

DISTRIBUTION AND VARIATION OF PLAGIOCLASE COMPOSITIONS ON MARS. K.A. Milam¹, J.E. Moersch², and H. Y. McSween, Jr.², ¹Department of Geological Sciences, Ohio University, 316 Clippinger Laboratories, Athens, OH 45701, milamk@ohio.edu, ²Department of Earth and Planetary Sciences, University of Tennessee, 1412 Circle Drive, Knoxville, TN 37996.

Introduction: Previous studies have addressed the abundance distribution of major minerals on the Martian surface [1,2], but few have examined compositional variations that may occur in solid solution minerals, such as plagioclase feldspar, and the implications such variations may have for the crustal evolution of Mars. Plagioclase is a solid solution mineral of anorthite and albite whose composition varies in accordance with changes in magma composition and temperature. Like other feldspars, plagioclase can be altered in the presence of water in specific ways in low- or high-temperature settings. Alteration products of calcic feldspar under low-temperature or hydrothermal conditions include various clay minerals and albite+clays respectively. Detection of regional albite deposits in an otherwise basaltic terrain could, for example, point to ancient hydrothermal activity.

In this study, we have built upon previous, laboratory-based studies [3-5] to produce the first plagioclase compositional maps of Mars using thermal emission spectra from the Mars Global Surveyor (MGS) Thermal Emission Spectrometer (TES). With these maps, we are able to speculate on the magmatic evolution and alteration of a planet dominated by a mafic crust [1, 6-7].

Methods:

Selection of TES Spectra. TES data (10 cm⁻¹ sampling) were selected from those collected during the mapping phase of the mission prior to orbit 5317 (ocks 1683-7000, L_s 104° - 352°) because instrumental noise became progressively worse beyond this point. The TES database was queried for spectra that met criteria specific to the Martian surface and was restricted using various quality parameters to avoid anomalous data. Spectra were selected from a region centered ±60° of the Martian equator. Higher latitude data tended to be collected at lower surface temperatures, and contain the polar ice caps and geomorphic features suggestive of surface ice. This region encompasses a significant portion of the southern ST1-dominated highlands, the northern ST2-dominated lowlands, and areas covered by considerable surface dust, such as the Tharsis area [1]. This area also corresponds to the lowest dust and ice-free regions on Mars demonstrated to have the highest abundance of plagioclase [2]. Spectra were also limited to those collected at surface brightness temperatures > 265 K. This constraint allowed us to focus on data with relatively high signal-to-noise ratios (>245 average SNR for 400 to 1300 cm⁻¹). Lower sig-

nal-to-noise ratios (especially below 200) can potentially affect the accuracy of processing results.

Dusty areas were eliminated by choosing TES spectra with Lambert albedos < 0.18. Higher albedo spectra correspond to dusty regions on Mars, where the true spectral signature of primary surfaces (e.g. bouldered terrain, bedrock) can be spectrally masked by a mantle of dust [8-10]. Because of our selection criteria, the study area happened to correspond mostly to intermediate thermal inertias [11], regions on Mars dominated mostly by fine to coarse-grained sand [12].

Atmospheric Correction and Unmixing. Atmospheric components were removed from TES spectra in a manner similar to previous studies [1-2, 13] using a linear deconvolution technique [14]. Corrected spectra were modeled using a library of 51 spectral endmembers representing primary igneous minerals common in mafic-intermediate volcanic rocks (including 23 different compositional varieties of plagioclase), and common alteration weathering phases, such as carbonates and clays. Hematite, sulfate, and carbonate spectral endmembers were also included due to their previous detection on Mars [15-17]. A blackbody was also included to model reduced spectral contrast in areas influenced by smaller grain sizes. Negative endmember percentages were initially allowed in modeled results to produce a linear least squares fit, but were later removed in an iterative fashion until all percentages were positive in order for the values to be geologically meaningful. The remaining modeled endmembers were re-normalized to 100 percent. Each TES spectrum was modeled over 1300-825 cm⁻¹ and 507-400 cm⁻¹. Other channels observed by TES were excluded to eliminate random and systematic noise often observed and to avoid major CO₂ and H₂O-vapor absorptions. The spectral ranges used encompass all major absorption features in most common minerals (i.e. silicates, carbonates, sulfates, etc.) and are also comparable to previous laboratory analog studies [3-4] and volcanic rocks [3, 18-19]. Outputs included modeled spectra, lists of percentages in which each endmember was modeled, and root-mean-squared (RMS) errors that characterized the differences between actual and modeled spectra. Selected modeled and actual spectra were qualitatively compared and RMS errors were examined globally to ensure the accuracy of deconvolutions. Ninety-nine percent of all RMS errors were < 0.006 in study regions.

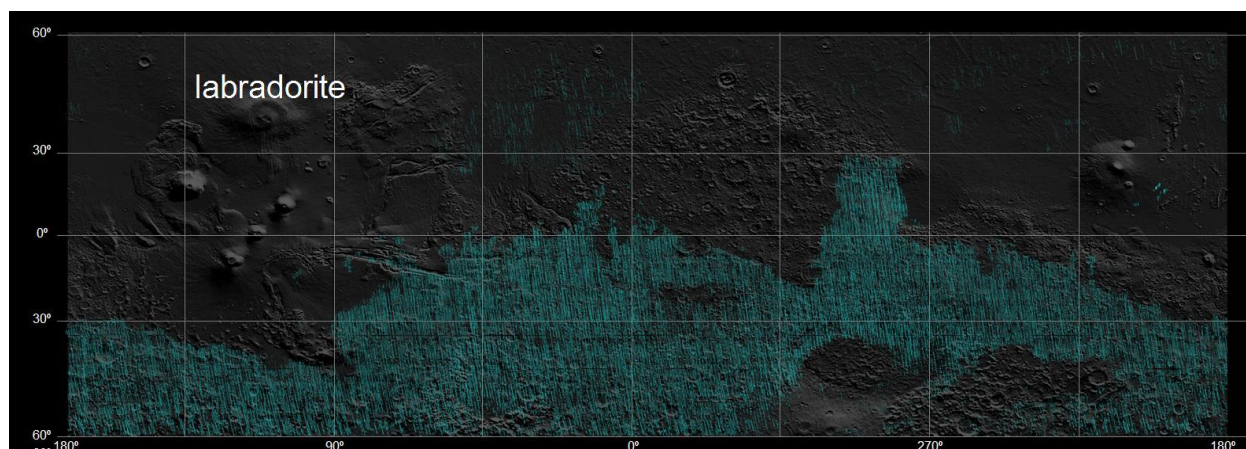


Figure 1. Plagioclase compositional map of Mars showing TES spectra whose average composition modeled as labradorite (blue) overlain on darkened Mars Orbiter Laser Altimeter (MOLA) shaded relief map. Of the spectra used in this study, a majority (42%) modeled as labradorite.

Plagioclase Compositional Mapping. An IDL computer algorithm was used to review output end-member percentages and retrieve only those of plagioclase spectral endmembers used in deconvolutions of each TES spectrum. Plagioclase abundances were renormalized so that the sum of all plagioclase end-member abundances equaled 100%. These renormalized abundances were multiplied by the anorthite (An) content of each endmember (as determined from laboratory measurements [3, 20] to get an appropriately weighted average plagioclase composition for each TES spectrum. This is the same technique used in previous studies [3-4]. Because we examined such a large portion of the Martian surface, TES observations were subdivided into scenes according to their geographic coordinates (mostly $10^\circ \times 10^\circ$ regions). For each scene, a new data product was then constructed, with pixel values equal to average plagioclase compositions. In order to minimize potential visual effects that noisy data might introduce and to highlight potential compositional trends by region, each pixel was binned into one of the six fundamental plagioclase compositional ranges: albite (An_{0-10}), oligoclase (An_{10-30}), andesine (An_{30-50}), labradorite (An_{50-70}), bytownite (An_{70-90}), and anorthite (An_{90-100}). Pixels were then color-coded according to each of the plagioclase types. To better visually discern compositionally-distinct regions on Mars, images were mosaicked together in cylindrical projection covering the area $\pm 60^\circ$ of the equator, to produce six plagioclase compositional maps.

Results and Discussion: The first plagioclase compositional maps (e.g. Figure 1) show that: (1) Mars is a planet dominated by calcic plagioclase (primarily labradorite and bytownite, with an average composition of An_{61}); (2) Surface types 1 and 2 are indistinguishable in terms of average plagioclase compositions (An_{62} and An_{59} respectively), but do show minor variations in

the percentages of TES spectra that model as different plagioclase compositions (ST2 is slightly more variable); (3) the similarity in average plagioclase compositions between ST1 and ST2 may be explained by either a lack of variability in modeled plagioclase compositions during fractional crystallization of Martian magmas or aeolian, fluvial, or impact redistribution of primary igneous material; this redistribution likely resulted in a relatively homogenized (with respect to plagioclase compositions) surface layer. Compositional variability at the scale of individual or overlapping TES observations makes localized geologic investigations on this scale problematic. This is most likely results from grain size and signal-to-noise effects, even in the conservatively-screened TES spectra used in this study.

References: [1] Bandfield J. L. et al, 2000, *Science*, 287, 1627-1630. [2] Bandfield, J.L. (2002) *JGR*, 107. [3] Milam K. A. et al. (2004) *JGR*, 109. [4] Milam K. A. et al. (2007) *JGR*, 112. [5] Milam, K. A. et al. (2008) in prep. [6] Hamilton V. E. et al. (2001) *JGR*, 106, 14733-14746. [7] Wyatt M. B. & McSween H. Y., Jr. (2002) *Nature*, 417, 263-266. [8] Kieffer H. H. et al. (1973) *JGR*, 78, 4291-4312. [9] Kieffer H. H. et al. (1977) *JGR*, 82, 4249-4292. [10] Ruff S. W. and Christensen P. R. (2002) *JGR*, 107. [11] Mellon et al. (2000) *Icarus*, 148, 437-455. [12] Pelkey S. M. et al. (2001) *JGR*, 106, 23909-23920. [13] Christensen P. R. et al. (2000) *JGR*, 105, 9623-9642. [14] Ramsey M. S. and Christensen P. R. (1998) *JGR*, 103, 579-596. [15] Christensen P. R. et al. (1999) *JGR*, 105, 9609-9621. [16] Christensen P.R. et al. (2004) *Science*, 306, 1733-1739. [17] Bibring, J. P. et al. (2006) *Science*, 312, 400-404. [18] Hamilton, V. E. and P. R. Christensen (2000) *JGR*, 105, 9717-9733. [19] Wyatt M.B. et al. (2001) *JGR*, 105, 14711-14732. [20] Christensen P. R. et al. (2000) *JGR*, 105, 9735-9739.