EXTENSIVE EXPOSURES OF OLIVINE-RICH VOLCANIC ROCKS IN NOACHIAN-AGED SURFACES ON MARS.
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Introduction: Although it has been hypothesized that the Noachian era experienced global volcanism [1], there is a lack of clearly defined Noachian-aged lava flows; therefore, the composition of such materials has not been properly assessed. [2] noted a VNIR (visible near infrared) change in spectral character across different igneous regions; namely, Noachian terrains tend to be more olivine- and LCP- (low calcium pyroxene) rich, whereas Hesperian terrains tend to have more HCP (high calcium pyroxene) than LCP. We know that volcanism occurred in the Noachian, e.g. [3], but outside of volcanic centers it is very difficult to pinpoint Noachian lava flows. Both [4] and [5] have outlined an area just to the east of Ares Vallis on the Noachian-aged plains, e.g.[6], that bear olivine-rich signatures as seen with TES (Thermal Emission Spectrometer) [4] and CRISM (Compact Reconnaissance Imaging Spectrometer for Mars) and OMEGA (Observatoire pour la Mineralogie, l'Eau, les Glaces et l'Activité) [5] data. Olivine has been detected globally with various instruments including TES, e.g. [4, 7, 8, 9, 10], THEMIS, e.g. [4, 9, 11], OMEGA, e.g. [2, 12, 13], and by the MER rovers in situ, e.g. [14, 15, 16], but if we can further document Noachian terrains that are olivine-rich in a volcanic context, while showing that they are widespread, we may be able to constrain the overarching trend in the igneous evolution of Mars, as seen by the surface expression of volcanic materials (surface expression of Noachian-aged volcanics has not been well-established).

Since [4] and [5] show that olivine is abundant in this Noachian-aged plains unit, the aim of this study is to (1) quantify the areal extent of the deposit in order to further document Noachian-aged volcanism and (2) explain how the spectral information we can gather may relate to global processes.

Datasets and Methods: Spectral data from OMEGA [17] on the Mars Express spacecraft was used for surveying the large plains area, since it is well-suited for regional analyses. OMEGA collects data from 3 separate detectors, including 352 spectral channels, that cover the visible and near infrared wavelength range from 0.35-5.09 microns; however, only the C-channel (SWIR 0.94-2.70 microns) detector is used here and has a corresponding spectral resolution of 14 nm [17]. Basic reduction of OMEGA data from radiance to reflectance including atmospheric removal was performed as described by [13].

Where available, guided by the OMEGA survey of the region, CRISM TRR3 [18, 19] data will be examined in order to confirm and assess the outcrop scale mineralogy of the unit. The atmospheric and photometric corrections are implemented as described in [20]. CRISM spectra will be extracted from regions of interest on the basis of spectral parameter maps [21] using a 5 X 5 pixel average. Residual artifacts after calibration and atmospheric removal can be suppressed by ratioing the spectra to a spectrally neutral region from the same column because of the nature of 2-D detectors.

HiRISE (High Resolution Imaging Science Experiment) [22] and CTX (Context Camera) [23] data are incredibly instrumental in determining the geomorphic nature of the olivine-rich deposits and ensure that we are actually tracking a unit of igneous origin and not dunes, for example.

Preliminary Results: The previously mapped olivine-bearing unit appears to be contiguous outside of the region studied by [4] or [5]. Figure 1 shows the study region of [5], which are extended eastward. Olivine-rich areas are denoted by the colored index where red is the strongest detection of olivine-bearing material. Here, olivine-rich material occurs as a unit that fills pre-existing craters. Figure 1 also shows sample OMEGA spectra extracted from the numbered regions to the right. Olivine is recognized by it's broad 1 micron absorption due to three overlapping crystal field transition absorptions and procedures for this recognition and mapping have been presented previously [13, 20]. Further mapping of this unit will proceed eastward between the eastern edge of Ares Vallis and Meridiani Planum to establish the scope and character of the Noachian-aged volcanic unit east of Ares Vallis.

Discussion: If it is possible to document Noachian lava flows or igneous outcrops that all have the same general spectral character, we may be able to constrain a more global process for extensive olivine-rich production of igneous materials. Although Earth's surface rarely contains true signatures of melts directly from the mantle due to crustal assimilation and extensive fractional crystallization, [24] implies that we can assume that Hesperian-aged volcanism on Mars should be sourced directly from the mantle. Following that logic, if Hesperian-aged terrains experienced volcanism that was sourced directly from the mantle, it is likely that Noachian terrains did also. Because the olivine phase field expands as pressure decreases, we can generally assume that all melts produced by mantle melting are olivine saturated and will crystallize olivine first, regardless of mantle temperature. Dunite channels in peridotite on Earth, e.g. [25], gives clear evidence for this process. For a mantle that is hotter in comparison to one that is colder, melts would have to fractionate more olivine to get to pyroxene and plagioclase saturation; in addition, it is plausible that the lithosphere may be thinner for a hotter mantle as opposed to a cooler mantle. If it can be demonstrated that very olivine-rich volcanic material is present increasingly in the Noachian igneous terrains that are identifiable, a scenario where either a hotter mantle and/or a thinner lithosphere in the Noachian as compared to the Hesperian is more likely to be the process that formed the trend noted by [2] [26]. If this is indeed the case, then confirming the lack of plagioclase in the unit studied herein, as noted by [4], would be a compliment to the pyroxene distribution we see through time. In addition, being able to discern the composition of the olivines we detect can be a third confirmation that the Noachian volcanism sourced from a hotter mantle (i.e. melts from a hotter mantle should be more Fo-rich).

References:

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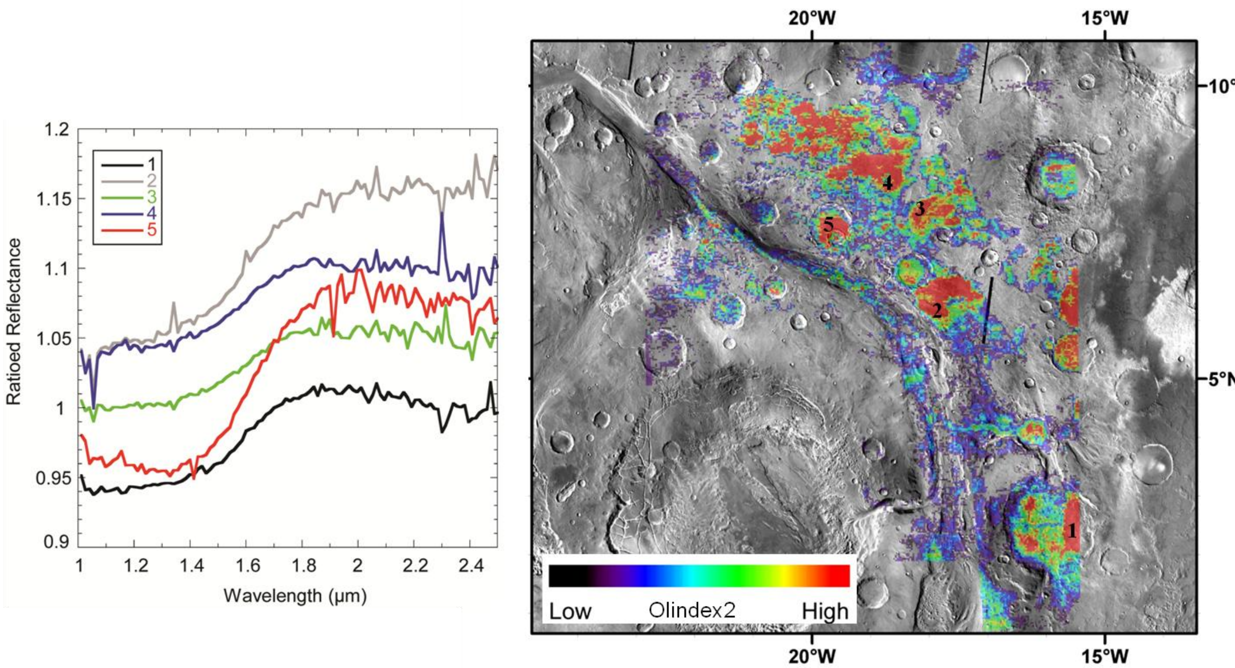

Figure 1. Left: CRISM TRR3 ratio spectra showing the broad, 1 micron absorption feature due to the mineral olivine. Numbers correspond to the locations in the image on the right. Right: The updated olivine index of [27] for CRISM was re-calculated to OMEGA wavelengths and overlain on THEMIS daytime IR. Numbers correspond to the locations of spectra extracted and shown on the plot to the left.