character of opaline silica, it is insufficient to account for the range of contrast and position of the ~1260 cm^{-1} feature in Mini-TES spectra. Moreover, the fact that the facets of key Mini-TES targets were not oriented at a high emission angle yet produced a strong ~1260 cm^{-1} feature requires an alternative explanation.

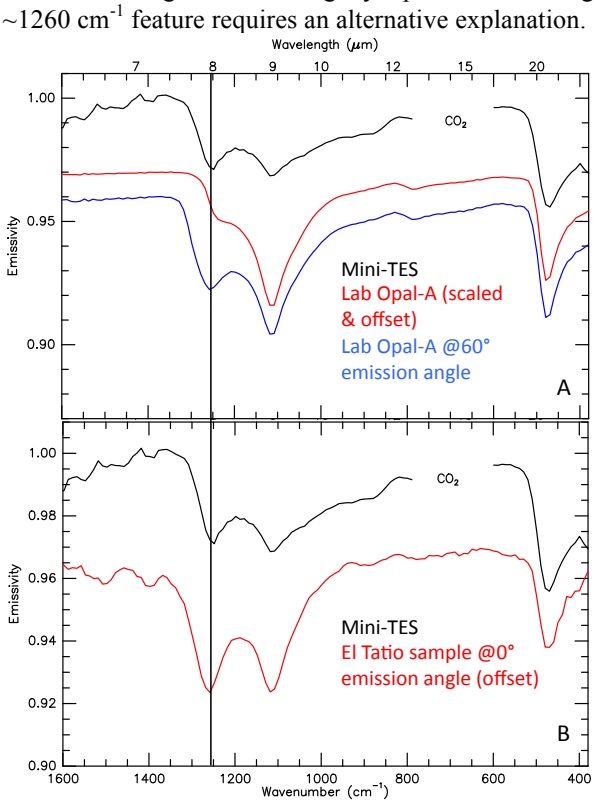

Figure 3. Comparison of spectral effects of viewing geometry (A) vs. halite crust (B) on silica. Vertical line indicates feature sensitive to both and present in Mini-TES spectra but better fit by halite crust.

The role of halite in contributing to this feature is unanticipated given that halite is not absorbing in this spectral range. Instead, perhaps it serves to accentuate the known geometric effect in a way that mimics a high emission angle viewing geometry. Regardless of the mechanism, the presence or absence of a halite crust on silica sinter can account for the range of contrast and position of the ~1260 cm^{-1} feature previously documented in Mini-TES spectra of opaline silica outcrops but not fully reconcilable as a viewing geometry effect alone.

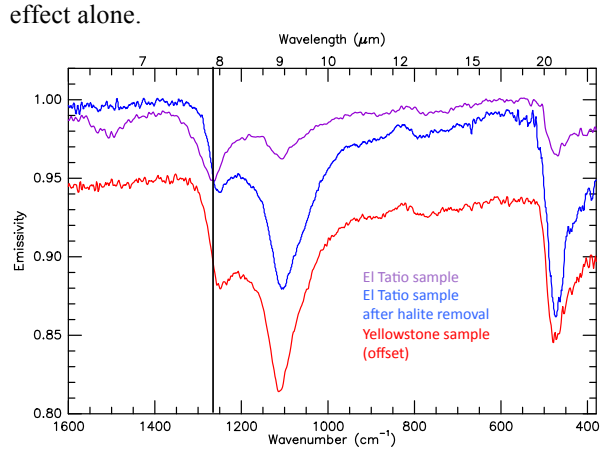

Figure 4. Evidence for the role of halite crust in affecting feature near 1260 cm^{-1} (vertical line), which is diminished and shifted after crust is removed, similar to non-halite silica sinter like that of Yellowstone.

Conclusions: The high evaporation rates of silica-bearing alkali chloride solutions at El Tatio produce silica deposits encrusted with halite. The presence of halite is detectable via a pronounced spectral feature near 1260 cm^{-1}. Mini-TES spectra of silica deposits adjacent to Home Plate show this feature in addition to morphologic characteristics consistent with the sedimentary structures of silica at El Tatio. A straightforward interpretation of these observations is that the Home Plate silica occurrence is the result of silica-bearing alkali chloride solutions from hot spring and/or geyser activity in a low precipitation, high evaporation ancient environment on Mars.

References: [1] Squyres, S. W., et al. (2008), Science, 320, 1063-1067, 10.1126/science.1155429.
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