GEOCHEMISTRY OF MARTIAN SURFICIAL MATERIALS WITH GAMMA RAY DATA FROM MARS ODYSSEY: INITIAL OBSERVATIONS FOR CALCIUM

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Introduction: The Mars Odyssey Gamma Ray Spectrometer (GRS) determines the chemistry of the upper few tens of centimeters of the surface [1]. The chemistry of the mobile components (soil, drifts, dunes, mantles, etc.) provides clues to geochemical processes during martian history, including possible chemical fractionations between the crust and these loose surficial materials (soil). There is a current dust component that occurs as thin (easily churned up by rover wheels) bright dust observed at the MER landing sites [2] and which also occurs over large areas of Mars as seen in remote sensing observations [3]. However, the variability of surface chemistry seen in the GRS results by Newsom et al., [4] suggest that this presumably homogeneous bright material is less than 10's of cm in thickness over most areas. New data for calcium (**Fig. 1**) is examined for additional information about the chemical variations on the martian surface, and the possible role of alteration in the evolution of surface materials.

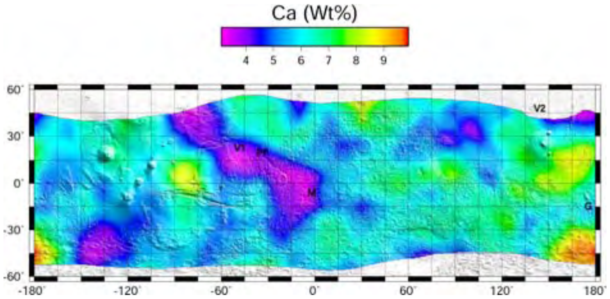

Fig. 1. Calcium concentrations in wt% for areas within approximately 45 degrees of the equator, because of greater uncertainties in the GRS data where ice is present at higher latitudes [1]. The GRS data used in the current study represents about 70% of the surface area of Mars.

Calcium is an important major element that is present in the minerals plagioclase and pyroxene in the martian crustal rocks. During alteration, calcium is removed from crustal rocks as observed in the Columbia Hills. Ca is enriched in the ejecta regolith at the Lonar crater in India [5]. In an earlier study [6], we investigated the origins of an apparent depletion of calcium in soils analyzed at the Viking and Pathfinder sites compared to common martian basaltic meteorites. That study suggested that erosion of altered, Ca-depleted rocks could lower the Ca concentration of the present martian soil compared to fresh basaltic rocks. The alteration processes probably occurred early in Mars history, long before formation of the present soils. The GRS global data and local MER analyses of rocks and soils allows us to further investigate these questions.

Comparison of GRS data with landing sites: The landing site data in **Fig. 2** from Karunatillake et al., [7] is based on an evaluation of the rock and soil compositions at each landing site. The GRS data and associated uncertainty are based on ten by ten degree binned data. The agreement is within about 20% except for Spirit, which sits in an area with a more complicated regional geology. Considering the large footprint of the GRS instrument (450 km) this agreement is satisfactory.

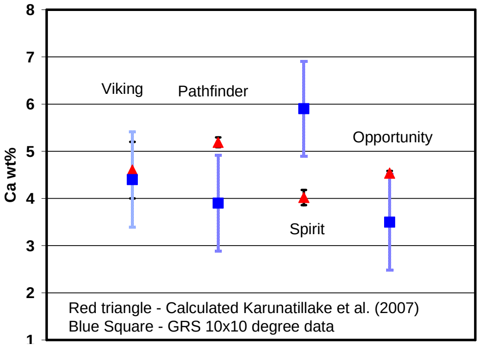

Fig. 2. Comparison between the Ca wt% abundance at four landing sites, with the GRS 10x10 degree data.

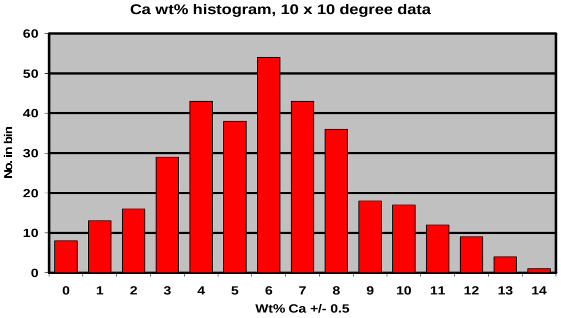

Fig. 3. Histogram of Ca wt% abundance within approximately 45 degrees of the equator.

Characteristics of Ca-rich and Ca-poor regions: Based on 10 x 10 degree data, the data fall into three broad categories, with approximately 25% of the bins having < 4% Ca, 53% with Ca between 4% and 8%, and 23% with Ca > 8%. From the map in **Fig. 1**, the areas with low and high Ca were identified and characterized (**Table 1**). There is no particular correlation of calcium concentrations with the bright dust seen in other remote sensing data, such as the TES visible/near infrared reflectance [3]. Both high and low Ca concentrations are present in dusty and not-dusty regions.

	Low Ca regions (<4wt%)	**Dusty?**
1	Plain between Iani and Meridiani	N
2	Xanthe Terra	N
3	Tempe Terra	Y
4	Nansen Crater vicinity	N
5	Nili Fossae	N
6	Propontis	Y
	High Ca regions (>8%)	
1	Terra Sirenum	N
2	Fortuna Fossae	Y
3	Cerberus	Y

Table 1. Locations of areas with high and low Ca concentrations.

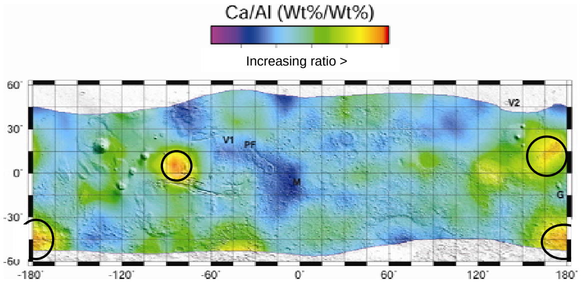

Fig. 4. Map of calcium/aluminum concentrations. The circled areas with high Ca (**Fig. 1**), have high Ca/Al, arguing against high plagioclase abundances. Ca-rich pyroxene or other Ca-rich minerals may be abundant in the high Ca areas.

Comparison of GRS data with martian meteorites and rocks at landing sites: The range of concentrations observed in the GRS data is similar to the range seen in martian rocks. The Nakhlite meteorites, for example, contain up to 13 wt% calcium. Feldspar-rich rocks could also have high Ca abundances, but the Ca/Al data for the high Ca regions (**Fig. 4**) rules out a large plagioclase component. The lack of GRS data for S further limits the interpretation of the mineralogy of Ca-bearing minerals. In addition, the GRS data need to be corrected for the dilution due to the added Cl and S (not yet available), adding to the difficulty of making direct comparisons. The depletion of Ca in martian soils can be addressed by comparing the composition of typical martian basaltic rocks (5.5 – 8.0 wt% Ca), and the histogram of data in **Fig. 3**. A substantial portion of the surface has lower Ca abundance than typical basalts, but whether the soils are generally depleted in Ca compared to local rocks, as seen at the landing sites can not be confirmed.

Implications for soil formation and evolution: The substantial variations in the abundance of Ca observed in the GRS data support the conclusion of Newsom et al., [4] for other elements that the soils on Mars have not been homogenized. The composition of the surficial materials therefore reflect either derivation from local source rocks with different compositions or the effects of chemical alteration and chemical transport [e.g. 5], either of the soil itself, or of the local source rocks.

The heterogeneity of surficial materials also has implications for the evolution of the soil composition with time. In order to maintain the heterogeneity in the soils the soils must be relatively young, and there must be sinks to maintain the disequilibrium over geological time scales. MER observations of soil settling into fractures (e.g. Anatolia) and filling depressions and craters suggests that the regolith and upper crust can provide the necessary sinks, as included in a revision (**Fig. 5**) of the soil flux model proposed in Nelson et al., [6] and discussed by Newsom et al., [8].

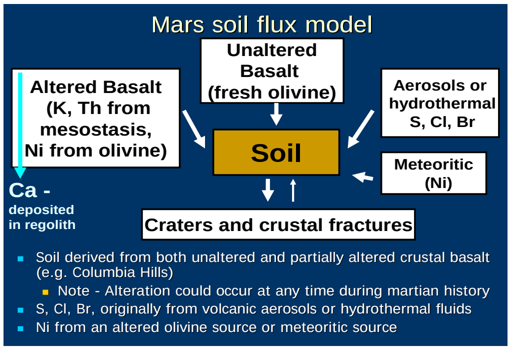

Fig. 5. Mars soil flux model further developed from discussion in Nelson et al. [6].

Conclusions: The new GRS results from for calcium confirm the presence of substantial variations in the chemistry of mobile surficial materials on the surface of Mars. The range of abundances from the GRS data is similar to the range of Ca in martian rocks. Chemical fractionation of Ca in soils compared to rocks cannot be confirmed. Variations in soil abundances imply a relatively young age for martian soils, and imply that sinks are present in the martian regolith and crust for sequestering older soils. These sinks may include small craters and fracturing of the martian surface.

References: [1] W. Boynton et al, (2007) *JGR*, submitted. [2] A.S. Yen. et al, (2005) *Nature*, *436*, 49-54. [3] N. E. Putzig et al., 2005 *Icarus* 173, 325-341. [4] H. E. Newsom et al., 2007, *JGR* in press. [5] H. E. Newsom et al., 2007 LPSC 38th, submitted. [6] M.J. Nelson. et al, (2005) *Geochim. Cosmochim. Acta*, *69*, 2701-2711. [7] S. Karunatillake et al., 2007, *JGR* submitted. [8] H. E. Newsom et al., (2005) *LPSC XXXVI*, abstract #1142.