INSIGHT: CONSTRAINING THE MARTIAN HEAT FLOW FROM A SINGLE MEASUREMENT.. M. Grott, T. Spohn, *German Aerospace Center, Berlin, Germany (matthias.grott@dlr.de)*, S.E. Smrekar, W.B. Banerdt, T.L. Hudson, *Jet Propulsion Laboratory, California Institute of Technology, Pasadena, USA*, P. Morgan, *Colorado Geological Survey, Denver, USA*, T.v. Zoest, *German Aerospace Center, Bremen, Germany*, G.Kargl, *Space Research Institute, Austrian Academy of Sciences, Graz, Austria*, M.A. Wieczorek, *Institut de Physique du Globe de Paris, France*, and the HP^3 Team.

Introduction: The thermal state of the Earth has been constrained from more than twenty thousand measurements [1], and heat flow was found to vary widely with tectonic setting and geological province. Terrestrial heat flow averages around 65 mW m^{-2} on the continents and 101 mW m^{-2} in the oceans [1], and continental heat flow variations were found to be primarily caused by a heterogeneous distribution of heat producing elements in crustal rocks [2].

As a comparison, the thermal state of the Moon has been constrained from only two heat flow measurements conducted during the Apollo 15 and 17 missions [3], and values of 21 and 14 mW m^{-2} have been obtained. Lacking plate tectonics, heat flow on the Moon varies less with geological location, but the proximity of the Apollo 15 and 17 landing sites to the Procellarum KREEP geochemical anomaly complicates the interpretation of the measured heat flow values. Models indicate a background heat flow close to 11 mW m^{-1} [4,5], and a bulk lunar uranium content of 20 ppb has been derived.

The InSight mission will land a geophysical station in the Elysium region of Mars. The long-lived station consists of a radio science experiment, a seismometer, and a heat flow probe, and will conduct the first planetary heat flow measurement since Apollo. Here we will discuss what we can expect to learn from a heat flow investigation using a single station.

Martian Heat Flow: Heat flow on Mars is expected to be relatively homogeneous, and data from the gamma ray spectrometer on board the Mars Odyssey spacecraft indicate that a geochemical enrichment of heat producing elements similar to the Procellarum KREEP terrain is absent on Mars [6]. Surface Th abundances vary only between 0.2 and 1 ppm, as compared to 0.1 and 12 ppm on the Moon, and surface heat flow variations on Mars are expected to be primarily caused by crustal thickness variations.

Surface heat flow has been modeled [7] assuming a bulk compositions corresponding to the compositional model by Wänke and Dreibus (WD), observed surface abundances of heat producing elements [6], and crustal thicknesses derived from gravity and topography data [8]. Results of these calculations are shown in Fig. 1, and these models can be used to obtain a first order estimate of the overall planetary heat loss. In this context, the Elysium measurement will provide an important anchor point to estimate average planetary heat flow, and additional measurements from future missions can then be used to refine these estimates.

Along with the Tharsis rise [9], the Elysium volcanic province exhibits some of the youngest volcanism on the Planet [10,11], and heat flow in this region can place important constraints on the feasibility of present day volcanism on Mars. Therefore, apart from providing the baseline measurement to estimate global heat loss, the Elysium measurement will shed some light on the working of recent volcanism.

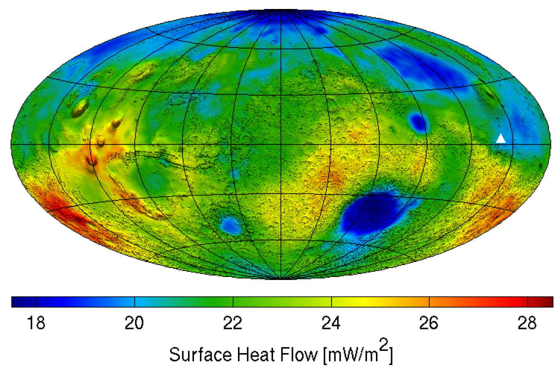

Figure 1: Model for the present day surface heat flow on Mars. The InSight landing site is indicated by the white triangle.

Bulk Composition: Planetary heat flow is intimately connected to the bulk abundance of heat producing elements in the planetary interior, and the WD compositional model, which is derived from element correlations observed in the SNC meteorites [12], is currently the most generally accepted. Radioactive elements in the WD model generate heat close to the chondritic rate, and observed surface K/Th ratios are consistent with model predictions [6].

Planetary heat flow reflects contributions from heat produced by radiogenic elements and the loss of heat via secular cooling. The ratio of radioactively produced heat to total planetary heat loss can be expressed in terms of the Urey ratio Ur, which can be estimated using thermal evolution models. Results of such calculations using the model by [13] are shown in Fig. 2, where different mantle viscosities and initial upper mantle temperatures have been assumed. While the evolution takes different paths during the early stages, present day Ur is close to 0.7 irrespective of the initial conditions. Note that Ur for Mars is significantly larger than its value estimated for the Earth, which is close to 0.35 [14] due to the efficient mantle cooling caused by plate tectonics.

The small uncertainties associated with Ur on Mars enable a comparison between measured heat flow and compositional models, and given core size and crustal thickness from the InSight seismological investigation, models such as that given in Fig. 1 can be considerably refined. Extrapolation of the single heat flow measurement using these models will yield an estimate for the total planetary heat loss, and given abundance ratios for K/Th and Th/U from observations and cosmochemical models, a model for the Martian bulk composition can be derived.

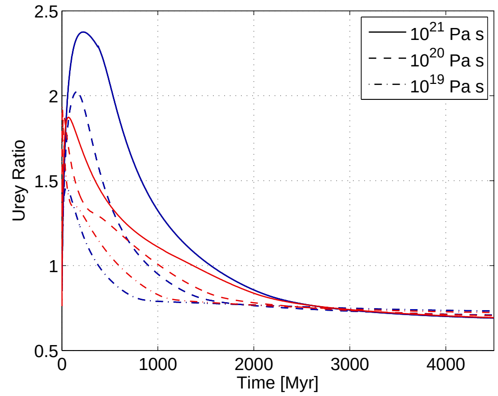

Figure 2: Urey ratio as a function for three different mantle reference viscosities and two initial upper mantle temperatures of 1650 K (blue) and 1850 K (red).

The present thermal state of Mars has been constrained from lithospheric loading models and large elastic thicknesses [15] associated with low heat flows $<$15 mW m^{-2} [8] have been derived for the north polar region. As a comparison, average surface heat flows derived from the WD compositional model are 22 mW m^{-2}, and it has been speculated that Mars might be subchondritic with respect to its bulk content of heat producing elements. Here, the Elysium heat flow measurement will contribute an independent test of the WD compositional model.

External Heat Flow Contributions: Apart from the heat flow from the deep interior, heat flow in the shallow subsurface can be influenced by external temperature perturbations arising from climatic changes associated with oscillations and chaotic jumps of the rotational axis. These occur on timescales of 10^5 and $5{\cdot}10^6$ yr, respectively [16], and additional seasonal changes associated with dust storms can also affect the subsurface temperature profile.

The influence of chaotic reorientations of the planet's spin axis on surface heat flow has been investigated and was found to be negligible at timescales $>10^6$ yr [17]. Furthermore, the influence of climatic changes has been investigated and was found to be smallest at near equatorial landing sites. In the Elysium region, heat flow perturbations are expected to be $>$3 mW m^{-2} [18], thus contributing a maximum of 10% to the expected heat flow.

Interannual variability as a source of error has been investigated by [16], but surface albedo changes are usually erased within a few hundred sol [19]. For a near equatorial landing site surface heat flow is affected by less than 2 mW m^{-2} [8], such that the heat flow measured by InSight can be confidently viewed as to originate from the planetary interior. Further, albedo could be monitored with HiRISE or CTX cameras on Mars Reconnaissance Orbiter, such that the effects of albedo changes can be modeled and removed from the data.

Conclusions: The heat flow investigation conducted by the InSight mission will provide an important baseline measurement to constrain the average heat flow from the Martian interior. The near equatorial landing site minimizes external contributions to the surface heat flow and is ideally suited to study the intrinsic heat flow. Together with a determination of the core size and crustal thickness from the InSight seismic experiment, heat flow in the Elysium region will place valuable constraints on the bulk composition of Mars and provide an independent test for the Wänke and Dreibus compositional model [12]. Furthermore, being located close to a likely still active volcanic province, the InSight measurements will place important constraints on the feasibility of present day volcanism on the planet.

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