HYDROTHERMAL ALTERATION PRODUCTS IN THE CIRCUM-HELLAS REGION: TARGETS FOR FUTURE LANDED MISSIONS

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Introduction: In response to the Mars Exploration Critical Data Products Program, we have performed a study of the NW Hellas region, where hydrothermal alteration products have been identified [1, 2]. The study of past hydrothermal regions on Mars is of particular interest to the astrobiological community due to the close association between hydrothermal systems and primitive life forms on Earth.

The Hellas basin is thought to have formed during the late heavy bombardment [3] as a consequence of a massive impact. Such an impact would not only have excavated rocks from the deep stratigraphy, but it would have also deposited enough energy into the ejecta to support hydrothermal conditions [Newsome reference]. Of particular interest to the question of habitability is the possibility that a variety of aqueous systems, in particular marine/lacustrine [4, 5] and hydrothermal systems [6], may have formed in the region after the Hellas impact. Spectroscopic evidence for aqueous activity in the greater region has been presented [7, 8] and more recently, phyllosilicates and sulfates have been identified on and near the rim of Hellas in association with multiple geological features [1, 9].

In this study, we have focused on the analysis of spectral and imaging data of a roughly 5x5 degree region centered around 56.5 E, 26.1 S, where an large prehnite deposit has been identified. We have characterized the regional geological context of the deposit, and have established the feasibility of landing within range of the deposit given the technical constraints of modern landing systems.

Mineralogical and spectral indicators of hydrothermal activity: Multiple terrestrial studies to date have reported on a variety of mineral assemblages resulting from the hydrothermal alteration of primary minerals as a function of temperature, pressure, and aqueous chemistry [10]. Often, however, the individual minerals do not unequivocaly indicate hydrothermal conditions. Published analyses of CRISM and OMEGA data to date have revealed the presence of several of these alteration products on the surface of Mars, including kaolinite, chlorite, serpentine, prehnite, alunite, and carbonates [11, 12; 13]. Of these, prehnite and serpentine are exclusively hydrothermal mineralas. Prehnite is of particular interest to this study because it is identified in the circum-Hellas region, and forms under specific conditions ($P < 3$ kbar, $200° < T < 250°$; and $XCO_2 < 0.004$).

Prehnite can be identified by a sharp OH overtone at 1.48 µm, and metal-OH combination bands at 2.23, 2.28, 2.35-2.36, and 2.57 µm, where the 2.35-2.36 µm band is the strongest [13]. In particular, the 1.48, 2.23, and 2.28 bands make it distinguishable from chlorite, which has a similar spectral shape, but exhibits its OH overtone at 1.40 µm and metal-OH combination bands at 2.25-2.26 (as a shoulder), and 2.33-2.35 µm.

The proposed study region exhibits spectra consistent with prehnite, chlorite, and illite, all of which can be of hydrothermal origin. Often, the chlorite spectra in CRISM data will also exhibit an absorption or shoulder at 1.48 µm, suggesting that it is present in association with prehnite.

Location and geological context: The prehnite deposit is exposed on a local topographic high at an elevation of approximately 150 m on the cratered plains northwest of Hellas, and occurs in several semi-contiguous units over an areal extent of at least 15 km. The prehnite-bearing units consist of both rocky outcrops and rippled mantles. Although these units are found in proximity to 10-km craters, they occur up to two crater radii away from the rims of these craters, and its formation is therefore not thought to be associated to impact that produced these craters.

The cratered plains surrounding these deposits exhibit morphological and mineralogical indicators of aqueous processes. At elevations above approximately 500 m, the plains are dissected by tributary valley networks. At elevations below approximately 500 m, the plains are largely undissected, but exhibit broad (10s of km in width) pits in multiple locations. The transition from dissected plains to smooth plains varies in elevation between 0 and 500 m as a function of location, but is sharply defined by a sudden break in slope and abrupt valley termination. Stratigraphically, the undissected plains unit overlyes and embays the dissected unit.

Most of the craters in the region also exhibit evidence for modification: their floors are flat and smooth, their walls are dissected, and sometime their rims are bridge. In many cases, the smooth crater floors also exhibit broad pits.

The material forming the walls of the pits both on the plains and in the crater interiors is yardanged and appears extensively layered at HiRISE scales. The pits are typically 100-250 m deep on the plains, and 300-500 m deep in the interiors of craters.

CRISM spectra of the pit walls and other outcrops on the smooth plains unit exhibit absorptions around

1.42, 1.92, and 2.29-2.31 μm, consistent with the presence of Fe/Mg smectites. However, in most cases, the 2.3 μm band occurs in association with a dropoff in reflectance. This dropoff has been interpreted in the past to be due to a mixture of smectites and chlorites [14] or chlorite-smectite mixed-layer phyllosilicates such as corrensite [15].

These extensive, etched, and thick sequences of layered, embaying hydrated material occurring at the terminus of truncated drainage systems suggest that the smooth plains units were deposited in either a lacustrine or aeolian setting akin to that of the Meridiani Planum deposits, and consist of fluvially reworked material derived from higher elevations. The relationship of the prehnite-bearing outcrops to these units is still unclear. However, its occurrence on top of a topographic high that is embayed by the pitted plains unit suggests that the prehnite units pre-existed the deposition of the pitted plains units and may be outcropping through them.

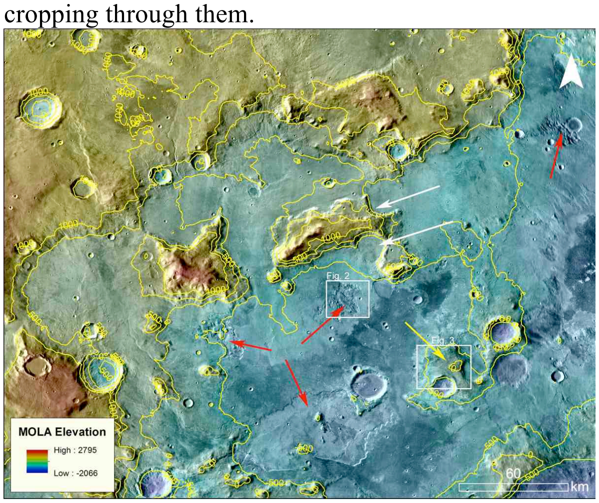

Figure 1. Regional view of the study area, centered on 55.3 E, 25.2 S. White arrows indicate examples of embayment relationship between the smooth, pitted unit (blue tones) and the higher unit. Red arrows indicated examples of pits, and yellow arrow indicates prehnite-bearing mound. White boxes indicate inset for figures 2 (upper left) and 3 (lower right).

Accessibility: The prehnite-bearing units exhibit km-scale slopes greater than 4°, and rocky outcrops, which would make landing on the science target hazardous. However, the terrain immediately to the NW of these outcrops exhibits average slopes <0.5° and is extensive enough to easily fit a 20x20 km landing ellipse. In this context, the chlorite and prehnite bearing units would be 10 km from the center of the landing ellipse, and easily accessible to a MER or MSL-class rover.

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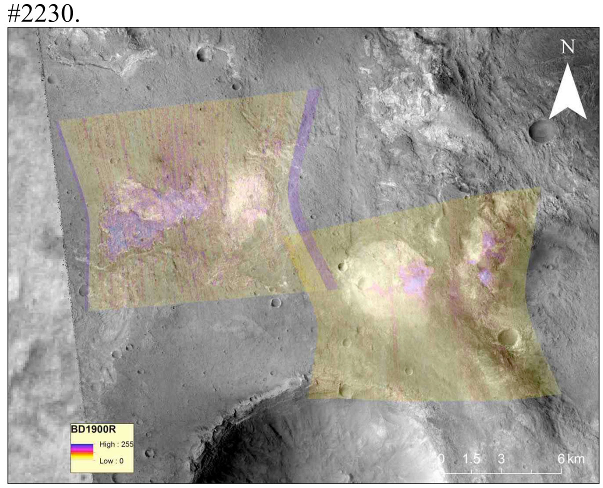

Figure 2. CRISM parameter maps showing the distribution of of prehnite/chlorite-bearing units (magenta) overlayed on CTX image.

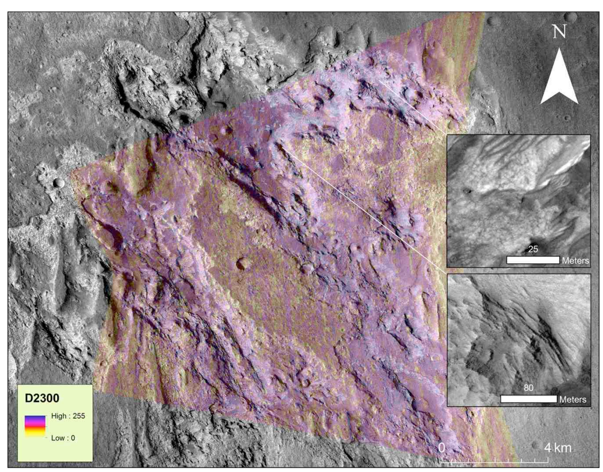

Figure 3. CRISM parameter map of Fe/Mg smectite/chlorite-bearing units (magenta) overlayed on CTX data.