GAMMA-RAY SPECTROMETER ELEMENTAL ABUNDANCE CORRELATIONS WITH MARTIAN SURFACE AGE: IMPLICATIONS FOR MARTIAN CRUSTAL EVOLUTION.

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Introduction: The 2001 Mars Odyssey orbiter began primary mapping in February 2002 and continues its extended mission to this day. The Gamma-Ray Spectrometer (GRS) instrument suite has determined statistically reliable elemental abundance maps for H, Si, Fe, Cl, K, and Th [1]. The GRS Science Team continues to investigate abundance variations across different geographic regions (high topography vs. low topography, northern plains vs. southern highlands, etc.) and geologic provinces, as well as correlations between measured elements and element ratios. Here, we examine and report initial results of correlations between element abundances and the apparent surface age of the Martian crust as determined by USGS geologic mapping and crater count statistics [2]. Secular changes in element abundances as recorded in age-specific provinces may reveal information about crustal and planetary formation and evolution.

Data Sources. Comparisons were made between a digitized 1ºx1º global age map produced from existing, public geologic maps of the Martian surface [2]. Five age categories were assigned: Noachian; Hesperian; Amazonian; and 2 intermediate age groups spanning across the primary epochs [Figure 1]. The GRS data are binned into 5ºx5º cells and smoothed with a 10º radius filter to eliminate noise. A H-mask, as detailed in [1], has been applied to H, Fe, Si and Cl maps to eliminate regions with high-ice content. Average elemental abundances were determined for entire epochs, summed over the planet and specific smaller coherent regions of predominantly the same age. Surface age data were also reaveraged into 5ºx5º cells and binned according to dominant age epoch.

Sources of Uncertainty. The GRS instrument samples only the upper-most portion of the Martian surface. Penetration depth can vary from 10-50 cm depending on the density of the underlying substrate [1]. It remains to be determined to what degree this uppermost portion of the surface is representative of the bulk Martian upper crust. However, GRS elemental abundances for regions encompassing the MER landing sites agree well with average soil compositions determined by the rovers' APXS instruments [3, 4]. GRS also has an inherently low resolution and cannot discern small, detailed features. However, this is not a factor for this study as we examine the average abundances for areally large regions.

Apparent surface ages were determined in past studies using statistically determined crater count isochrons [2, 5, 6]. Absolute surface ages have considerable uncertainties. These include: the statistical effects of secondary craters produced by ejecta from large, primary impacts; the degree of crater preservation in an active weathering environment; and the recent discovery of "ghost" craters, particularly in the Northern Plains, that have led to re-evaluations of surface age [7, 8]. However, relative ages between geologic provinces are likely robust.

Initial Results: K and Th show a decrease in abundance with decreasing apparent surface age [Figure 2a,b]. K can be mobilized by aqueous processes. Also, while Th is generally immobile in terrestrial

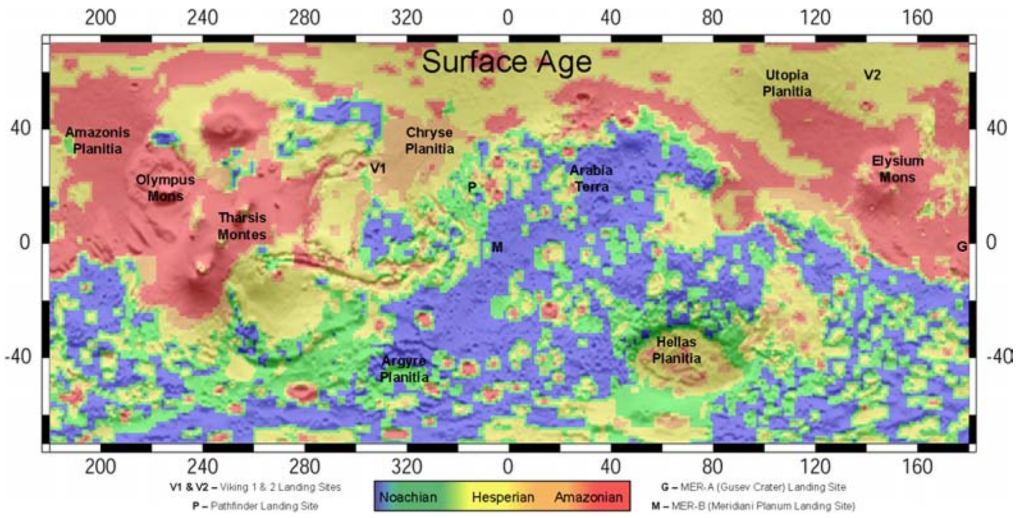

Figure 1: Apparent surface age determined from the USGS Martian Geologic map series [2] and major geologic features at 1ºx1º resolution. Five age categories have been assigned: Noachian; Hesperian; Amazonian; and two intermediate age groups.

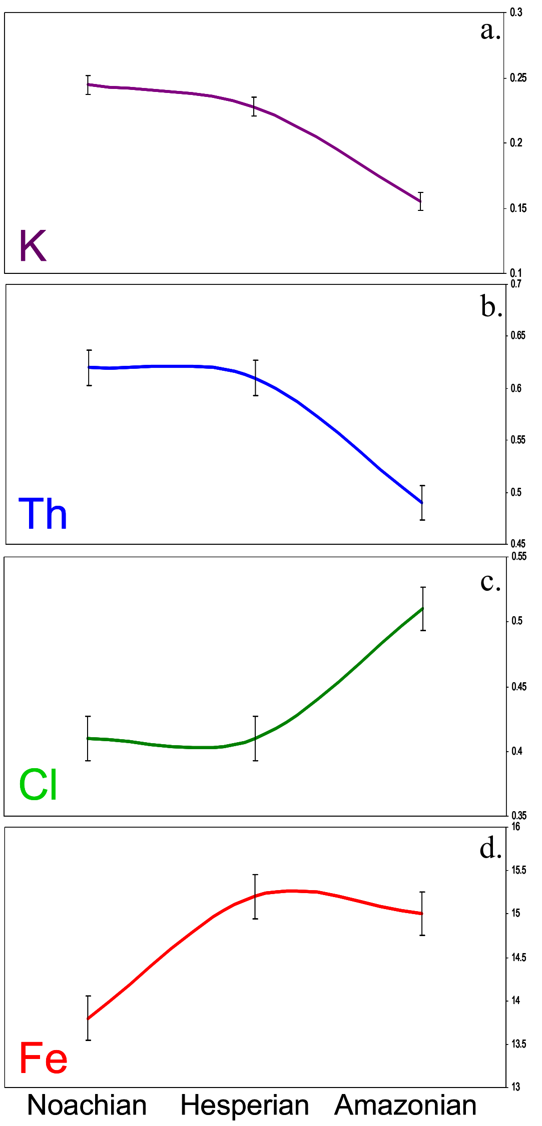

Figure 2: GRS determined element abundances by age epoch. GRS data is binned into 5°x5° cells and smoothed with a 10° radius filter.

aqueous systems, it has been suggested that enhanced mobility may be allowed in a highly-acidic Martian environment [9-11]. Consequently, some variation in K and Th could be explained by surface weathering and transport. However, the correlation between both K and Th with surface age suggests an igneous origin for the variation. Earlier terrains derived from a relatively undepleted mantle would show an enrichment in K and Th compared to younger terrains produced by resurfacing from a more evolved relatively depleted mantle source.

Both Cl and Fe show an increase in average abundance with decreasing apparent surface age [Figure 2c,d]. Cl is clearly mobilized through aqueous processes [12]. A positive correlation with decreasing surface age could be the result of broad-scale aqueous deposition into younger terrains; deposition from volcanic activity; or, more-likely, some combination of both. In Martian low-pH environments, Fe is also highly mobile [10, 11]. However, it is unclear from just this correlation whether this is a result of a secular change in igneous composition or aqueous surface alteration or both. Additional datasets will be examined to attempt to acertain which of these processes is the dominant cause of the variation.

There are no statistically significant correlations between surfaces age and Si and H element abundances. Although GRS has determined some geographic variations in Si abundance, the full range over which Si varies is relatively small and a correlation may be difficult to discern. Among other factors, H (in the form of water ice or hydrated mineral phases) has likely been transferred to different regions of the planet by a variable climate caused by changes in planetary obliquity. As obliquity varies on a timescale shorter than the age epochs defined for this study, a H vesus surface age correlation is not expected.

While the K/Th ratio determined by GRS varies across the Martian surface, the variance is largely a function of changes in Th abundance. As both K and Th decrease with increasing surface age, a statistically reliable correlation between the K/Th ratio and surface age is not immediately apparent. Changes in the Fe/Si ratio are governed primarily by variance in Fe content as Si is relatively constant across the Martian surface. Due to the inherent uncertainties, the Fe/Si ratio appears insensitive to surface age; however, additional datasets will be examined and cross-correlated.

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