AQUEOUS ALTERATION OF GRANITOID-BEARING TERRAINS IN NORTHWEST SYRTIS MAJOR, MARS: EVIDENCE FOR ALTERATION GRADIENTS IN A HYDROTHERMAL ENVIRONMENT.

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We analyzed a unique mineral assemblage in northwest Syrtis Major and Antoniadi Crater, Mars, building upon previous studies [1-2], to provide a comprehensive characterization of its mineralogy and geology. Utilizing the complementary mineralogical sensitivities of a combination of spectral datasets (Thermal Emission Imaging System [THEMIS], Thermal Emission Spectrometer [TES], and Compact Reconnaissance Imaging Spectrometer for Mars [CRISM] instruments), we investigated exposures of hydrated minerals which provide evidence of alteration in the presence of at least temporarily stable liquid water. This, joined with the local intrusion of a felsic pluton [2], might indicate a sustained hydrothermal system in a neutral-to-alkaline environment, one that has shown to be highly conducive to the existence of primitive life [4]. Because of its unique potential as a site of astrobiological interest, this location warrants a high level of detailed research.

Previous Work: The study of the region near the northwestern portion of Syrtis Major (Fig. 1) has become important because of two recent findings. The first is the occurrence of various hydrated minerals, including those which indicate alteration in the presence of liquid water, such as zeolites [1], phyllosilicates [5] and hydrated silica [6]. These were predominantly identified with the Compact Reconnaissance Imaging Spectrometer for Mars (CRISM) utilizing the visible and near-infrared (VNIR) wavelengths.

The second new discoveries are surfaces composed primarily of quartz and plagioclase, which may indicate the presence of evolved magmas on Mars, and were identified using thermal infrared wavelengths.

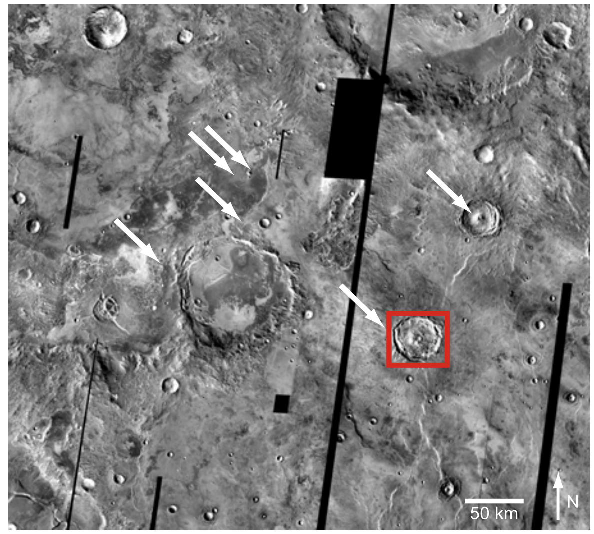

Figure 1. Regional occurrence of granitoid exposures (marked with white arrows), modified from [3]. Red box indicates the crater discussed in further detail.

They exist as exposures of crystalline quartz and plagioclase within impact craters and in nearby knobs and fractured terrain in Antoniadi Crater [3] (Fig. 1, 2a). The material is most spectrally similar to quartz monzonite, an intrusive igneous rock, and marks the first identification of a felsic igneous rock on the martian surface. Felsic rocks on Earth usually form due of the action of plate tectonics, a mechanism which has not operated on Mars. However, felsic rocks are known to form in areas unaffected by plate tectonics both terrestrially, such as Iceland and Hawaii, and on the Moon.

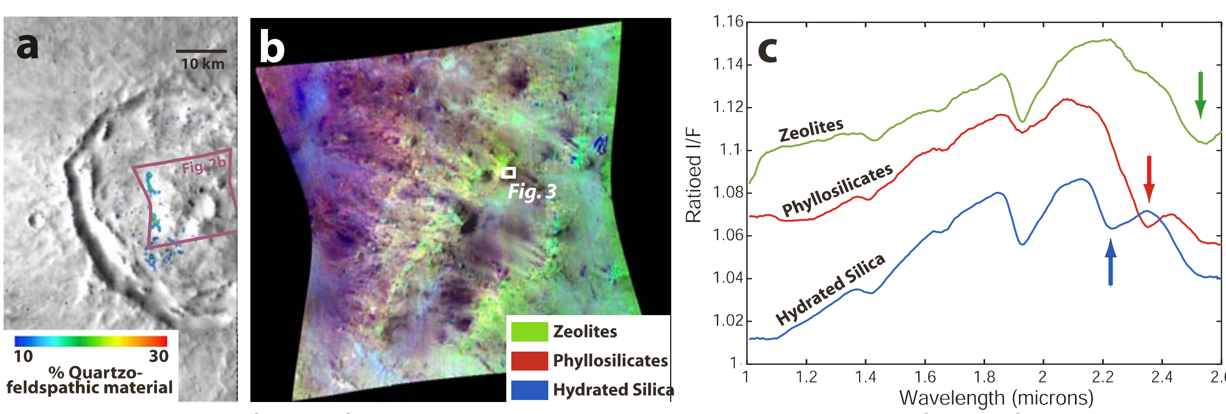

Figure 2. Spectral identification of minerals in the crater denoted in Fig. 1. a) THEMIS identification of granitoid material [2], b) Location of hydrated minerals on crater floor and central pit, c) Ratioed CRISM spectra of hydrated minerals located within Fig 2b. Arrows mark unique absorption features.

Geological Characterization of Study Site: We analyzed the one of the exposures within the region (Figs. 1-2) for the presence of hydrated minerals and their location relative to granitoid material, to determine a geologic history.

Surface Mineralogy. Throughout the region, we identified hydrated minerals (Fig. 2b) – utilizing the VNIR wavelength range with the CRISM instrument – according to their characteristic indices similar to those of [7] (Fig. 2c). We found a zonation of hydrated minerals radiating outward from the center of the crater (SE of center of Fig. 2b), with zeolite exposures at the highest elevations, phyllosilicates exposed further from the center and lower in elevation and hydrated silica deposits shown to be at the lowest elevations and often associated with areas of mass wasting. The quartz- and plagioclase-rich exposures appear to be spatially coincident with the hydrated silica. The granitoid material is not found in association with zeolites or phyllosilicates. TES and THEMIS data indicate that all surfaces in the area of interest outside of the quartz-bearing unit are dominated by a basaltic mineralogy [2], suggesting that any alteration is relatively limited.

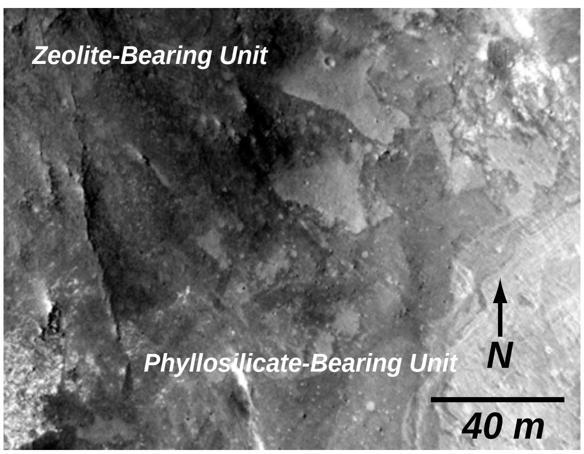

Figure 3. Subset of HiRISE image PSP_007464_198. Location shown in Fig. 2b.

Morphological Context. HiRISE images have been acquired over several of the regional sites, allowing for a detailed association of the exposed mineralogies with surface morphological units. For example, we observe a relatively low-albedo zeolite-bearing unit with a coarse and blocky texture overlying a nearby lighter-toned and smoother phyllosilicate-bearing unit (Fig. 3). The morphological differences associated with the alteration mineral zones may be attributed to different protoliths or different alteration textures from the same protolith, as seen in some terrestrial examples [e.g. 8].

Terrestrial Analogs: Zoned exposures of zeolites, hydrated silica, and phyllosilicates in close association with granitoid lithologies would indicate that they likely formed coevally. Similar mineral suites form terrestrially in hydrothermal systems, low-temperature alteration of tephras, and in impact breccias within craters. Hydrothermally driven alteration systems are found in many locations on Earth [e.g. 9] and typically exhibit a zonation of mineral alteration, with the degree of alteration decreasing with distance from the magma body. Likewise, in low-temperature alteration of tephra deposits, there is a similar zonation of minerals with increasing degree of alteration along the path of water movement (increasing downward for meteoric water input and horizontally for ground water movement) or along a salinity gradient (for a closed saline lake, alteration increases toward the center of the lake) [8]. Terrestrial impacts can also exhibit a similar alteration sequence (usually in vertical section, with alteration increasing downward). Impact breccia (suevite), which forms the base of the new crater, contains a considerable amount of residual heat, which can drive a hydrothermal system to alter the suevites for thousands of years following the impact [e.g. 13]. However, the complete sequence of alteration has only been observed in craters which have substantial post-impact fluids, typically in the form of a crater lake, and significant alteration is absent in arid impact craters or those with short-lived post-impact lakes [13].

The observed mineral sequence (Fig. 2b) is congruous with these formation environments. Since these minerals are found within a crater, an impact-related formation should be the preferred explanation, as argued previously [1]. However, the same minerals are also found in nearby plains material, at least making this interpretation non-unique. Though phyllosilicates may form in ejecta through the devitrification of impact glasses [14], hydrated silica and zeolites require long-term fluid-rock contact, which does not occur in terrestrial ejecta [13]. The presence of amorphous silica provides an upper bound on water-rock contact at 100-400 Ma, due to calculations of the conversion rate between amorphous silica and quartz [15].

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