GEOCHEMISTRY OF MARTIAN SOIL AND BEDROCK IN MANTLED AND LESS MANTLED TERRAINS WITH GAMMA RAY DATA FROM MARS ODYSSEY.

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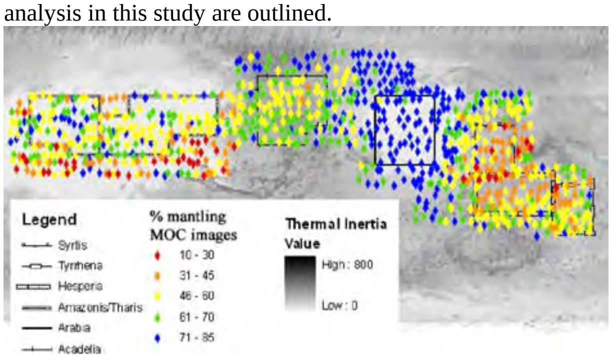
Introduction: The Mars Odyssey Gamma Ray Spectrometer (GRS) uniquely determines the chemistry the upper few tens of centimeters of the surface [1,2]. The chemistry of the mobile components (dust, soil, drifts, dunes, mantles, etc.) provides clues to geochemical processes during martian history, including possible chemical fractionations between the crust and the surface soils. Deposits of globally mixed aeolian dust could also provide an average composition of the martian crust, similar to loess on the Earth [e.g., 3-5].

Mapping procedures: We have used MOC images to statistically sample the nature of the surficial materials on Mars [6]. The random distribution of the MOC image data set allowed us to determine the actual fraction of exposed bedrock and to define areas whose GRS derived chemistry could be examined (e.g., Fig. 1). An additional semi-quantitative procedure was used to evaluate the amount of rocky outcrop in each area using bright and dark areas as a proxy for rough topography. The areas selected for analysis represent large regions with relatively similar physical and chemical properties and mantling characteristics.

Fig. 1. Near global thermal inertia map [7] with MOC locations and estimated amounts of mantling obtained by examination of the high-resolution images. The 7 areas selected for analysis in this study are outlined.



Global heterogeneity of surficial materials: The three mantled terrains provide a test of whether surficial materials on Mars are globally homogenized. Our study of the MOC images of these areas and the TES thermal inertia map [7] confirm that very little bedrock is exposed in these areas and that the surficial materials have buried the underlying topography, mainly to a depth of at least several meters. Cl is distinctly higher in the Amazonis area compared to the Tharsis or Arabia regions (Fig. 2), while for K, Arabia is distinctly higher than Tharsis and Amazonis. For Th, there is an increasing trend from Tharsis to Amazonis to Arabia (Fig. 3). The mantled areas have similar Fe, but Arabia has a distinctly higher Si concentration (Fig. 4). Limited bedrock exposures in the mantled areas makes it unlikely that an extreme bedrock composition could explain the variations. Therefore, the data for the mantled terrains strongly argues against a globally homogeneous source of dust.

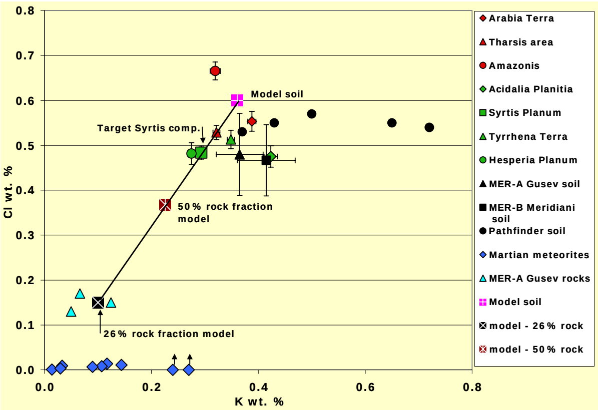
Less-mantled terrains: The Cl, K, and Th abundances are substantially enriched in all of the areas relative to most basaltic martian meteorites and the Gusev basaltic rocks, but a closer examination suggests that the four less-mantled areas may have somewhat lower abundances of Cl, K and Th, possibly due to the presence of bedrock with less of these elements. Keller et al. [8] has shown that there is a rough anticorrelation between Cl abundance and thermal inertia on a global basis that is consistent with our observations, although exposure of bedrock with lower Cl cannot explain all the Cl variations. The areas in our study where bedrock may be partly exposed are the Syrtis and Hesperia volcanic constructs and to a lesser extent the Tyrrhena highlands region located between them.

The Acidalia region has a high thermal inertia and low Cl, suggesting exposure of bedrock, but the K and Th are high. This could reflect a crustal composition [e.g., 9], alteration of the surface material [10], or enrichment of the soils in this region, possibly because the area is a depositional basin.

Comparison of Mars-rock data with GRS data: The extent to which the abundance of Cl, K, and Th in the surface reflects the underlying crust depends on the composition of the bedrock in these areas. The simplest assumption adopted by Taylor et al. [4] is that the composition of the surficial materials reflects the crustal composition, much like terrestrial loess [3]. However, if the bedrock on Mars (like martian meteorites) is generally lower in Cl, K and Th than the soils, the average surface composition from the GRS data only represents an upper limit for the composition of the crust.

As a test case, we have constructed a mixing model between plausible soil and rock compositions to obtain the Syrtis composition. Assuming a bedrock fraction of 50% requires a rock composition intermediate between the soil and average meteorite abundances and implies that about 35% of the Th and K are present in the crust compared to 50% for the assumption that the crust is the same as the surface abundances, assuming the Wänke-Dreibus abundances. The case with an exposed bedrock abundance of 26% requires lower rock concentrations, but requires a greater enrichment of K and Th in the soil or dust relative to the rocks (factor of about 4), and implies that only about 10% of Th and K are partitioned into the crust or that bulk Mars has lower abundances with significant implications for martian thermal history that may not be reasonable [4].

Fig. 2. Lower abundances of K and Cl in less-mantled areas such as Syrtis Major Planum and Hesperia Planum could be due to lower concentrations in the exposed bedrock. A mixing model shows that Syrtis Major Planum could be a mixture of an enriched model soil composition and bedrock with lower abundances of Cl and K.



The elements K and Th are not highly volatile, and both elements can be fluid mobile under low pH conditions [5]. Thus, aqueous processes could have enriched these elements in the surficial materials. These elements also share the characteristic of being incompatible during igneous fractionation and are enriched in the mesostasis during the final stages of crystallization of basalts [11]. Preferential alteration and aeolian erosion of the mesostasis could therefore enrich the soils. This component could be due to erosion of rocks altered early in Mars history, which would be consistent with an origin for the Mars soil strictly as a geochemical sink [12]. In a similar fashion Newsom et al. [13] has argued that preferential alteration and erosion of olivine could explain the high Ni abundances of the soils measured at the MER landing sites [14].

Iron and silicon relationships. In contrast to Th and K, the Fe and Si data show no relationship at all between the degree of mantling and abundance. This supports the conclusion that the variations in Fe and Si are due to local processes, not due to different amounts of bedrock versus soil.

Conclusions: These early results from the GRS experiment suggest that the mobile materials on the surface are not homogeneous on a global basis. Furthermore, the soils may be somewhat enriched in K and Th compared to the crustal bedrock on Mars.

Fig. 3. The model crustal rock compositions fall within the range of martian meteorite compositions for K and Th. The model results argue that the crustal abundances of K and Th may be less than the average GRS concentrations [4].

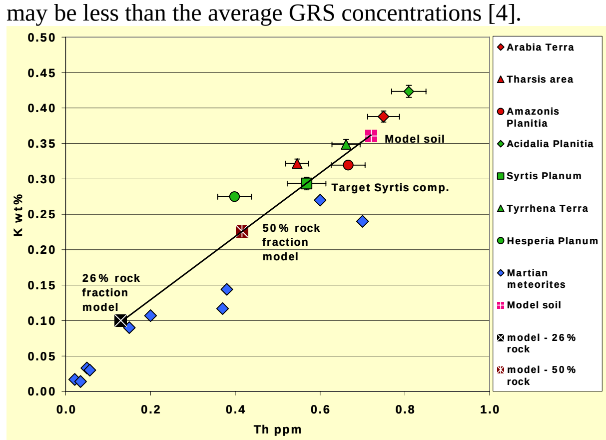
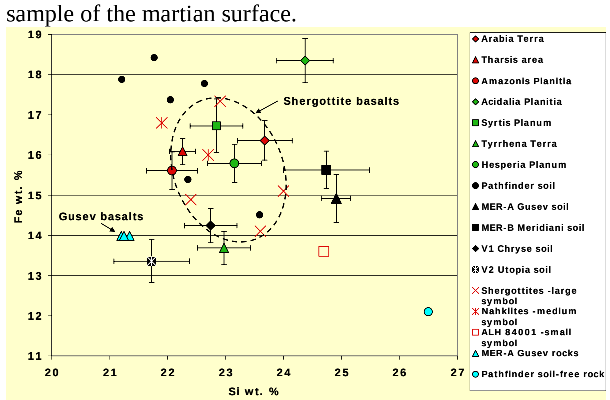


Fig. 4. The Fe and Si abundances in the areas studied are plotted with normalization to a volatile-free (H_2O, SO_3, Cl) composition. The data for the GRS areas and the landing sites have a larger spread compared to the martian meteorite data, suggesting that the meteorites are not a comprehensive sample of the martian surface.



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