

FELSIC AND ALTERED MINERAL SUITE IN ANTONIADI CRATER, MARS AS A FUTURE ROVER LANDING SITE. M. R. Smith, J. L. Bandfield, and A. R. Gillespie, University of Washington (1500 15th Ave NE, Box 351310, Seattle, WA 98195-1310; matthers@uw.edu)

Introduction: We are investigating the varied and unique mineralogy in an area of SE Antoniadi Crater (63°E, 20°N), proposed as a potential landing site for future Mars rovers. This location provides, in close proximity, basaltic and quartzofeldspathic materials and associated hydrous alteration products in an assemblage that meets several criteria deemed favorable for a landing site, as stated by MEPAG [1]: potentially habitable conditions, minerals indicating formation in liquid water, and minerals formed in neutral to reducing conditions. Because of its exceptional mineralogic diversity and accessibility, we believe that this is an optimal location for a more thorough in situ study to determine its geologic history and viability for biological activity and preservation.

Previous Work: This region (Figure 1) has been previously investigated spectrally in thermal (TIR) [2,3] and visible/near-infrared (VNIR) wavelengths [4]. TIR analysis revealed exposures of quartzofeldspathic material (composed primarily of quartz and plagioclase) in knobs and fractured terrain in our proposed study area [2,3]. This is especially remarkable because its identification represents the only crystalline quartz and most felsic mineralogy yet identified on Mars. Previous VNIR analysis also revealed exposures of many hydrated alteration minerals to craters to the east of the proposed landing target, including the zeolite analcime, phyllosilicates, and hydrated silica [4].

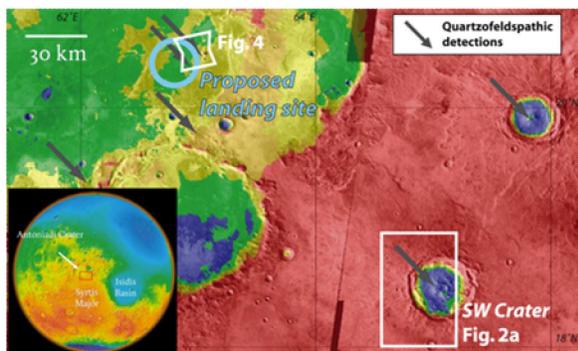


Figure 1. Context image for landing site and associated mineralogy.

Eastern Craters. In previous work in this region, we have shown that the hydrated silica and quartzofeldspathic detections are coeval and may both be explained by the presence of chalcedony (hydrated microcrystalline quartz) [5]. Chalcedony is uniquely detectable in the VNIR due to the appearance of an additional absorption feature at 2.26 μm that increases

with additional hydration (Figure 2) [6]. Siliceous glass in the presence of water will undergo this diagenetic transition – representing increasing hydration – to opaline silica → chalcedony [7]. The rate of transformation varies considerably depending on temperature, but the presence of chalcedony represents a higher degree of alteration than diagenetic minerals elsewhere on Mars [8].

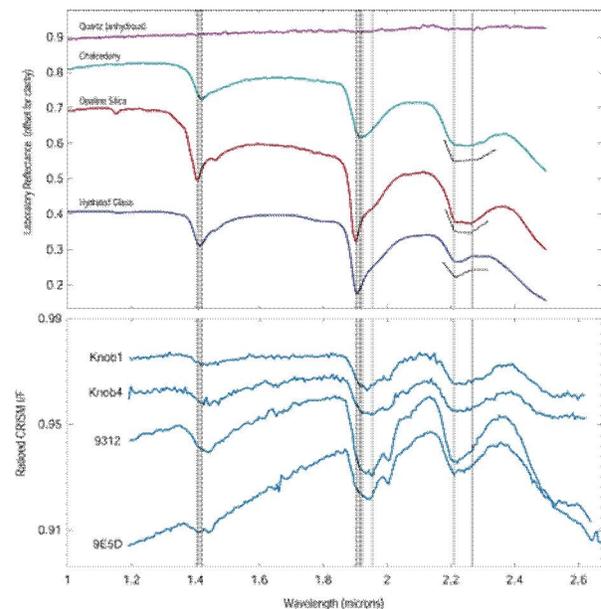


Figure 2. VNIR spectra of hydrated silica species compared with CRISM spectra of hydrated silica within landing site (Knob 1,4) and eastern craters (9312, 9E5D).

In the SW crater (Figure 1), the hydrated alteration minerals also exhibit zonation (Figure 3) [9]. Additionally, the alteration zones exhibit differences in color and friability, as seen in HiRISE images. Mineral suites, like those found in this crater, are found terrestrially in hydrothermal systems, low-temperature alteration of tephra [10], and in impact breccias within craters [11]. A typical terrestrial mineral sequence, from least to most altered is: phyllosilicates → low-alteration zeolites (non-analcime) → high-alteration zeolites (analcime) → alkalic feldspars with hydrated silica [6]. Increasing degree of alteration typically follows gradients of heat or alkalinity, or occurs along the direction of water movement. Terrestrial impacts may also exhibit a similar alteration sequence when residual heat within the impact breccia (suevite), which forms the base of the new crater, drives a hydrothermal sys-

tem to alter the suevites for thousands of years following the impact [e.g. 11]. 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 [11].

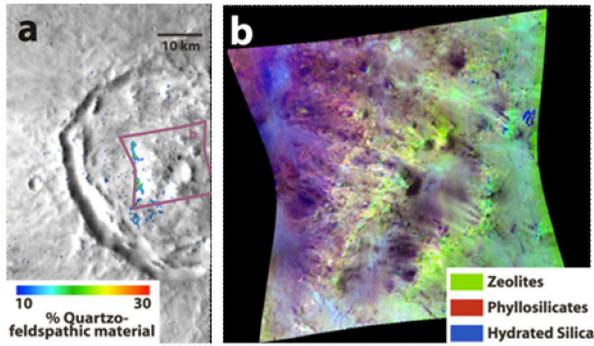


Figure 3. Quartzofeldspathic mineral detection and altered mineral zonation in SW Crater. Location in Fig. 1.

This mineral assemblage, proximal to a possible volcanic heat source at Syrtis Major, represents a potential hydrothermal system. This environment provides an energy source, potential nutrients, and liquid water, all of which are necessary for the development of primitive life [12].

Landing Site: The focus of this study is the exposures of similar mineralogy to the northwest of these craters, since they are more accessible and appear to represent the same geologic history as the nearby craters. Proximal to the potential landing site ellipse, there are many local outcrops of quartzofeldspathic and altered minerals that are easily accessible by a rover.

In a nearby knob to the east of our landing ellipse, we find similar exposures of hydrated silica and quartzofeldspathic detections, and they are also coincident. The VNIR spectra of these exposures also contain the broad 2.26 μm feature ('Knob 1', 'Knob 4' in Figure 2), indicative of its extensive alteration to chalcedony.

Phyllosilicates and zeolites are also detected within these outcrops (Figure 4), suggesting similar mineralogical processes were present in these knobs as in the

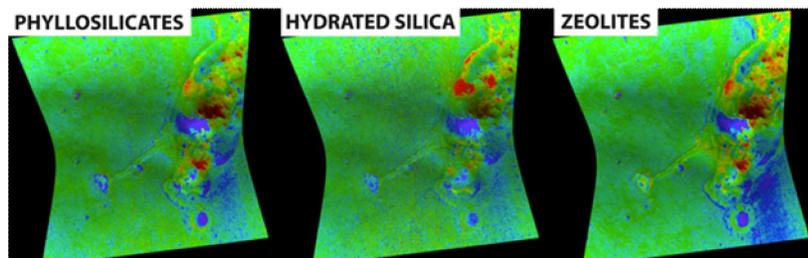


Figure 4. Altered mineral detections near a knobby outcrop near the landing site. Location shown in Figure 1.

nearby craters. Since they are not found within crater-formed exposures, they appear to not be correlated with an impact process, but instead in a past potential hydrothermal environment similar to that which was assumed to have altered rocks in the nearby Nili Fossae formation [4].

This site is particularly suited to meet the goals of MEPAG in searching for past astrobiological activity on early Mars. The identification of this particular mineral suite – chalcedony, zeolites, and phyllosilicates – indicates alteration in a moderate-to-high pH (>8.5; [14]) environment and in moderate temperatures (<200°C) [15], all of which are preferable conditions for nascent life [10, 16]. Additionally, silica and phyllosilicates are both good at preserving biosignatures over geologic time scales [16].

However, the unique advantage of this site is the presence of chalcedony. Elsewhere on Mars, the evidence of alteration – opaline silica, smectite clays, iron sulfates – indicate underdeveloped and juvenile altered sediments, and represent little total water-rock contact [8]. For example, chalcedony can form in natural environments on Earth in as little as a 1,000 years [7].

We believe that because of its unique mineralogy and excellent biological potential and accessibility, that this site merits additional investigation by a rover.

- [1] Pratt L. M. et al. (2009) Mars Astrobiology Explorer-Cacher: A potential rover mission for 2018 [2] Bandfield J. L. et al. (2004) *JGR*, 109, E10009. [3] Bandfield J. L. (2006) *GRL*, 33, L06203. [4] Ehlmann, B. L. et al. (2009) *JGR*, 114, E00D08. [5] Smith, M. R. et al. (2010) *AGU Fall Mtg.*, Abstract # P53C-1530. [6] Goryniuk M. C. et al. (2004) *GRL*, 31, L24701. [7] Lynne B. Y. et al. (2005) *Sed. Geol.*, 179, 249-278. [8] Tosca N. J. and Knoll A. H. (2009) *EPSL*, 286, 379-386. [9] Smith, M. R. et al. (2010) *LPSC XLI*, Abstract #2194. [10] Hay R. L. and Sheppard R. A. (2001) in *Natural Zeolites, Occurrence, Properties, and Applications*, New York. [11] Osinski G. R. (2005) *Geofluids*, 5, 202-220. [12] Miller S. M. and Orgel L. E. (1974), *The Origins of Life*. [14] Gottardi G. (1989) *Eur. Jour. Min.*, 1, 479-487. [15] Iijima A. (1988) in *Diagenesis II*, Amsterdam. [16] Farmer J. D. and Des Marais D. J. (1999) *JGR*, 104(E11), 26,977-26,995.