CHEMICALLY AND MINERALOGICALLY DISTINCT REGIONS ON MARS DERIVED FROM GRS AND TES DATA.

G. Jeffrey Taylor[1], Linda M. V. Martel[1], A. Deanne Rogers[2], Suniti Karunatillake[3], Olivier Gasnault[4], and William V. Boynton[5], [1]Hawaii Inst. of Geophys. and Planetology, Univ. of Hawaii; 1680 East-West Rd., Honolulu, HI 96822, gjtaylor@higp.hawaii.edu, [2]Department of Geosciences, Stony Brook University, Stony Brook, NY, [3]Center for Radiophysics and Space Research, Cornell Univ., Ithaca, NY, [4]Centre d'Etude Spatiale des Rayonnements, CNRS/UPS, France, [5]Lunar and Planetary Lab, Univ. of Arizona, Tucson.

Introduction: The Mars Odyssey Gamma-Ray Spectrometer (GRS) and the Mars Global Surveyor Thermal Emission Spectrometer (TES) provide complementary data that allow us to decipher chemical and mineralogical variations across the surface of Mars. TES has substantially higher spatial resolution than GRS (a few km versus a few hundred km), but samples only the upper ~100 µm compared to a few tens of cm for GRS. TES spectra deconvolved into mineral abundances are available for low-albedo, relatively dust-free regions of Mars, while GRS data provide elemental abundances for both dusty and rockier regions.

Here we show a geochemical classification map based on GRS data and compare the properties of identified geochemical regions to mineralogic groups defined by TES data [1]. Combined use of GRS and TES data promises to provide detailed information about the composition and evolution of the crust of Mars.

Methods: The Odyssey GRS and data reduction methods are described by [2]. We use only those points in regions where H contents are low enough to not interfere in the determination of the concentrations of Si, Fe, Al, and Ca. Because hydrogen has a high cross section for capturing thermal neutrons, it can significantly affect the flux of thermal neutrons in the upper ~30 cm of the Martian surface, so we use the "H-mask" described by [2]. This corresponds approximately to the region between 52.5° North and 52.5° South. Eight elements can be mapped at present with GRS data (K, Th, Si, Fe, Ca, Al, Cl, and H). To focus on igneous bedrock and sediments derived from it we omitted Cl and H because they can be redistributed readily by aqueous processes. Thus each GRS 5x5 degree grid point was adjusted for the subtraction of Cl and H (as H_2O).

We used multivariate cluster analysis [3] to use all six elements simultaneously to discern global trends. We used the K-means algorithm for clustering. In our calculations so far, it appears that between 7 and 9 classes are useful for the GRS data set; we use 8 classes in the work reported here. The element concentrations have been normalized by subtracting the mean of the global dataset from each point, and dividing by the global standard deviation. This gives concentrations in terms of standard deviation from the global mean for each element.

TES data have been used to define modal mineralogy of spectrally distinct regions in the low-albedo areas of Mars [1,4]. Detailed studies of spectral characteristics indicate that there are four distinct groups that have distinctive mineralogy. They differ in plagioclase, high-Ca pyroxene, low-Ca pyroxene, olivine, and high-silica phases. We binned the abundances of each of the four TES groups into 5x5 grid points for comparison with GRS data.

Results. GRS geochemical classes resulting from cluster analysis appear in Fig. 1, along with areas in which specific TES groups dominate. Fig. 2 gives the mean standardized concentrations of the elements in the GRS classes. Fig. 3 shows the mean relative proportions of the four TES groups within each GRS class.

Overview observations. Cluster analysis of the GRS data identifies large regions of chemically-similar materials. All of the GRS classes have at least one element that is one-standard deviation or more greater or less than the global mean (Fig. 2), demonstrating that those classes are statistically distinct. Class 8 is the most distinctive compositionally, and is dominated by TES group 1 (Fig. 3). The other GRS classes have only subtle variations in the abundances of TES groups. TES groups often overlap two or more GRS classes (Fig. 1), indicating mineralogical variations within the GRS classes.

Summary of GRS units. We briefly summarize the characteristics of each GRS class. Mineral abundances referred to below are from [1].

Class 1 has intermediate concentrations of Si, Fe, Ca, and Al, but is depleted in K and Th. It occupies a large portion of the southern highlands, including Noachian massif materials and Noachian to early Hesperian volcanic deposits. It contains regions dominated by TES group 3 and others dominated by group 4, indicating variation in plagioclase to mafic silicates, and in the abundance of olivine.

Class 2 is below the global mean in all elements except Al and is significantly depleted in Ca. It occupies a large portion of the western southern highlands, including Meridiani and portions of Aonia and Sirenum, and includes early to middle Noachian materials and Noachian to Hesperian volcanic deposits. It is higher than most classes in TES groups 1 and 4, and lower in group 3.

Class 3 is characterized by significantly low Si. It makes up much of Tharsis. The low Si may reflect the nature of the Amazonian lavas in this region. The area is dust-covered, so we have no TES data for it.

Class 4 features the highest mean Ca and Fe concentrations, and low K and Th. It composes a large area west of Tharsis. It is dominated by late Hesperian to late Amazonian volcanic deposits. It contains the second highest level of TES group 3.

Class 5 is low in Al but otherwise has roughly mean concentrations. It occurs adjacent to class 8 and might be transitional to it, consistent with it having the second highest concentration of TES group 1.

Class 6 is average in elemental abundances, except for a distinct enrichment in Al, and encompasses a large swatch of the southern highlands west and north of Hellas. It is dominated by TES group 3 mineralogy.

Class 7 is distinctly enriched in K and Th. It occupies the ancient highlands around Terra Sirenum and Terra Cimmeria, plus a region in the highlands at the highlands-lowlands border. Although it contains areas dominated by TES group 3, it is one of the lowest in group 3 abundance overall, and contains the highest abundance of group 4.

Class 8 has elevated Th, K, Si, and Fe, and significantly low Al, and is a distinctive unit in the northern plains. It is clearly dominated by TES group 1 materials. TES data indicate that the rocks in group 1 are enriched in low-Ca pyroxene.

Discussion. The Martian surface contains compositionally distinct regions, defined by both TES and GRS data. Regions identified by the two techniques do not always correspond exactly, which suggests variations in mineral abundances are not always correlated with composition. This may reflect variations in the amount of alteration of the surface, but in some cases it may mean that rocks have similar mineralogy but differ in trace element concentrations (e.g., GRS class 1, which is lowest in Th and K).

References: [1] Rogers, A. D. and P. Christensen (2007) *JGR* **112**, doi:10.1029/2006JE002727. [2] Boynton, W. V. et al. (2007) *JGR*.**112**, E12S99,doi:10.1029/2007JE002887. [3] Tyron, R. C. (1939) *Cluster Analysis*. Edwards Brothers, Ann Arbor, Michigan. [4] Rogers, A. D. et al. (2007) *JGR* **112**, doi:10.1029/2006/JE002726.

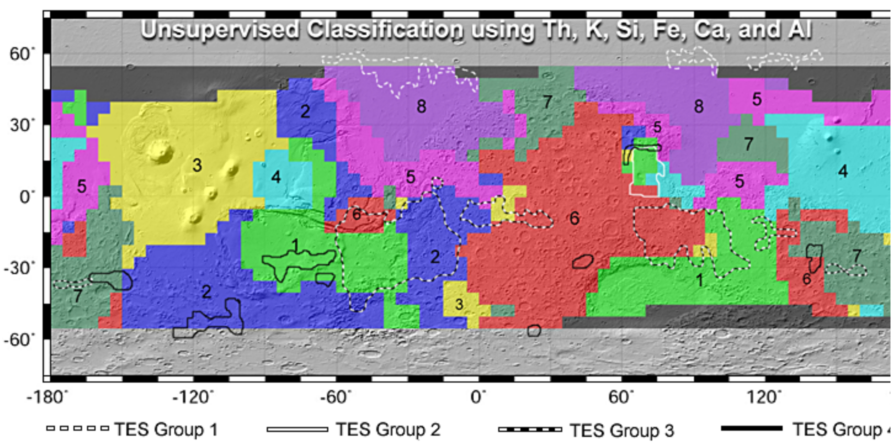

Fig. 1. Results of an unsupervised classification map obtained from 5 x 5 degree smoothed GRS data (Th, K, Fe, Si, Ca, Al), superimposed onto MGS MOLA shaded relief map. Geochemical cluster classifications are numbered. Fields indicate where TES mineralogic groups are most abundant.

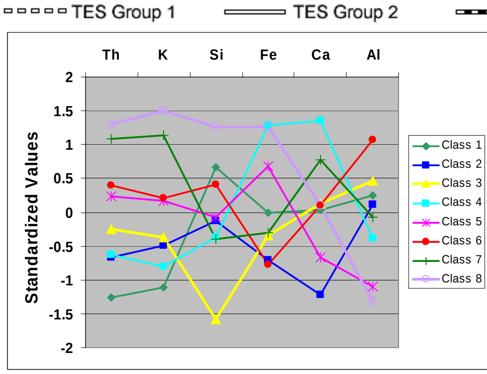

Fig. 2. GRS element concentrations in each of the geochemically-classified regions. To weight elements equally and to provide statistical information, concentrations are normalized to reflect deviations in terms of standard deviations from the global mean for each element.

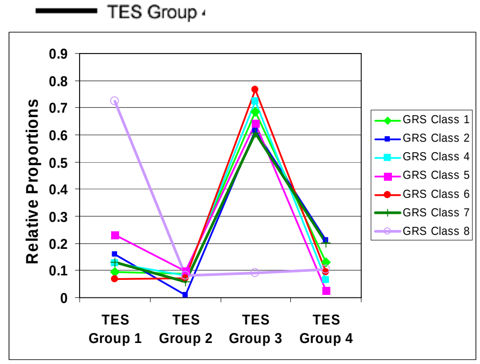

Fig. 3. Mean proportions of TES groups for each class defined by multivariate cluster analysis of GRS elemental data. TES Group 1 and GRS Class 8 (northern plains) are particularly distinct.