

Northern Low Albedo Regions of Mars: GRS Implications. S. Karunatillake¹, S. Squyres¹, J. Taylor², J. Keller³, O. Gasnault⁴, L. G. Evans⁵, R. C. Reedy⁶, R. Starr⁷, W. Boynton³, D. M. Janes³, K. E. Kerry³, J. M. Dohm³, A. L. Sprague³, B. Hahn⁸, D. Hamara³, and the Mars Odyssey Team ¹Cornell University (wk43@cornell.edu), ²University of Hawai'i, ³University of Arizona, ⁴Université Paul Sabatier Toulouse, ⁵Computer Sciences Corporation, ⁶Institute of Meteoritics, ⁷Catholic University of America, ⁸Stony Brook University

Introduction: Mid-infrared spectra from the Mars Global Surveyor Thermal Emission Spectrometer (TES) instrument indicated two distinct mineralogical units concentrated respectively in northern and southern low albedo regions of Mars [1]. Material comprising “surface type 1” (ST1), found primarily in the southern hemisphere, has been interpreted to be dominated by minimally weathered basalt [2, 3]. However, spectral comparisons with terrestrial mineral mixtures have not yielded a unique composition for the material concentrated within northern low albedo regions, collectively named “surface type 2” (ST2). We attempt to establish additional constraints on candidate models for ST2 using data from the Gamma Subsystem (GS) of the Mars Odyssey Gamma Ray Spectrometer (GRS).

Data Processing: [4] and [5] describe the processing steps applied to GS data in detail. In order to avoid complications due to large amounts of ice, regions corresponding to the polar H₂O ice regime were identified and excluded from both hemispheres using a “H-mask” [4]. For the study performed here, we have summed spectra that were acquired from June 2002 until April 2005 within the H-masked regions.

We processed GS data in two distinct ways to perform our study. First, we determined the mean element concentrations in regions dominated by ST1 and ST2, both smoothed with a 10° circular median filter to remove noise, enabling a direct compositional comparison between the two units. These H-masked re-

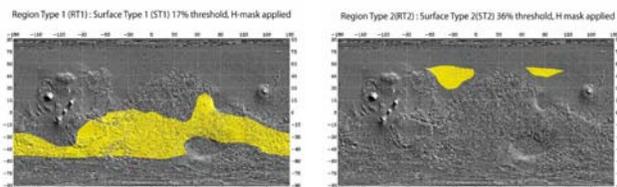


Figure 1. RT1 (left) and RT2 (right) highlighted in yellow

gions for ST1 and ST2 are “region type 1” (RT1: 17% threshold) and “region type 2” (RT2: 36% threshold), respectively (Fig 1). At present, GS data have determined surface concentrations of H (represented as wt% of H₂O), Cl, Fe, K, Si, and Th with sufficiently small uncertainties. We computed RT2/RT1 ratios of mean concentrations of these elements using cumulative γ

spectra that originated from within region boundaries (Fig 2).

In the second form of data processing, we created global maps of element concentrations and corresponding σ values [4]. We determined unique correlations among concentrations of various elements, areal concentrations of ST1 and ST2, and other parameters of interest. Our correlation coefficient algorithm was based on distinct linear multivariate regression methods: least squares with heteroscedastic weighting (heteroscedastic least squares, HLS) [6] and spatial autocorrelation (SA) [7]. We also implemented hierarchical modeling to eliminate redundant independent parameters and generate a limited set that

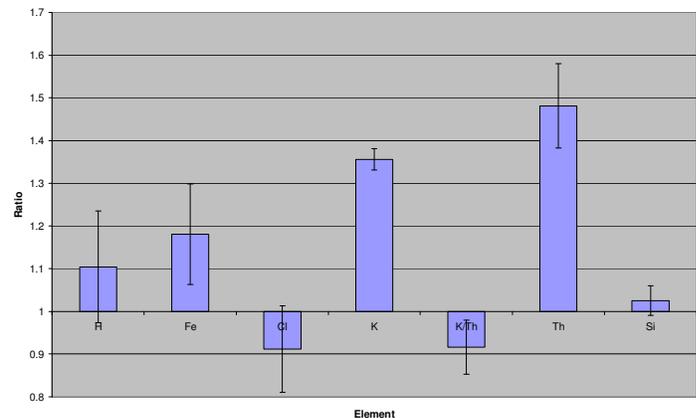


Figure 2 RT2/RT1 wt% ratios

would correlate significantly with each dependent parameter. All parameter values were binned at 5°×5° to establish spatially corresponding points across the datasets.

Results and Interpretation: An important result of our analysis is that RT2 is enriched in K and Th by more than 30% relative to RT1 (Fig 2). Among the most striking of our multivariate analyses results is that the spatial distribution of K correlates (at 95% and greater confidence) with only Th concentration (unique correlation, $r = 0.5$), ST2 areal abundance ($r = 0.2$), and ST1 areal abundance ($r = -0.2$). Similarly, the statistically most significant parameters for the spatial distribution of Th are K ($r = 0.5$), ST2 ($r = 0.2$), and ST1 ($r = -0.1$).

One factor that must be considered when interpreting any observed spatial variability in element concentrations on Mars is that the Martian surface is a mix of rock and non-rock of differing compositions. Physical processes like impact gardening and wind transport that vary the non-rock/rock ratio could then account for variations in bulk elemental composition. Our regression analyses test this idea by the use of albedo, thermal inertia, and rock abundance as independent parameters. All of these physical parameters might reasonably be expected to vary with non-rock/rock ratio over the depth range relevant to the GS. However, most of the elements, including K, do not show statistically significant (at 95% and greater confidence) variation with these parameters. We conclude therefore, that a suitable model for ST2 must explain K and Th enrichment relative to the basalts of ST1 (Fig 2) on the basis of rock composition rather than variations in non-rock/rock ratio.

Among the models for ST2, the leading candidates are basalts altered by aqueous processes [3] and unaltered basaltic andesite [1]. We discuss each possibility below. We do not include H and Cl in our interpretation, since the former is affected by the presence of subsurface ice and an unknown amount of bound water, while the latter may be influenced by the mobile component of the regolith [8].

Alteration by Water. Terrestrial analogs of subaerial aqueous alteration [9] and subaqueous alteration [10] suggest that K would fractionate from Th under either scenario. Furthermore, analyses of MER data suggest low-pH alteration at Gusev and Meridiani [11], which may fractionate the two elements more effectively than neutral conditions [12]. However, we do not observe significant fractionation of K from Th, as evident in the clear coupling of K and Th distributions with each other and ST2 and the similarity of K/Th ratios between the two regions (Fig 2). Other weathering models such as silica-coated basalt and oxidized basalt [13, 14] do not account in any simple way for the enrichment of K and Th in RT2.

Igneous Processes. One igneous mechanism that could enrich K in ST2 is fractional crystallization of basaltic magma [15]. However, this is primarily relevant in the evolution of an andesitic magma (55 wt% SiO₂). Evidence for Si enrichment in RT2 is highly inconclusive within 1 σ error bars (Fig 2). Therefore, in spite of the similarity of K and Th content in RT1 to the global averages [16], we cannot utilize a RT1 composition as proxy to the parent magma of ST2. Without a presumed source composition, it is unfeasible to test

the possibility of fractional crystallization with our data.

An alternative model, subduction zone magmatism, fractionates the trace elements, so K/Th would be high [17]. But the K/Th ratio for RT2, with a value of $(4.62 \pm 0.27) \times 10^3$, is typical for the Martian surface [16]. Therefore, decisive evidence for widespread formation of calc-alkaline andesite is lacking within ST2. Should ST2 material contain calc-alkaline andesites, it would probably be at spatial scales less than the GS's ~450 km diameter footprint [4].

An alternative to both localized fractional crystallization and plate subduction mechanisms is initial bulk differentiation processes on Mars producing compositionally distinct magma source regions in the mantle. If that were true, and present crustal dichotomy generally follows the source regions, northern and southern basaltic provinces of distinct trace element compositions, including K and Th, could be produced. Even though current simulations also predict differences in Si content [18], the difference in K and Th content between RT2 and RT1 is generally consistent with whole-mantle magma ocean models. This may further reinforce the possibility that in general, ST1 and ST2 are derived from compositionally distinct mantle sources.

References: [1] Bandfield J. L. et al. (2000) *Science*, 287, 1626-1630. [2] Ruff S. W. (2003) 6th International Conference on Mars, LPI, July 2003. [3] Wyatt M. B. and McSween H. Y. (2002) *Nature*, 417, 263-266. [4] Boynton W. V. et al. (2006) *JGR submitted*. [5] Evans L. G. et al. (2006) *JGR, submitted*. [6] Rawlings J. O. et al. (1998) *Applied regression analysis: a research tool* 2nd ed., Springer, NY. [7] Upton, G. J. G. and B. Fingleton (1985) *Spatial data analysis by example: Point Pattern and Quantitative Data*, J. Wiley, NY. [8] Keller J. M. et al. (2006) *JGR, submitted*. [9] Patino L. C. et al. (2003) *Chem. Geol.*, 202, 343-364. [10] Staudigel H. et al. (1996) *Subduction: top to bottom, Geophysical monograph* 96, 19-38, AGU. [11] Hurowitz, J. A. et al. (2005) *JGR, in press*. [12] Taylor G. J. et al. (2006a) *JGR, submitted*. [13] McLennan S. M. (2003) *Geology*, 31, 315-318. [14] Minitti M. E. et al. (2002) *JGR*, 107, doi:10.1029/2001JE001518. [15] Minitti M. E. and Rutherford M. J. (2000) *Geochim. Cosmochim. Acta*, 64, 2535-2547. [16] Taylor, G. J. et al. (2006b) *JGR, submitted*. [17] Hawkesworth C. et al. (1997) *Chem. Geol.*, 139, 207-221. [18] Elkins-Tanton L. T. et al. (2005) *JGR*, 110, doi:10.1029/2005JE002480.