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Water ice and hydrated mineral signatures in a mid-latitude area of the Southern Highlands: Underground water storage or seasonal permafrost?

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Abstract

Large water ice deposits and a variety of hydrated minerals including hydrated sulfates, phyllosilicates, and hydrated silica were found in an area of the Southern Highlands between latitudes of 15° and 45°. The ice was found to occur as patchy isolated deposits usually associated with more heavily eroded and chaotic terrain, where knobs and ridges provided a type of protection, but also as channel like features several kilometers in length that run parallel with the slope of a graben wall. The ice deposits may have originated as precipitation during Mars' high-obliquity periods or are currently being fed from an underground storage of water as the high elevation of the area ice is expected to evaporate at the surface. Hydrated minerals represent past aqueous activity and the possibility of present groundwater upwelling to the surface makes the location interesting when prospecting areas that may be associated with microbial life.

1. Introduction

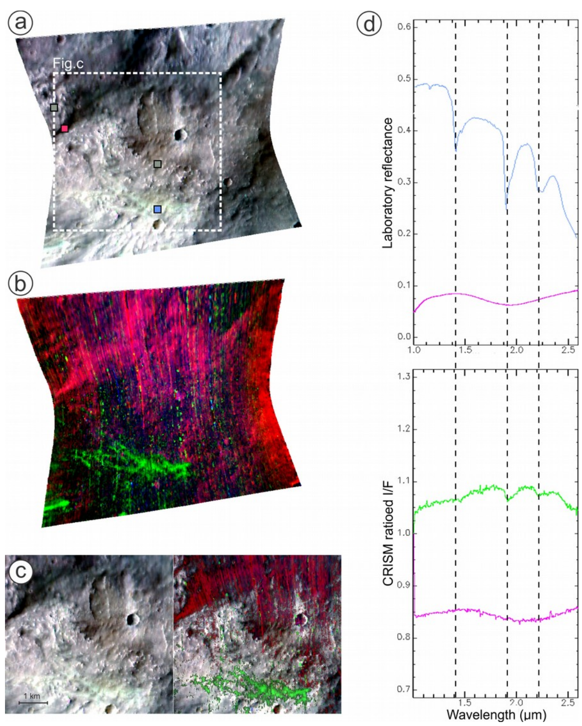
Water is perhaps the most sought after target in planetary science exploration. Due to it being a necessary requirement for the occurrence of life on Earth, deposits associated with water such as hydrated sulfates and phyllosilicates are useful indicators for locations of biological signatures on the surface of Mars. Although most of the identified hydrated minerals on Mars were formed during the Hesperian [4], the presence of water ice implies more recent aqueous activity. Water ice has been previously found in the Southern Highlands at similar latitudes [1].

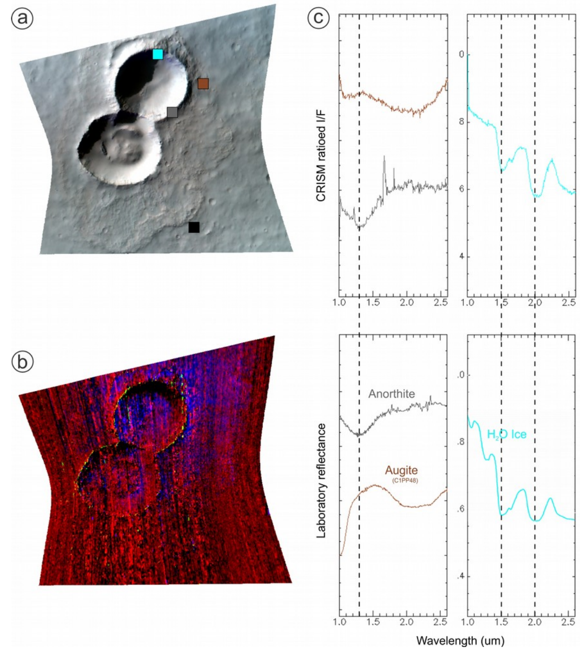
2. Methods

Spectral signatures were investigated using eight CRISM (Compact Reconnaissance Imaging Spectrometer for Mars) observations. The near infrared of all observations were processed using the CRISM Analysis Tool (CAT) package available in the Environment for the Visualization of Images (ENVI) [3], following the method used in Flahaut et al. (2015). Spectral analyses focused on significant absorption bands within the infared (1.0-2.6 µm). CRISM observations (Figs. 1,2) covering various structures such as graben walls, craters, impact ejecta, and peculiar erosional surfaces (knobs, mottled material, etc) used to infer the mineralogical characteristics and occurrence of water ice. A variety of spectral types were identified and matched to phyllosilicates, hydrated sulfates, hydrated silica (Fig. 1). These spectra were then compared with terrestrial spectra from the USGS library.

3. Results

A unique spectral type found only in observation FRT00013C86 displayed three absorptions at 1.4, 1.91, and 2.21 typical of hydrated silica [3] and matched well with opal. Other hydrated spectral types observed include both hydrated sulfates and phyllosilicates. Hydrated sulfates are readily identified by absorption bands at 1.9 µm and 2.4 µm due to the presence of H_2O [3]. A 2.4 µm absorption is common among sulfates due to vibrations of the SO_4 anion [3, 4]. Absorptions at 1.9 and 2.1 µm imply a single water molecule in the sulfate structure. When both are observed together it generally indicates the presence of monohydrated sulfates [4]. The three absorptions at 1.9, 2.1, and 2.4 µm, as well as the waveform of the spectra is representative of Mg-monohydrated sulfates corresponding to kieserite. Phyllosilicates show an assortment of extra absorption bands between 2.1 and 2.5 depending on the cation (generally Al, Fe, Mg) being supplied in the chemical bond and amount [4]. Observed signatures matche well with vermiculite, a common alteration mineral of the contact between felsic and mafic rocks. The final spectral type observed displayed a strong absorption at 1.5 µm, a broad absorption between 1.9 and 2.1 µm, 2.35, and two weaker absorptions at 1.3 and 1.67 (Fig. 2). This waveform matches nearly perfectly with water ice and the locations where it was found also had distinct a distinct blue colour in false-colour imagery. Water ice was found associated with all structures in the study area, craters, graben floor, graben wall, and even the plateau. It typically was found in more heavily eroded and chaotic terrain, where knobs and ridges provided a type of protection. The areas just below crater rims (Fig. 2) are also home to water ice signatures. The largest area of water ice was found in observation FRT0000C8C7. The ice is located on the graben wall in the form of channel like features that run parallel with the wall's slope and stretch from the plateau down to the graben floor. There are several of these channel-like features that display water ice signatures.





4. Summary and Conclusions

Mineralogical analyses imply a fair degree of aqueous history within various stages of the area's geological history. Vermiculite (found in HRL0000AAA2 and FRT0000C8C7) is typically an alteration product of the contact between felsic and mafic rocks. The presence of water ice at these high elevations may indicate an underground source continually supplying water as it evaporates or the study area's location and surface texture provides favourable conditions for seasonal frost to accumulate.

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