UNIQUE BASIN-RELATED ALTERATION ON EARLY MARS. C. E. Viviano[1], M. S. Phillips[2], K. D. Seelos[1], and J. H. Roberts[1]. [1]Johns Hopkins University Applied Physics Laboratory <Christina.Viviano@jhuapl.edu>, [2]University of Tennessee, Knoxville.

Introduction: The context of clay minerals on Mars can be grouped into three geologic settings: i) in-place stratigraphies of multiple clay-bearing units, perhaps formed via in situ alteration; ii) central peaks, walls, and ejecta of impact craters; and iii) clay-bearing units in sedimentary basins with [e.g., 1]. Kaolinite, Fe/Mg-smectite, and a dehydrated, talc-like hydroxylated phase [2] are exposed in a somewhat different setting: uplifted massifs on the rim of Hellas basin. While this clay-forming environment may be similar to those exposed through the cratering process, the structural and thermal characteristics of a massive impact basin provide a unique environment for studying alteration of the most ancient crust of Mars. Here we present preliminary work from our effort to test whether alteration phases formed through one of four mechanisms in association with the ancient crust surrounding the Hellas basin. If this mechanism can be constrained, this particular setting could represent a unique at- or near-surface environment where long-lived habitability may have been present on Mars in its past, and potentially where biosignatures are accessibly preserved at present.

Previous efforts to map topographic promontories surrounding the Hellas basin were performed as a pilot study to this effort [3-5]. In this work, putative 'massifs' were identified surrounding the Hellas basin based on topographic and thermal inertia characteristics, and initial efforts were made to characterize their composition from CRISM mapping-mode (200 m/pixel) data. Preliminary massif mapping along the northeastern to southwestern rim of topographic promontories unrelated to obvious cratering structures are shown in Fig. 1, and provide the basis for defining our mapping region. These efforts and others have revealed that within these putative massifs, detections of uncommon "feldspathic" rocks (used here to mean rocks with a visible-shortwave infrared (VSWIR) spectral signature of plagioclase feldspar with a minor Fe component characterized by a broad feature centered at 1.3 μm) are present [4-7].

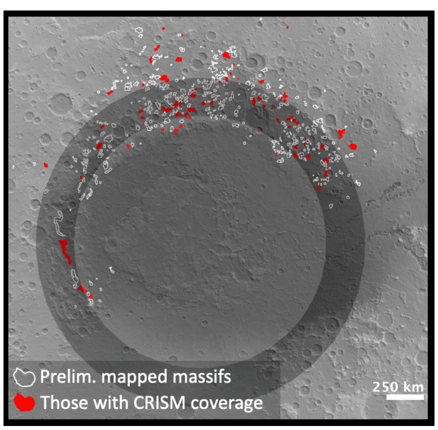

Figure 1. Study region along the northeast to southwestern Hellas rim. **Preliminary** mapping of topographic promontories unrelated to craters are shown in white. 69 of the 442 mapped massifs from the western to northeastern region of the Hellas rim have CRISM targeted coverage (red). Main basin ring beginning at 2200 km in gray.

Methods: We began an analysis of a subset of CRISM targeted data (~10 of the ~69 putative 'massifs' that have overlapping CRISM coverage, Fig. 1), in an effort to identify alteration throughout a much broader Isidis-to-Hellas regional survey [e.g., 8]. Analyses of these images in ENVI were used to determine mineral diversity within a scene, where point locations of spectral endmembers in an image were characterized.

Initial Results: Compositional results from the targeted observation investigation revealed the following: 1) the primary lithologies identified with CRISM included "feldspathic", olivine, and low-Ca pyroxene (consistent with results from [3-5]), 2) the secondary lithologies were dominated by kaolinite (often found in association with plagioclase), a hydrated Fe/Mg-smectite, and an unknown Mg-OH phase. The putative massifs appear to contain outcrops of primary lithologies that vary in composition throughout the exposure (Fig. 2a, left). The unknown Mg-OH phase is easily distinguishable from commonly-occurring Fe/Mg-smectite (Fig. 2b, right panel) as evidenced by the lack of a deep and broad 1.4- and 1.9-μm bands indicative of bound water. Though we have the Mg-OH phase plotted against laboratory spectra of talc, there are subtle differences in the position of a weak 2.25-μm band that makes identification less certain. Interestingly, both the Fe/Mg-smectite and the Mg-OH phase in this region display the 2.25-μm band, that is not observed in regions to the north of the Hellas rim [8].

Testable Hypotheses: The 4 formation hypotheses are depicted, pre- and post- Hellas impact, in Fig. 3. In Hypothesis I (null hypothesis), the Mg-OH phase formed prior to impact, and thus represent pre-Noachian altered materials. These materials were formed unrelated to the massif formation and uplift, and therefore the alteration may or may not coincide with any particular primary materials in the massif (e.g., pedogenic weathering at the surface, or deposition of widespread sedimentary deposits). Detailed mapping of the Mg-OH phase would not show a spatial correlation with fractures associated with structural deformation and uplift. Kaolinite may have also formed prior to

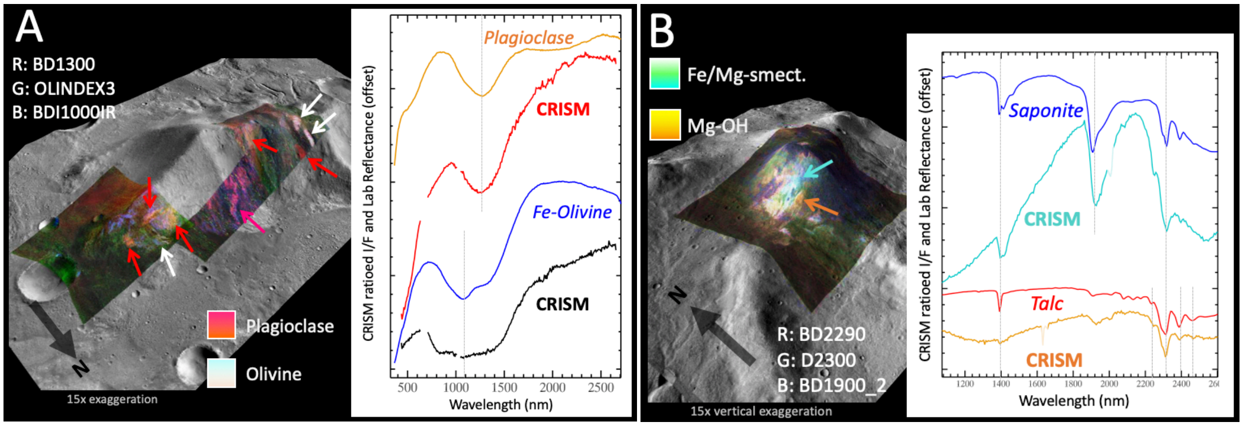

Figure 2. Two massifs with CTX overlain on MOLA/HRSC DEM. Extracted CRISM and lab spectra in right panels. (A) FRT000092B4, FRS00031336, and HRS0000C6A0 shown in summary parameter [9] color composite to highlight plagioclase and olivine. (B) FRT00008144 composite highlights variability in 2.3-µm band and hydration. Dehydrated Mg-OH phase in orange.

massif formation or may be a later-stage alteration product unrelated to the Mg-OH phase in timing. Future modelling work will be used to test whether mineral phases would have survived the maximum temperature for the impact basin at the distance of massifs. In Hypothesis II, the Mg-OH phase represents an accessory mineral within primary lithologies that make up the massif. These minerals (e.g., hornblende) would be associated with a particular mapped primary phase in the uplifted material. Kaolinite does not occur as a primary mineral and thus would represent some later alteration stage and not necessarily spatially coincide with the Mg-OH phase. In Hypothesis III, the massifs represent plutons intruding into surrounding basement rock that would be altered via contact metamorphism, potentially forming the Mg-OH phase. Here, the Mg-OH would be spatially adjacent to primary mineralogy that forms the plutons (e.g., plagioclase). Kaolinite could occur as a later-staged surface weathering product, or as a product of contact metamorphism. Lastly, in Hypothesis IV, dikes and/or fractures mobilize hydrothermal fluids within and surrounding massifs altering them to the Mg-OH phase. The Mg-OH phase would primarily occur in clear spatial associations with morphologically-mapped fractures and/or dikes. Again, kaolinite may occur as a later product, or as a product of hydrothermal alteration along the fractures. In all cases, it is expected that some of the alteration products will be eroded and transported to the margins of the massifs. Future work includes detailed CRISM mapping of the remaining ~60 massifs, mapping of fractures and/or dikes, and thermal modelling of the Hellas basin impact to constrain which of these four hypotheses may be applicable, and how this may have implications for the environment of clay formation on Mars.

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References: [1] Ehlmann, B. et al. (2011), Clays and Clay Mins., 59(4), 359-377. [2] Viviano-Beck et al. (2016), 47th LPSC, abstract #1738. [3] Phillips & Viviano (2016), AGU conference, abstract #121524. [4] Phillips et al. (2018), First Billion Years: Differentiation, abstract #4026. [5] Phillips et al. (2019), 50th LPSC, abstract #2137. [6] Carter & Poulet (2013), *Nat. Geo.*, 6, 1008-1012. [7] Wray et al. (2013), *Nat. Geo.*, 6, 1013-1017. [8] Viviano & Phillips (2019), 50th LPSC, abstract #2089. [9] Viviano-Beck et al. (2014), *JGR*, 119(6), 1403-1431.

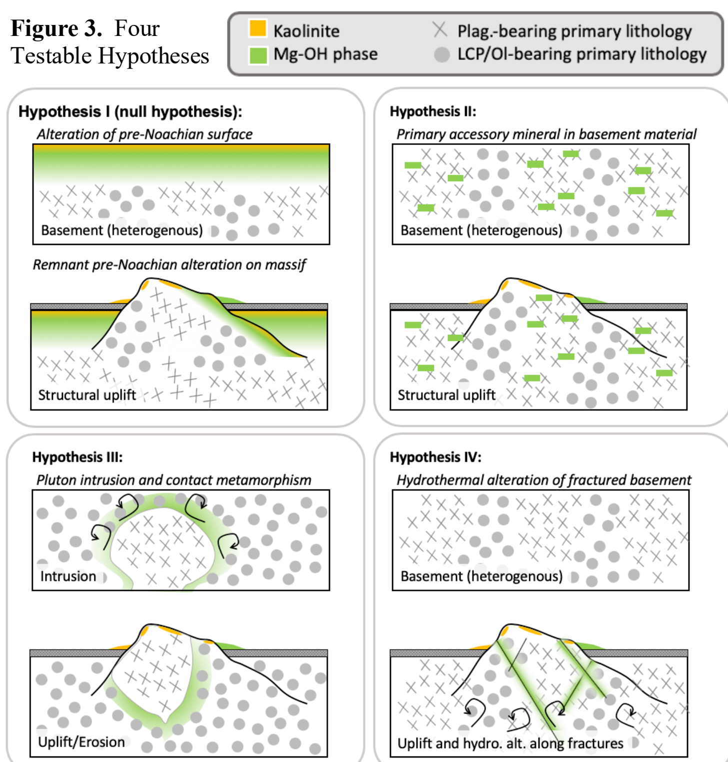

Figure 3. Four Testable Hypotheses