EVOLUTION OF THE MARTIAN CRUST: EVIDENCE FROM PRELIMINARY POTASSIUM AND THORIUM MEASUREMENTS BY MARS ODYSSEY GAMMA-RAY SPECTROMETER. G. Jeffrey Taylor[1], W. Boynton[2], D. Hamara[2], K. Kerry[2], D. Janes[2], J. Keller[2], W. Feldman[3], T. Prettyman[3], R. Reedy[4], J. Brückner[5], H. Wänke[5], L. Evans[6], R. Starr[7], S. Squyres[8], S. Karunatillake[8], O. Gasnault[9] and Odyssey GRS Team. [1]Hawaii Inst. of Geophys. and Planetology, 1680 East-West Rd., Honolulu, HI 96822 (gjtaylor@hawaii.edu). [2]Lunar and Planetary Lab, Univ. of Arizona, Tucson. [3]Los Alamos National Laboratory, Los Alamos, NM. [4]Inst. of Meteoritics, Univ. of New Mexico, Albuquerque, NM. [5]Max-Planck-Institü für Chemie, Mainz, Germany. [6]Computer Sciences Corp., Lanham, MD. [7]Dept. of Physics, Catholic Univ. of American, Washington, DC. [8]Center for Radiophysics and Space Research, Cornell Univ., Ithaca, NY. [9]Centre d'Etude Spatiale des Rayonnements, Toulouse, France

Introduction: Potassium and thorium are useful elements for determining the inventory of moderately volatile elements in planetary interiors and for deciphering the evolution of the crust and mantles of the planets. We report preliminary measurements by the Gamma-Ray Spectrometer (GRS) on Mars Odyssey of the K and Th concentrations on the Martian surface between 45 degrees south and 45 degrees north longitude, divided into 15x15 degree pixels. The data were corrected by procedures outlined in Boynton et al [1]. In addition, we normalized the K concentration to the composition of the Mars Pathfinder landing site, and we used the same normalization factor for Th. Results are shown in Figs. 1 and 2.

We use these data to make preliminary tests of three concepts: (1) The idea that the Martian crust contains geochemically-enriched and depleted regions, reflecting distinctive reservoirs in the mantle [e.g., 2-6]. (2) The concept that Mars is richer in moderately-volatile elements such as K, Mn, and P [5,7,8] compared to Earth. (3) The effect of surface alteration processes and the composition of the pervasive dust on Mars. Although preliminary, our data show the great promise of having a global data set of geochemically-diagnostic elements.

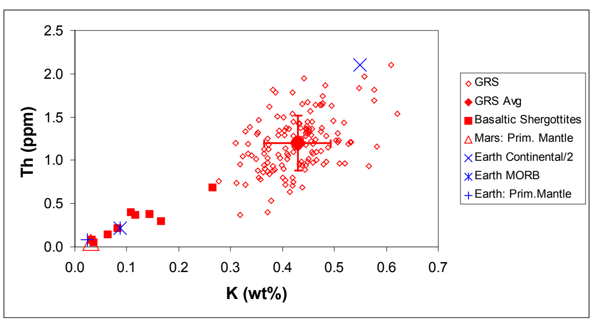

Fig. 1. Preliminary data for Th vs. K for 15x15 degree pixels in equatorial (45 south to 45 north) zone of Mars. Error bars are 1-sigma of the mean of the population, not counting statistics. Data Sources: basaltic shergottites (literature); Primitive Mars mantle [7]; Earth crust and MORB [9]; Primitive Earth mantle [10]. Vaules of Earth continental crust have been divided by 2.

Enriched and Depleted Crustal Components: Global Th and K concentrations correlate reasonably well (Fig. 1), giving a roughly constant K/Th ratio (Fig. 2). The measurement uncertainty for each point (1-sigma) is slightly less than 10% (relative) for K and about 40% for Th. As more spectra are collected these values will improve, allowing us to assess the extent to which the scatter is caused by variations in K/Th rather than measurement uncertainty.

K and Th concentrations are substantially higher than those in basaltic Martian meteorites (Fig. 1). K is also higher in rocks at the Pathfinder site than in Martian meteorites [5]. This suggests that there is a larger variety of lithologies on Mars than represented among the meteorites. Most of the surface may be composed of rocks enriched in trace lithophile elements, as has been inferred from rare-earth elements (REE) abundances and Nd isotopic compositions of shergottites. For example, Norman [2,3] concluded that shergottites formed from magmas that originated by partial melting of depleted mantle sources (giving them a characteristic REE pattern depleted in the light REE) and that subsequently reacted with a crustal component enriched in light REE. The enriched component appears to have formed early in the history of Mars [4,5,8]. We suspect that the high K and Th measured by the GRS (if confirmed by additional data and refined calibration) compared to Martian meteorites reflects the presence and high abundance of enriched crust. The apparent small quantity of regions with concentrations like those in Martian meteorites is consistent with the rarity of SNC-like spectra obtained by the Thermal Emission Spectrometer on Mars Global Surveyor [11]. The high concentrations of K and Th in the Martian crust, especially if the crust formed early in Martian history [4], places constraints on the extent of melting after crust formation [12]. The high K and Th may also suggest the presence of differentiated igneous rocks such as andesite.

Martian Bulk Composition: The K/Th ratio of the Martian surface is consistent with that in basaltic shergottites (Fig. 2). It is higher (3800 vs. 3000) than in the bulk silicate Earth [10] and the average continental crust, consistent with the idea that Mars is somewhat enriched in moderately-volatile elements than Earth. Wänke and Dreibus [7] used element correlations such as K/La to deduce the composition of Mars from the compositions of Martian meteorites. Their composition contains 0.0305 wt% K and 0.056 ppm Th, giving K/Th of 5450 in bulk silicate Mars. The extent to which Mars is enriched in K compared to refractory elements awaits improved counting statistics for our data and an improved understanding of how igneous and aqueous processes affect the behavior of K and Th on Mars. Nevertheless, Martian meteorite data clearly show that the Martian mantle was enriched in Mn and P compared to Earth [7,8]. This fundamental difference between Earth and Mars is consistent with the idea that the terrestrial planets formed from relatively narrow accretion zones [13-16]. We hope to more rigorously use K and Th (and eventually U) to place limits on the composition of Mars.

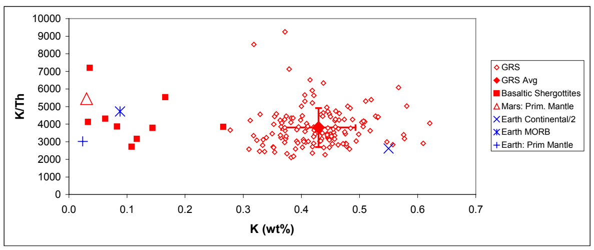

Fig. 2. K/Th ratios for 15x15 degree pixels in equatorial (45 south to 45 north) zone of Mars. Data sources given in Fig. 1. Vaules of Earth continental crust have been divided by 2.

Surface Alteration Processes: K and Th behave fairly coherently during igneous processing, although they do vary among major groups of igneous rocks on Earth. Nevertheless, their geochemical behavior during melting and fractional crystallization are very similar compared to their behavior during aqueous processing. For example, during weathering of basalt on Earth, Th is resistant to transport while K is very mobile [17]. The elements occur in different phases (e.g., K in residual igneous glass and feldspar, Th in phosphates), so their behavior during low- and high-T aqueous reactions can be drastically different. Given this, the presence of a strongly altered component rich in Mg, S, and Cl on the surface of Mars [5,18-20], and evidence that water sculpted the Martian surface, one might expect that any K-Th correlation would have been erased. Perhaps some of the scatter in Figs. 1 and 2 is caused by differing amounts of igneous rock mixed with a range of K/Th in alteration products. It seems more likely, however, that the observed correlation between K and Th indicates that the major altered component on the surface of Mars (the ubiquitous dust) contains only small amounts of K and Th compared to their abundance in primary igneous rocks. This is consistent with models based on Viking and Pathfinder soil and rock compositions that depict the Martian surface as being composed of basaltic and possible andesitic rock mixed with a salt component rich in Mg, S, and Cl [18-20]. It is also consistent with the correlation between K and Th concentrations and rock abundance [21], which implies that the dust is low in K and Th.

Conclusions: Although the GRS data for K and Th are only preliminary, we propose the following tentative conclusions. (1) The surface materials on Mars indicate that K and Th are higher than in typical Martian meteorites, consistent with suggestions that much of the crust formed early from undepleted Martian mantle. (2) K and Th are correlated. (3) The K/Th ratio is higher than on Earth, consistent with suggestions that Mars is richer in moderately-volatile elements. (4) The compositional differences between Earth and Mars favors accretion of the terrestrial planets from relatively narrow feeding zones. (5) The alteration (or salt) component on the surface of Mars does not appear to have been rich enough in either K or Th to affect the general, presumably igneous, K-Th correlation.

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