REGIONAL MARTIAN CRUSTAL HEAT FLOW FROM MARS ODYSSEY GAMMA-RAY SPECTROMETRY. B. C. Hahn[1] and S. M. McLennan[2], [1]Department of Earth and Planetary Sciences, University of Tennessee, Knoxville, TN 37996 (hahnbrian@hotmail.com), [2]Department of Geosciences, Stony Brook University, Stony Brook, NY 11794-2100 (smclennan@notes.cc.sunysb.edu).

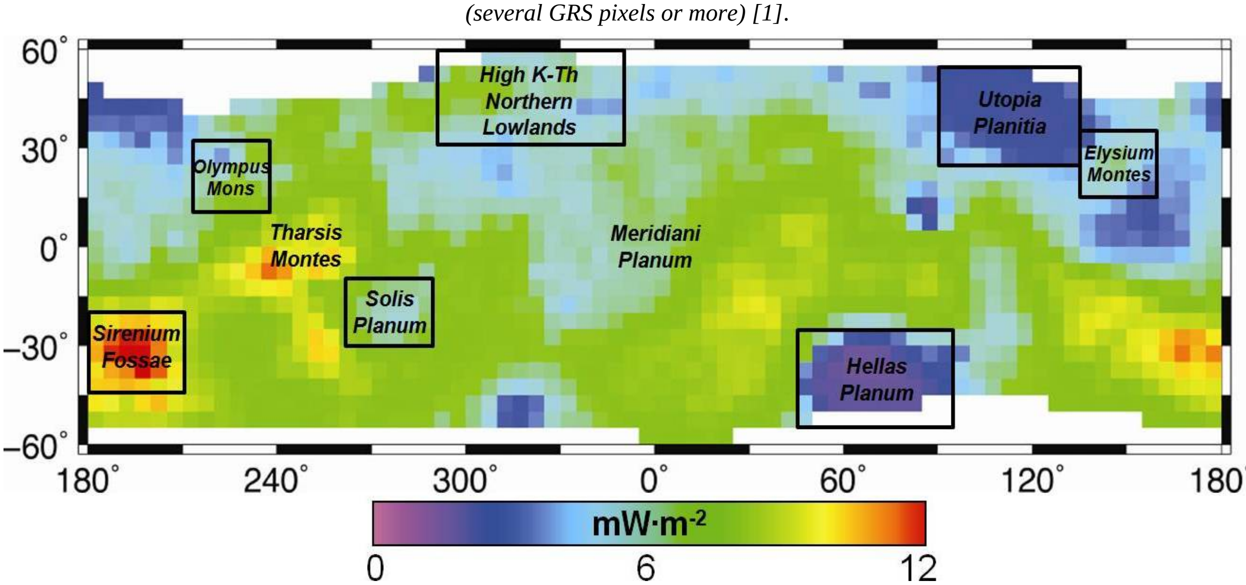
Introduction: The incompatible, heat producing elements (K, Th, and U) are the primary sources of radiogenic heat in the martian crust and all three can be measured in the upper few decimeters of the martian surface from orbit by remote sensing, with K and Th mapped in detail. Using elemental abundances measured by the Gamma-Ray Spectrometer (GRS) instrument suite onboard the 2001 Mars Odyssey spacecraft [*1*], *Hahn and McLennan (2008)* calculated and mapped the global distribution of the crustal component of martian surface heat production and crustal heat flow [*2*]. Evident from these maps are specific regions of anomalous heat flow, showing significant geographic variation in the crustal thermal reservoir. We explore in greater depth these specific regions of anomalous heat flow as well as report on the present crustal heat flow and heat flow at the time of formation for certain geologically important terrains (**Figure 1**, *below;* **Table 1**, *right*).

Regional Crustal Heat Flow: A number of previous studies have attempted to constrain martian heat flow, primarily through geophysical methods [*3-6*]. Most of these previous studies were primarily interested in mantle heat flow as it relates to mantle convection or surface deformation. These studies estimated total heat flow; combining both mantle and crustal components of heat flow due to the inability to distinguish between the two thermal reservoirs using existing methods. However, as the radiogenic heat-producing isotopes are preferentially sequestered into planetary crusts during differentiation, the crustal component of heat flow is especially important [*7*].

Table 1: *List of geologic features and regions, average radiogenic concentrations (U concentrations are calculated assuming Th/U=3.8), and present day average crustal heat flow.*

Geologic Feature/Region	Average K Concentration (ppm)	Average Th Concentration (ppm)	Crustal Heat Flow ($mW \cdot m^{-2}$)
Olympus Mons	3340	0.67	8.9
Elysium Mons	2900	0.53	5.9
Tharsis Montes	3300-3700	0.55-0.73	8.4 (6.3-10.0)
Solis Planum	2320	0.37	5.0
Meridiani Planum	3790	0.66	5.6
High K-Th Northern Plains	6130	1.02	5.4
Sirenum Fossae	4340	0.98	11.9
Hellas Basin	2830	0.34	0.9
Utopia Planitia	4000	0.71	2.2
Northern Lowlands	4250	0.71	4.5
Southern Highlands	3990	0.70	8.8
Global Average	*3980*	*0.70*	*6.43*

Figure 1: *Crustal heat flow for low- and mid-latitudes based on 5x5 smoothed re-binned global GRS elemental abundances adapted from* Hahn and McLennan (2008). *Also indicated are the specific geological regions and features detailed in this study. Because of the areally large GRS footprint, only relatively large regions or features can be measured with statistical reliability (several GRS pixels or more) [1].*



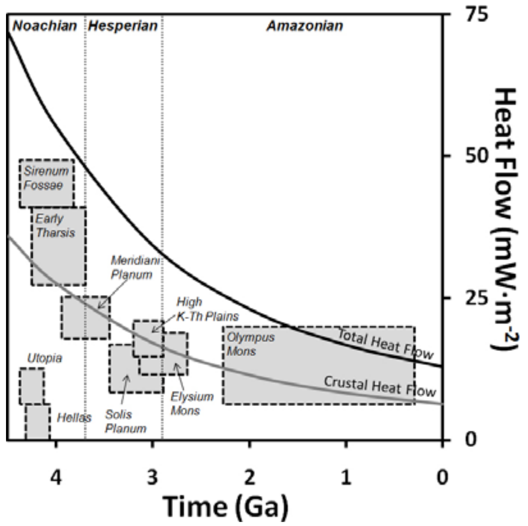


Figure 2: *Heat flow modeled through Martian geologic history. The gray curve indicates the crustal component of heat flow from this study. Gray boxes indicate the formation age and crustal component of heat flow for each geologic region or formation calculated at the age of formation. Many geologic regions fit reasonably well, with older features showing higher crustal heat flow at formation. However, some features, such as the Hellas and Utopia impact crater basins are clearly anomalous. Total radiogenic heat flow (black line) is calculated assuming the crustal component represents 50% of total heat flow due to the preferential sequestering of 50% of radiogenic elements into the crust [*9,10*]. Note that additional sources of heat, such as planetary secular cooling and core crystallization, are neglected. Age boundaries are from* Hartmann (2005) *and* Head et al. (2001) *[*11,12*]. After* Montesi and Zuber (2003) *[3].*

Using GRS radiogenic abundances and the crustal thickness model of *Neumann et al. (2004)* [*8*], we calculate the crustal component of radiogenic heat flow for a number of large regions (**Table 1**), specifically, volcanic provinces, chemically anomalous regions, and large impact basins.

Heat Flow at Formation: An important factor for any geologic region is the heat flow conditions that contribute to thermal behavior at the time of formation. Given the measured present-day abundances of heat producing elements and an estimated age of formation for a geologic region, it is possible to calculate the crustal component of heat flow at the time of formation using the respective half-lives of the heat contributing isotopes (**Figure 2,** *above*). Apparent surface ages for geologic features on Mars are estimated using crater count statistics and cross-cutting relationships; however, formation ages are only loosely constrained with high uncertainties. Generally, our estimates agree well with previous, geophysical studies (although our method does not provide reliable values for impact basins due to the destruction of the underlying crust at the time of formation) [*3*,*4*].

Upper/Lower Crust vs. Homogeneous Crust: One of the lingering unanswered questions from the GRS dataset is to what degree the elemental abundances measured in the upper tens of centimeters of the surface correctly reflect the underlying crust (**Figure 3**, *below*). The crustal heat flow model presented here assumes that lacking terrestrial style intracrustal differentiation, the surface abundances for the radiogenic elements are near-constant vertically through the total thickness of the martian crust. This interpretation also implies that approximately 50% or more of the total planetary budget of K, Th, and U have been sequestered into the crust [*7*,*9*,*10*].

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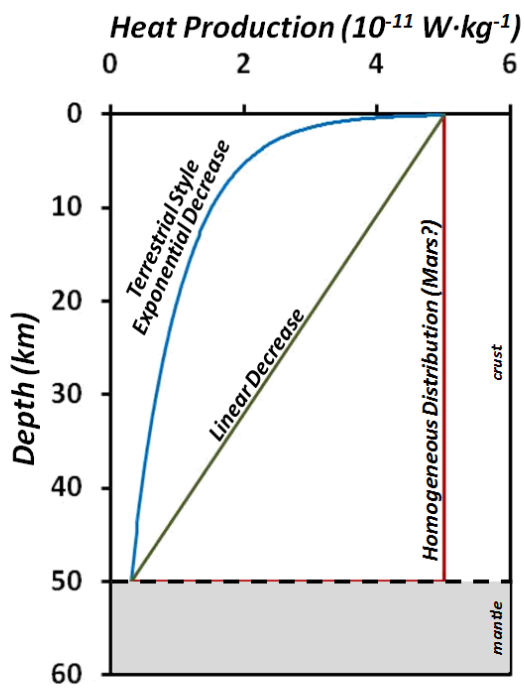

Figure 3: *Radiogenic heat production vs. depth. On Earth, radiogenic abundances decrease approximately exponentially with depth do to processes that fractionate the crust [*11*]. These intracrustal differentiation processes are unlikely to be active on Mars to any significant degree, leading to a more vertically homogeneous distribution. Also plotted is a possible intermediate, linearly-decreasing distribution.*