MAPPING MARS GEOCHEMICALLY. G. Jeffrey Taylor[1], Linda M. V. Martel[1] , and William V. Boynton[2], [1]Hawai`i Institute of Geophysics and Planetology, University of Hawaii at Manoa. Honolulu, HI 96822 (gjtaylor@higp.hawaii.edu), [2]Lunar and Planetary Lab, University of Arizona, Tucson, AZ 86721.

Introduction: The Mars Odyssey Gamma Ray Spectrometer (GRS) has mapped the distribution of six elements (Cl, Fe, H, K, Si, and Th) on the Martian surface. Maps of individual elements or element ratios (e.g., K/Th), and x-y graphs of chemical data are useful for understanding Martian crustal evolution, planetary bulk compostion, and early differentiation. In an attempt to enhance our understanding of the geochemical and geological evolution of the crust, we have used multivariate classification techniques to define mappable geochemical units on Mars. We report our preliminary results here.

Methods: GRS data acquisition and data reduction techniques are given by [1]. Data for Cl, Fe, Si, and H are restricted to regions where H is not rapidly increasing towards polar ice-rich regions. This was done by use of the H-masking technique described by *Boynton et al.* [1]. We have used 5 x 5 degree data smoothed with a 10 degree radius filter. The 10-degree smoothing is appropriate as this is about the inherent spatial resolution of the GRS instrument from the Mars Odyssey orbit. This procedure smooths out noise in the data.

We used multivariate analysis on the six-element mapped data, using the image processing and analysis program, ENVI (Environment for Visualizing Images). We first normalized the data to ensure that the clustering procedure gives equal weight to each element (Th is as valuable as Si). Otherwise, the element with the largest concentration will dominate. We used K-means clustering [2], which assigns each point to the data cluster whose center is nearest, and let the process repeat until less than 1% of the pixels changed classes and we achieved optimal separation of class clusters. This took less than 25 iterations. The number of classes the program defines is selected by the user. We increased the number of classes until the addition of a class did not add sufficient information to warrant its inclusion; in other words, adding additional classes explained only marginally more of the total variance. Our approach differs in detail from that taken by [3], who also includes principal component analysis.

Results: We examined two cases. In one we used all six elements (Fig. 1). In the other (Fig. 2) we did not use the clearly mobile elements Cl and H. Both are affected by aqueous processes and Cl can be added through volcanic emissions. Thus, using only the rock-forming elements Fe, K, Si, and Th may give insight into the nature of the bedrocks on Mars, although there is some evidence that K and Th might be mobile as well [4,5] We compare these maps to a simplified geological map of Mars [6] and to MOLA topography (shown in each figure).

Fig. 1 shows the results for the six element case, for ten classes. Notable correlations with geologic features include: Class 5 (low Si and Fe, high Cl) covering much of Tharsis. Class 4 (moderate Cl, Fe, and H, and low K, Si and Th) includes Noachian to Early Hesperian volcanics in eastern Tharsis and Syrtis Major, and the Late Hesperian to Amazonian volcanics in Elysium. Class 8 (high H and Th) is concentrated in Arabia Terra, distinguishing this region from other geochemical units in the southern highlands. Classes 2 and 3 compose much of the southern highlands. They differ in detail, but have in common lower levels of Cl, Fe, H, and K than they do Si and Th. Classes 7 and 10 compose the northern plains in the mapped area. They are different, but have in common high Si, Fe, K, and Th.

Fig. 2 shows the results without using Cl and H. There are similarities to Fig. 1; the northern plains are not classified very differently from the six-element map, and Elysium still stands out. We also note some differences between the two classification maps. The Arabia area is classified very differently (largely because of its high water content), with the highlands unit west of Hellas extending much farther north. Tharsis is divided differently because of the high Cl content on its western half. Class 1 in this case is characterized by low Si and Fe. Classes 3, 4, and 7 make up 90% of the area defined as Surface Type 1 [7]. These classes have distinctly different compositions (Fig. 2), suggesting that Surface Type 1 is compositionally variable, though generally basaltic. Surface Type 2 corresponds to class 8 (Fig. 2), although class 8 is more extensive.

Discussion: These results are promising. There are interesting correlations with geologic units, not that one expects such correlations to be perfect because geologic mapping is based on numerous observable features, not composition. We intend to make more detailed comparisons between the geochemical and geological maps, and to compare to maps based on TES and other databases. A difficulty with such comparisons is the different sensing depths or different measurements (e.g., TES senses the upper 100 microns or so, GRS the few tens of cm). During the coming year we expect to be able to map Ca and U, and possibly S and Al. We can certainly obtain values for all these elements in each of the classified areas.

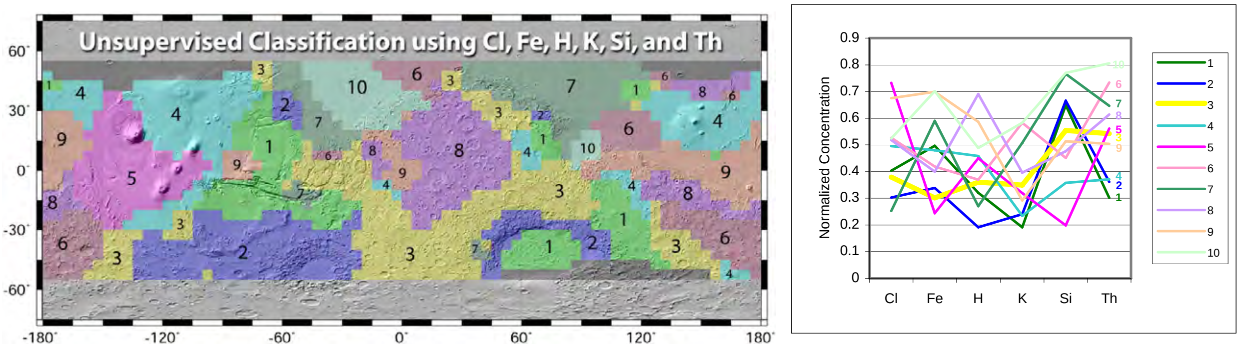

Figure 1. Results of an unsupervised multivariate classification using six elements, shown on a MOLA shaded relief map (left). Chemical characteristics of each class are shown on the right. All elements were normalized to their full range by subtracting the lowest value from each pixel and dividing by the range. Thus, each element ranges from 0 to 1 in concentration. This prevents elements with the highest concentrations being given too much weight.

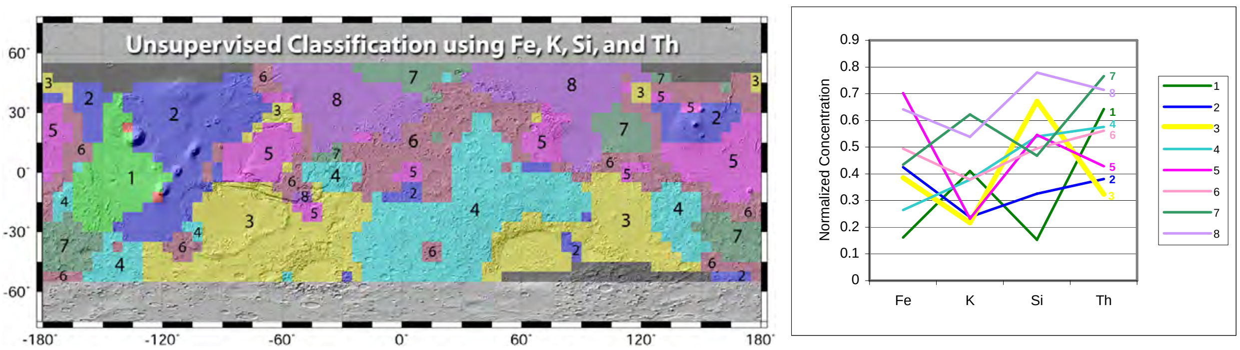

Figure 2. Results of an unsupervised multivariate classification using four elements, shown on a MOLA shaded relief map (left). Chemical characteristics of each class are shown on the right. See Fig. 1 for information about normalization.

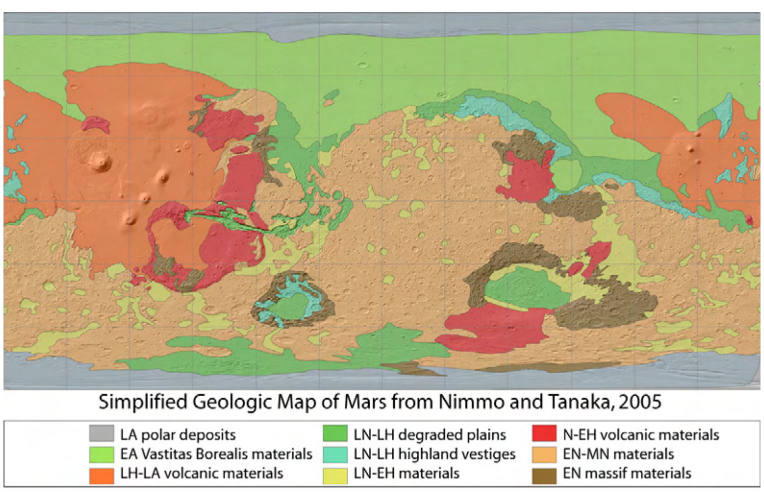

Figure 3. Simplified geologic map [6].

References: [1] Boynton, W. V. et al. (2006), *J. Geophys. Res.*, submitted. [2] MacQueen, J. (1967). In Le Cam, L. M. and Neyman, J., editors, *Proceedings of the Fifth Berkeley Symposium on Mathematical Statistics and Probability*, volume 1, pages 281-297. University of California Press. [3] Gasnault, O. (2006) LPSC 37. [4] Newsom, H. et al. (2006) LPSC 37. [5] Taylor, G. J. (2006) *J. Geophys. Res.*, submitted. [6] Nimmo, F. and K. L. Tanaka (2005) *Ann. Rev. Earth Planet. Sci.*, **33**, 133-161. [7] Banfield, J. et al. (2000) *Science*, ***287***, 1626-1630.

Acknowledgement: We thank Jim Skinner and Ken Tanaka (U.S. Geological Survey) for the geologic map shown in Fig. 3.