MINERALOGICAL EVIDENCE FOR SUBGLACIAL VOLCANOES IN THE SISYPHI MONTES REGION OF MARS.

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Introduction: The Sisyphi Montes region (55-75°S, 25°W-40°E; Fig. 1) is located in the southern highlands between the Argyre and Hellas basins. It is composed of isolated domical features [1, 2] and a unit interpreted to be portions of the ancient Dorsa Argentea ice sheet [3, 4]. While the domes are thought to be volcanic in nature, it is still unclear whether they were formed subglacially or subaerially. [1] proposed the morphologies seen are consistent with volcanoes that were built and erupted under a more extensive Hesperian-aged ice sheet. Here we test this hypothesis by comparing the mineralogy of the Sisyphi Montes edifices [5] to subglacial volcanoes on Earth.

Methods: On Earth, subaerial hydrovolcanism produces a mineral assemblage containing glass (palagonite), clays (kaolinite, smectite), sulfates (gypsum, jarosite), mafics (olivine, pyroxene), and Fe-oxides (hematite, goethite), where the clays are the dominant spectral class of minerals [e.g. 6]. Subglacial volcanism produces a mineral assemblage containing glass (hyaloclastite), clays, sulfates, mafics, Fe-oxides, and zeolites, where zeolites are the most prevalent spectral feature in this environment [7, 8]. These analogs provide a framework for evaluating a subglacial vs. subaerial origin for mineral assemblages associated with volcanic edifices in the Sisyphi Montes region.

To search for mineral signatures, we utilized data from the Compact Reconnaissance Imaging Spectrometer for Mars (CRISM, [9]). Spectral summary parameters [10] were used to identify absorption bands associated with minerals of interest. We extracted spectra and divided by spectrally neutral regions in the same scene to suppress systematic artifacts, dust, and atmospheric absorptions, a common method in CRISM data analysis. Resulting ratioed spectra were analyzed from 0.42 to 2.65 µm and visually compared to laboratory spectra to identify possible mineral constituents.

Results: Analysis of fifteen CRISM images located on the volcanic edifices revealed three distinct spectral classes (Fig. 2) in the region.

Class 1 – Gypsum-dominated: Spectra in this class exhibit absorption bands at 1.44, 1.75, 1.92, 2.22, and 2.46 µm. The ~1.4 and ~2.4 µm features tend to be broad and have the same relative strength as the ~1.9 µm feature. These spectral features are consistent with laboratory spectra of gypsum.

Class 2 – Zeolite-dominated: Spectra from this class have narrow absorption bands at 1.78 (sometimes not present), 1.92-1.96, and 2.21 µm, as well as a broad band centered between 2.43 and 2.50 µm. These bands exhibit variable band depths but similar overall spectral character (band shape, continuum slope, etc.). We interpret the 1.78 µm band to be consistent with a zeolite-dominated rock and the combination of this band with the ~2.2 µm band to be a zeolite-rich palagonite.

Class 3 – Fe-oxides and Sulfates/Zeolites: Absorption bands in this class are seen at 0.50 and 0.92 µm and are consistent with Fe-oxides, although variable between scenes. Additional bands at 1.43, 1.91, 2.45 µm could indicate either polyhydrated sulfates or zeolites, which are difficult to distinguish spectrally, although the bands centered at shorter wavelengths are more consistent with a sulfate interpretation.

Conclusion and Future Work: The assemblage of sulfates, zeolites, and Fe-oxides located on the volcanic edifices (Fig. 3) in addition to the geomorphology of the region [1, 4] strongly suggests that the volcanoes in the Sisyphi Montes were formed subglacially. Subglacial eruptions are highly habitable environments with good biosignature preservation potential [8]. Furthermore, this implies that an ice sheet must have been present when these volcanoes erupted. Because subglacial volcanoes on Earth retain morphologic signatures of the height and thickness of the ice sheet under which they erupted, our results suggest that these volcanoes could be used to place constraints on the glacial history of this region.

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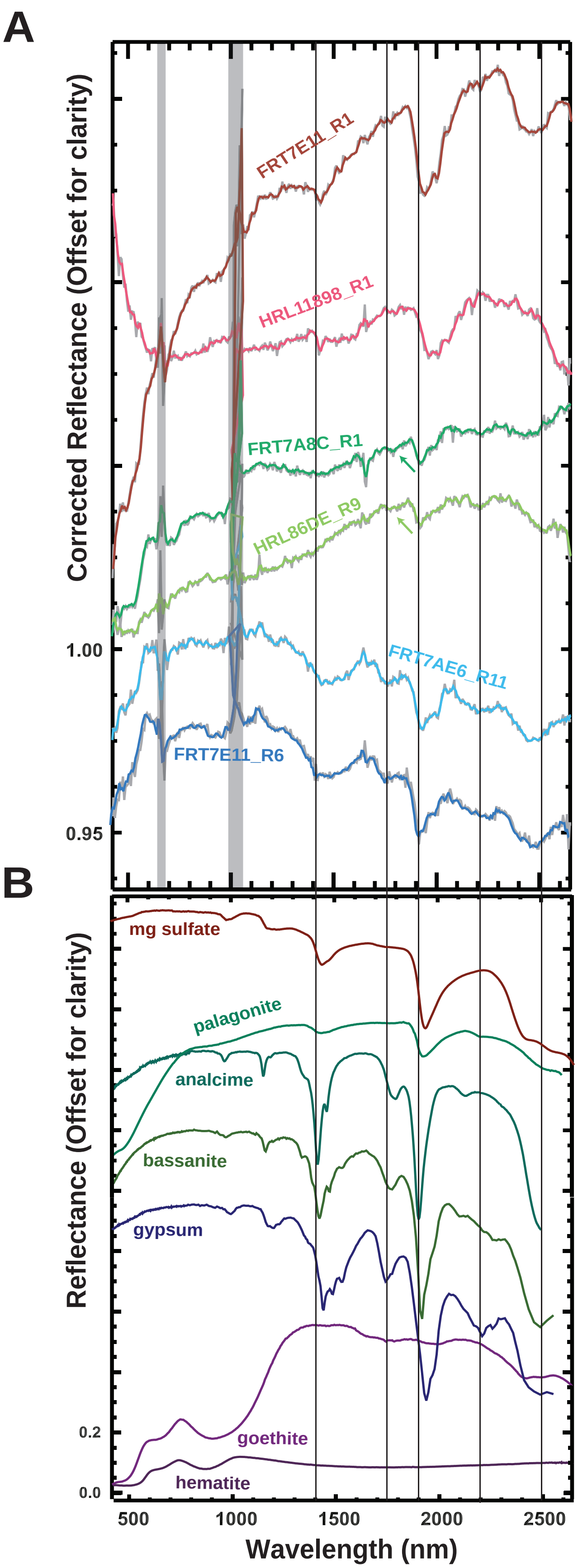

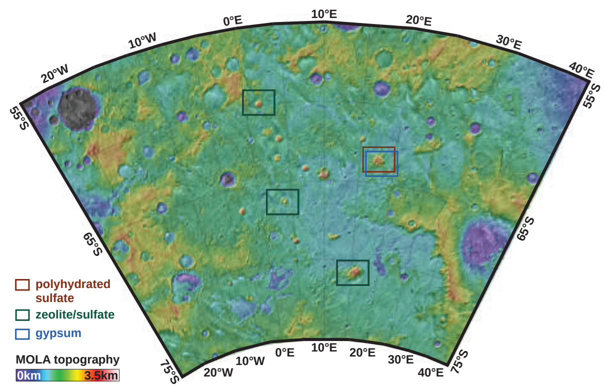

Figure 1 (above). Sisyphi Montes study region with MOLA topography overlying THEMIS data. Locations where spectra are presented are marked by colored boxes. (Zoom in on PDF for more detail.)

Figure 2 (left). (a) Spectra from 5 CRISM images in the Sisyphi Montes region where colors indicate spectral groups - red denotes fe-oxides and sulfate/ zeolite dominated material, green denotes zeolite dominated material, and blue denotes gypsum dominated material. (b) Laboratory spectra.

Figure 3 (below). CRISM parameter maps [10] showing albedo on the top and corresponding mineralogy on the bottom.