**ALTERATION ASSOCIATED WITH LARGE IMPACT BASINS ON MARS.**

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**Introduction:** The Nili Fossae region (west of Isidis Basin) contains a diverse mineralogy, including olivine and compositionally varying phyllosilicates exposed in outcrops across the entire region. One interpretation for the presence of olivine, serpentine, and magnesium carbonate in the easternmost portions of Nili Fossae (near the western Isidis rim) is that it is evidence for hydrothermal alteration of an olivine-rich protolith [1-3]. The Mg-phyllosilicates associated with these carbonate-bearing units have a unique spectral component, possibly consistent with talc [3,4], which would be a reaction product (along with carbonate) from the carbonation of serpentine. The underlying basement materials in the Nili Fossae region have experienced varied metamorphism, resulting in metamorphic grades from diagenesis to prehnite-pumpellyite facies (and perhaps greenschist facies) [1,5].

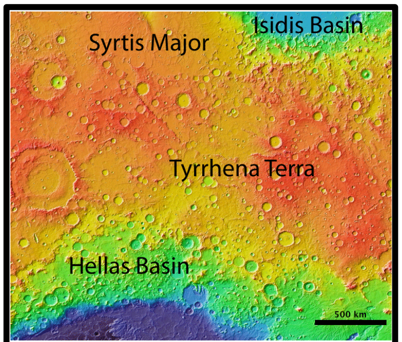


Figure 1. MOLA elevation map of study region.

**Methods:** Here we analyze CRISM targeted data for the presence of metamorphic- and hydrothermally-related alteration phases in the greater Tyrrhena Terra region between Isidis and Hellas Basins (Fig. 1), where past studies indicate similar assemblages may be present [6,7]. About 120 new prototype MTRDR calibrated images [8] (through 06/2008) and updated spectral parameters [9] were analyzed within this region to allow for more complete mapping of phases. The rest of the targeted images in the region will be analyzed as they are processed. Mapping of these phases can be used to examine the distribution of alteration type (metamorphic vs. hydrothermal) and determine any potential associations with large impact basins (Isidis and Hellas).

**Primary mineral mapping results:** The initial mapping effort of primary minerals (Fig. 2, top) reveals significant plagioclase abundance in the northern Hellas Rim, even more extensive than initially identified by [10]. As consistent with [11], low-Ca pyroxene (LCP) dominates the Noachian-aged crustal materials between Hellas and Isidis, whereas high-Ca pyroxene (HCP) appears more often associated with younger volcanic provinces (*e.g.*, Syrtis Major) and sands that may not be locally derived.

**Secondary mineral mapping results:** Alteration phases, including Mg-smectite, chlorite/prehnite, hydrated silica, kaolinite, illite/muscovite, analcime and other zeolites, Mg-carbonate, and possible talc, appear

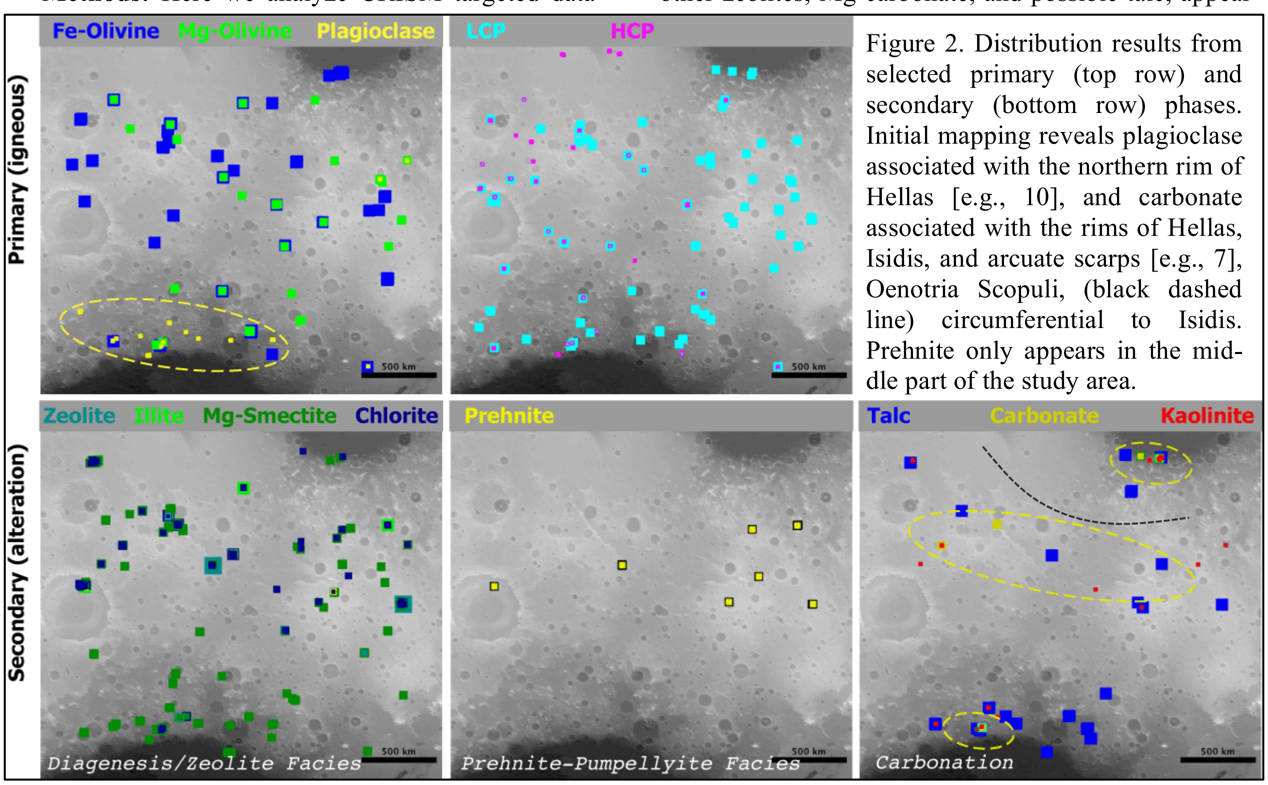


Figure 2. Distribution results from selected primary (top row) and secondary (bottom row) phases. Initial mapping reveals plagioclase associated with the northern rim of Hellas [e.g., 10], and carbonate associated with the rims of Hellas, Isidis, and arcuate scarps [e.g., 7], Oenotria Scopuli, (black dashed line) circumferential to Isidis. Prehnite only appears in the middle part of the study area.

throughout the region (Fig 2., bottom). At a minimum, low temperature diagenetic to zeolite-facies metamorphic grade, indicated by the presence of illite and chlorite (the transformation of trioctahedral smectites to chlorites and dioctahedral smectites to illites during diagenesis) and zeolite (including analcime), is prevalent throughout Tyrrhena Terra. Prehnite, which forms at 200-400°C, provides clear evidence for higher temperature alteration (prehnite-pumpellyite facies [*e.g.*, 1]) and appears only in the region between two basins in mapping thus far. Carbonate, possible talc, and kaolinite appear to be associated with the southern rim of Isidis Basin (and western rim near Nili Fossae [4]) and the northern rim of Hellas Basin. There is also a region surrounding Oenotria Scopuli, a basin-ring structure [13] circumferential to Isidis (black dashed line, Fig. 2), where carbonate is identified [7]. Kaolinite and possible talc are also observed near this scarp.

**Possible talc endmember:** Particularly along the northern rim of Hellas, we observe material that is dominated by an Mg-OH spectral component. The CRISM spectra have distinctly little to no spectral features due to bound water (lack of broad and deep 1.4- and 1.9-µm, Fig. 3). The material displays strong 2.31- and 2.39-µm bands and shallow, but present ~2.25-µm band and narrow 1.39-µm band. The ~1.4-µm band depth is commonly weak in Fe/Mg-phyllosilicates on Mars, and may be due to effects of mixing with other opaque Fe-bearing oxides [*e.g.*, 1]. While thermal alteration of Mg-smectite may allow for significant weakening of the water absorption features, it does not account for the appearance of the ~2.25-µm band (see thermally altered saponite spectra from [12]). Tremolite and actinolite (amphiboles) exhibits correct positions for the Mg-OH bands and absent water features, however they also lack the ~2.25-µm band (Fig. 3). Phlogopite (Mg-mica) and hydrobiotite (not shown) can exhibit this band, but the 2.3-µm band minimum appears too long. While it is possible the phase represents a mixture of phlogopite and a dehydrated Mg-smectite, laboratory talc provides the best single endmember match for all features, although the ~2.25-µm band is slightly shifted, possibly from minor substitution of $Fe^{3+}$ in the octahedral site, and the ~2.39-µm band is relatively weak in the CRISM spectra.

**Alteration conditions:** Precursor primary lithologies for talc on Earth are typically mafic to ultramafic (Mg-rich). Thus, while the possible talc appears spatially associated with evolved, plagioclase-rich material in the Hellas rim, it is unlikely the talc or any other Mg-OH phase was actually derived from that lithology. It is more likely derived from an nrich pyroxene/olivine lithology previously identified as co-occurring with the plagioclase-rich unit in this region [10]. The preferential alteration of more plagioclase-rich primary materials to Al-rich phyllosilicates is consistent with the association of kaolinite and plagioclase on the northern rim. The apparent association of plagioclase-rich material, potentially emplaced as anorthositic plutons [10], and talc (+/- carbonate) may suggest a metasomatic origin for the talc via contact metamorphism of an Mg-rich ultramafic unit during intrusion of the anorthositic pluton.

**References:** [1] *Ehlmann et al.*, (2009), *JGR*, 114. [2] *Ehlmann et al.*, (2008) *Science*, 322, 1828-1831. [3] *Brown et al.*, (2010) *EPSL*, 297, 174-182. [4] *Viviano et al.*, (2013) *JGR*, 118, 1858-1872. [5] *Carter et al.*, (2013) *Planet. Space Sci.*, 76, 53-67. [6] *Fraeman et al.*, (2009) *LPSC*, #2320. [7] *Bultel et al.* (2015) *Icarus*, 260, 141-160. [8] *Seelos et al.*, (2012) *Planet. Data Workshop*, USGS, VA. [9] *Viviano-Beck et al.*, (2014) *JGR*, 119, 1403-1431. [10] *Carter & Poulet* (2013) *Nat. Geo.*, 6, 1008-1012. [11] *Mustard et al.* (2005) *Science*, 307, 1594-1597. [12] *Che & Glotch* (2012) *Icarus*, 218, 585-601. [13] *Tanaka et al.* (2013) *USGS*, 3292.

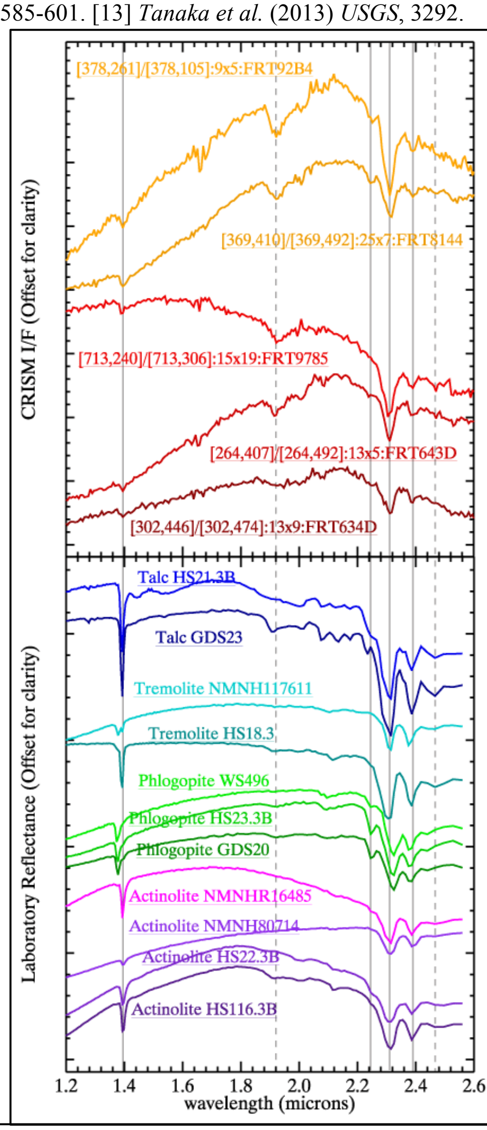


Figure 3. Example CRISM spectra from the northern Hellas rim (top) and laboratory spectra of Mg-OH phases with no bound water (bottom).