COMPLICATIONS IN CORRELATING THERMAL INERTIA AND OLIVINE ABUNDANCE ON MARS.

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Introduction: Weathering of bedrock to sediment can occur via mechanical or chemical processes. Pure mechanical weathering (with no sorting or removal) results in little mineralogical change from the primary lithology whereas chemical weathering can remove phases or produce secondary ones resulting in sediment with a mineralogical composition significantly different from the bedrock from which it was derived. Bedrock exposures on the Martian surface are very limited [1] and therefore the surface observed with remote sensing instruments is dominated by sediment. Globally, the Martian surface is characterized by large fractions of primary igneous minerals [e.g., 2, 3]. But geomorphological evidence suggests that liquid water was available at least episodically to enable alteration of these igneous minerals [e.g., 4, 5]. In addition, there are geochemical arguments for the production of secondary silica from chemical weathering of Mars' largely basaltic crust [6]. Locally, there is evidence for occurrences of secondary phases (phyllosilicates, hydrated sulfates, silica) resulting from chemical weathering due to the presence of liquid water, but these are very limited in extent, requiring the resolution of CRISM or MER to detect and map out [e.g., 7 - 10]. But in areas where secondary phases are not identified, non-detection does not necessarily imply that the surface represents an unaltered, primary lithology. Therefore, chemical weathering may be a widespread, rather than limited, process on Mars [11, 12].

Olivine is sensitive to chemical weathering at certain pH and water to rock ratios, and in the presence of liquid water may be preferentially altered and removed as a rock is weathered into sediment [e.g., 13 - 15]. Therefore, if chemical weathering is a significant contributor to Martian sediment production it is expected that sediments derived from olivine-rich bedrock will have a lower olivine content than the bedrock from which they originated. To test this hypothesis we have begun to look for evidence of a positive correlation between olivine abundance and thermal inertia using TES data, where thermal inertia can be considered a proxy for mean particle size. Surfaces with relatively high thermal inertias are rockier and those with relatively low thermal inertias are dominated by sands. Using this approach, evidence of chemical weathering can be discerned even if secondary alteration phases are not directly detected [11, 12].

An initial investigation into the global trend of olivine versus thermal inertia found no correlation between the two, but concluded that the various assumptions regarding global geology required to find such a correlation could be flawed and regional trends of chemical weathering may be masked by such a global analysis [16]. In continuation of this project, we are investigating several regional exposures of olivine-rich materials to examine the relationship between olivine content and thermal inertia in order to determine if there is evidence for chemical alteration resulting in the removal of olivine as bedrock is broken down to sediment in these areas.

Data and Methods: We used data from the Mars Global Surveyor Thermal Emission Spectrometer (TES) and 2001 Mars Odyssey Thermal Emission Imaging System (THEMIS) for this study. For each study region we extracted all of the TES measurements in a specified region of interest (ROI) that met our selection criteria for the highest quality data. In addition, we used the dust cover index of [17] to limit our analysis to dust-free surfaces (DCI $\geq$ 0.962) and we avoided high water-ice and dust opacities, which can complicate thermal inertia measurements [18]. For all analyses, we used daytime bolometer-derived thermal inertia from the TES database [19] and same-pixel total olivine content derived via TES spectral analysis from [20]. THEMIS IR image mosaics were used to delineate ROIs and decorrelation stretched (DCS) images (with THEMIS radiance bands 8, 7, and 5 as red, green, and blue, respectively) were used to verify TES footprint locations and olivine detections as the magenta color in these images is usually characteristic of the presence of relatively mafic materials typically containing olivine [e.g., 21].

Initial Results: To date we have completed analyses on two regions with exposures of olivine-rich materials: around the Nili Fossae and in Aurorae Planum. For each region we defined several ROIs that included either a broader region or a smaller area within it and plotted (for all non-zero olivine detections) the olivine fraction versus thermal inertia to determine if there was a correlation between the two variables. For both regions and for all ROIs, no correlation was found. The coefficient of determination (R^2; found via linear regression in Excel, generally values over ~0.6 can be interpreted as showing a positive correlation between the two variables) for Nili

Fossae ROIs ranged from 0.019 to 0.119, and for Aurorae Planum ROIs, R^2 = 0.037 to 0.169.

TES-derived thermal inertia varies with season [18], so we investigated the seasonal variance of thermal inertia in our regions and its effect on our analysis. Similar to the analysis done by [18], we extracted three years (OCKs 1583-24,346) of daytime TES observations in each region. Bolometric thermal inertia was binned by 10° L_S and a median thermal inertia calculated. We used the mean and standard deviation of these 10° L_S bin medians to determine a subset of "normal" L_S observations. Limiting our analysis to these observations did not change our results. However, it did have a variable influence on the calculated R^2 value, in some cases nearly doubling it. Although seasonal effects on thermal inertia did not change our results for these two regions, our preliminary analysis shows that it could influence results in other regions if olivine content and thermal inertia are found to be positively correlated (or nearly so).

We also observed a variance in the degree of non-correlation depending on the size and location of the ROI drawn within each region. For instance, near the Nili Fossae, increasing the size of the ROI to include a western area dominated by lower olivine contents more than doubled the R^2 value (from 0.054 to 0.119). This apparent increase in correlation would only be significant if the westward deposits are genetically related to the higher olivine materials to the east, and highlights the importance of understanding the local geology when examining an area for a correlation between olivine content and thermal inertia, especially when determining the ROI bounds to be used in the analysis.

The importance of scale of observation and knowledge of local geology is further emphasized when comparing our results to those found by [12] near the Nili Fossae. Using THEMIS nighttime temperature and DCS (875) imagery as proxies for thermal inertia and olivine content, respectively, [12] found a qualitative correlation between high thermal inertia surfaces and high olivine content, but noted that the correlation is not perfect. One of our ROIs closely approximates the region examined by [12], and within it we see no correlation of olivine abundance and thermal inertia in TES data, quantitatively exposing this non-perfect correlation around the Nili Fossae. This also highlights the risk in using a visual, qualitative approach; as pointed out by both [12] and [16], spectral parameter images can be misleading because they enhance relative, not absolute, differences, especially when images with varying observation conditions are mosaiced together.

Although it is possible that the non-correlation is a result of a lack of acceptable TES measurements in the area precluding a spatially complete analysis, it seems more likely that the assumption (implicitly made by [12] as well) that all lower inertia materials within the ROI are directly derived from the higher inertia materials may not be valid. Examining even smaller areas with TES data does not result in correlation, just as [12] found that quantitative analysis on a smaller area still resulted in a non-perfect correlation between olivine and thermal inertia. This doesn't seem surprising considering OMEGA and CRISM results, which have indicated that along with an olivine-bearing unit, a phyllosilicate-bearing and (olivine-poor) mafic unit are exposed around the Nili Fossae at scales much smaller than that of an individual TES footprint [22].

Conclusions and Future Work: To date we do not see any regional correlations between TES-derived thermal inertia and olivine content and suspect that complicated geological relationships below the scale of the ROIs (and possibly the TES footprint) play a large role in this apparent non-correlation. We plan to continue our analysis to several other regions and carry out more localized analyses at the THEMIS scale to limit the scale of observation and analysis to one where knowledge of the local geology can be incorporated with more confidence.

References: [1] Edwards, C.S. et al. (2009) *JGR,* 114, E11001. [2] Bandfield, J. L. et al. (2000) *Science*, 287, 1626-1630. [3] Rogers, A.D. and Christensen, P.R. (2007), *JGR*, 112, E01003. [4] Malin, M.C. and Edgett, K.S. (2000) *Science*, 290, 1927 -1937. [5] Malin, M.C. and Edgett, K.S. (2003) *Science*, 302, 1931 -1934. [6] McLennon, S.M. (2003) *Geology*, 31(4) 315-318. [7] Bibring, J.-P et al. (2005) *Science,* 307, 1576-1581. [8] Mustard, J.F. et al (2008), *Nature*, 454(7202) 7305-7309. [9] Milliken, R.E. et al. (2008), Geology, 36(11) 847-850. [10] Squyres, S.W. et al. (2008), *Science*, 320, 5879, 1063-1067. [11] Bandfield, J.L et al. (2008) *Geology*, 36(7), 579-582. [12] Bandfield, J.L. et al. (2011), *Icarus*, 211, 157-171. [13] Tosca, N.J et al. (2004) *JGR*, 109, E05003. [14] Stopar, J.D. et al. (2006) *GCA*, 70(24), 6136-6152. [15] Hurowitz, J.A., et al. (2006) *JGR*, 111, E02S19. [16] Hamilton, V.E. et al. (2010), LPSC XLI, abs #2239. [17] Ruff, S.W. et al. (2002), *JGR*, 107, E12, 5127. [18] Putzig, N.E. and Mellon, M.T. (2007) *Icarus*, 191, 68-94. [19] Mellon, M. T. et al. (2000) *Icarus, 148*, 437-455. [20] Koeppen, W. C. and Hamilton, V. E. (2008) *JGR*, 113. [21] Hamilton, V.E., and Christensen, P.R. (2005) *Geology*, 33, 433-436. [22] Mustard, J.F., et al. (2009) *JGR*, 114, E00D12.