CONSTRAINING THE AMOUNT OF RADIOGENIC ELEMENTS IN THE INTERIOR OF MARS FROM THE HP³ HEAT FLOW MEASUREMENT. A. C. Plesa[1], D. Breuer[1], M. Grott[1] and N. Tosi[1] (DLR, Institute of Planetary Research, Rutherfordstr. 2, 12489 Berlin, ana.plesa@dlr.de).

Introduction: The InSight mission (**In**terior Exploration using **S**eismic **I**nvestigations, **G**eodesy and **H**eat **T**ransport) to be launched in 2016 will study Mars' deep interior and improve our knowledge of the interior structure and thermal evolution of the planet. InSight will carry a seismometer (SEIS) and heat flow probe (HP³) to the martian surface, and address questions related to the size, physical state, and composition of the core and mantle, the thickness of the crust, and the thermal state of the martian interior.

Heat flow F_s measured at the planetary surface depends on the amount of heat producing elements (HPE) present in the interior, and offers a measurable quantity which can help to constrain the planetary heat budget. If the Urey ratio Ur - the ratio between internal heat production and surface heat loss - is known, the heat production rate H (in pW/kg) in the interior can be determined from

$$H = {F_s A}/{Ur V_{sil} \rho_{sil}} \quad (1)$$

where A is the surface area of the planet, V_{sil} is the volume of the silicate fraction, and ρ_{sil} the average silicate density.

Models and methods: We have calculated the Urey ratio of Mars using the mantle convection code Gaia in 2D cylindrical and 3D spherical geometry [1, 2], as well as 1D parameterized models [3]. We have run numerical simulations of increasing complexity and compared the obtained present-day Urey ratio for a set of different models/parameters. Our models use cooling boundary conditions at the core-mantle boundary (CMB) and self-consistently treat the decay of radioactive elements.

We vary the initial amount of HPE according to different HPE models suggested for the interior of Mars [4,5,6,7]. Additionally, we use various viscosity formulations (e.g. temperature-, temperature- and depth-dependent viscosity, viscosity jump in the mid mantle), we vary the size of the core between 1500-1700 km, and we consider models with and without phase transitions in the mantle. Another set of models considers different partitioning of HPE between mantle and crust, where the crustal thickness is kept constant. Different initial conditions (e.g., initial temperatures ranging from 1650-1950 K, initial thermal boundary layer thickness between 50 and 300 km) and reference viscosities between 10^{20} - 10^{23} Pa s have also been tested.

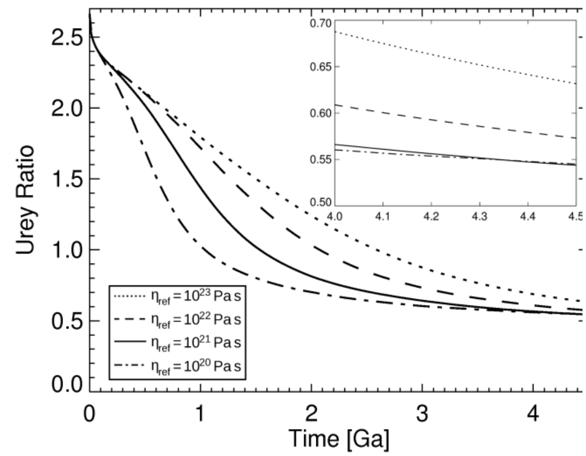

Fig. 1: Urey ratio as function of time for various reference viscosities assuming a Wänke et al. chemical composition [4].

Results: Our simulations show that for a one-plate planet like Mars the Urey ratio is mainly sensitive to the efficiency of mantle cooling, i.e., the mantle viscosity, and the mean half-life of long lived radiogenic isotopes. This is a result of the thermostat effect, which is caused by the temperature-dependence of viscosity and results in similar present-day temperatures for different initial temperature distributions: For higher initial temperatures, viscosity is reduced, resulting in enhanced cooling, whereas lower initial temperatures result in larger viscosities and slow cooling. Therefore, ultimately both sets of initial conditions will result in similar present day temperature structures, provided the time for temperature adjustment is long enough.

As shown in Fig. 1, the thermostat effect is efficient for reference viscosities smaller than 10^{23} Pa s at a reference temperature of 1600 K, and present day Urey ratios converge for viscosities smaller than 10^{22} Pas. Given that models of the thermo-chemical evolution of Mars generally indicate reference viscosities below 10^{21} Pa s [e.g., 3,8], the martian Urey ratio is likely only a function of the Thorium concentration in the planetary interior.

This is illustrated in Fig. 2, where the Urey ratio is shown as a function of time for different compositional models (top), as well as the abundance of heat producing elements (bottom). Only the model by Morgan and Anders [6], which has about twice the Thorium concentration of the other models considered, differs significantly from the average value of Ur = 0.55. Therefore, for a given Th concentration, the uncertainty in the present-day Urey ratio is expected to be less than 10%.

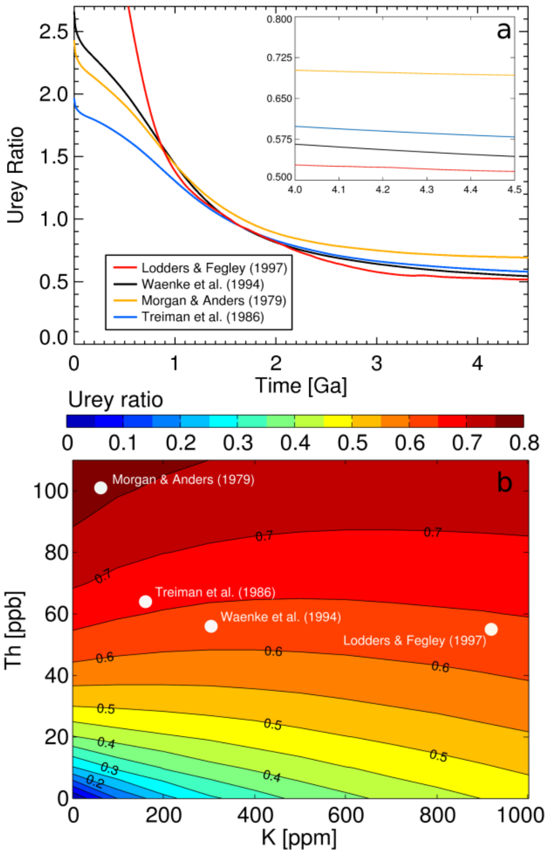

Fig. 2: Top: Urey ratio as a function of time for different compositional models [4,5,6,7]. Bottom: Urey ratio as a function of Th and K content.

The bottom panel of Fig. 2 shows the Urey ratio as a function of Th and K concentration in the planetary interior, and a fixed ratio between Th and U abundance of 3.5 has been assumed. Concentrations for martian compositional models are also shown for reference. Results only weekly depend on the abundance of the relatively short-lived K, which mainly influences the early evolution of the planet. However, the dependence on Th concentration is quite pronounced.

These results have been confirmed for models using different core sizes, models with phase transitions, different viscosity formulations, and partitioning of HPE between mantle and crust. Some of these results are shown in Fig. 3, and all models considered result in Urey ratios of 0.58 ± 0.04, corresponding to an uncertainty of less than 10%. Note that 2D models result in slightly smaller values for Ur than fully 3D models.

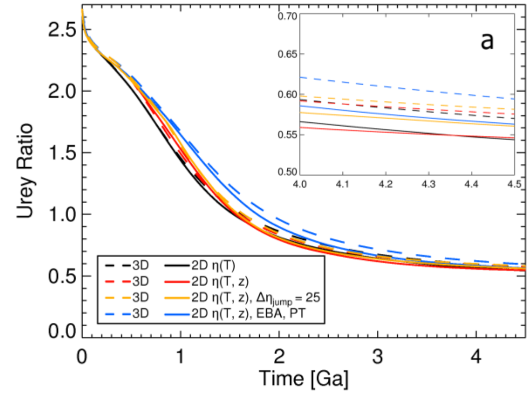

Fig. 3: Urey ratio as a function of time for 2D (solid) and 3D (dashed) models including temperature-dependent viscosity (black), temperature- and depth-dependent viscosity (red) including a viscosity jump in the mid-mantle (yellow), and with extended Boussinesq approximation and phase-transitions (blue).

Conclusions: The Urey ratio of Mars was found to be close to 0.58 for a variety of models, and to only weekly depend on the assumed initial conditions. Instead, the Urey ratio is a function of the bulk abundance of long-lived radioisotopes like Thorium. Surface radiogenic abundances have been determined from gamma ray spectroscopy [9], and results are best consistent with the Wänke et al. compositional model [4]. Assuming the bulk Th abundance to be known, our simulations indicate that the Urey ratio of Mars can be computed with an uncertainty of likely less than 15%.

Together with an estimate of the global heat loss derived from the upcoming heat flow measurement, the heat production rate H and thus bulk abundance of heat producing elements in the martian interior can be estimated. If global heat loss can be estimated with an uncertainty of 20%, and if the InSight seismological investigation can determine the silicate mass fraction of the planet to within 20%, error propagation (Eq. 1) yields an uncertainty of 35% for the heat production rate. Furthermore, the InSight measurement should allow us to distinguish between different proposed compositional models.

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