PRESENT-DAY MARS’ SEISMICITY PREDICTED FROM 3-D THERMAL EVOLUTION MODELS OF INTERIOR DYNAMICS A. C. Plesa1, M. Knapmeyer1, M. Golombek2, D. Breuer1, M. Grott1, N. Tosi1, 3
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Introduction: The InSight (Interior exploration using Seismic Investigations, Geodesy and Heat Transport) mission, to be launched in 2018, will carry a seismometer and a heat flow probe to the surface of Mars as well as a precision tracking instrument. This Discovery-class mission will perform a comprehensive geophysical investigation of the planet and provide an important baseline to constrain the present-day interior structure and heat budget of the planet, and, in turn, offer constraints on the thermal and chemical evolution of its interior [1].

The InSight lander will perform the measurements at a single designated location in the Elysium Planitia region on Mars [2]. Nevertheless, numerical simulations of planetary interiors will greatly help to interpret the data in a global context. In this study we use a series of numerical models of thermal evolution in a 3-D spherical geometry to assess the magnitude and distribution of Mars present-day seismicity.

Model: We use the models already presented by [3] and perform additional simulations to collect a significant number of cases for which we can carry out some statistical analysis. In all models we assume a Newtonian mantle rheology and an infinite Prandtl number, and consider the extended Boussinesq approximation (EBA). Our models assume a crust whose thickness does not change with time but varies laterally as inferred from gravity and topography data. The crust is enriched in radiogenic heat sources according to the surface abundances inferred from gamma-ray measurements. We test several parameters by varying the mantle reference viscosity as well as the depth-dependence of the viscosity, considering constant and variable thermal expansivity, varying the crustal thermal conductivity, and the size of the core.

We use these thermal evolution models to compute the present-day cumulative seismic moment Mcum similar to [4]:

\[ M_{\text{cum}} = \eta \varepsilon V \mu \Delta t \]  

where \( \eta \) is the seismic efficiency varied between 0.5 and 1, \( \varepsilon \) is the rate of deformation computed from the thermal evolution model either taking into account the convective stresses (here \( \varepsilon \) is the second invariant of the strain rate tensor) in the seismogenic volume or the stresses produced by planetary contraction (here \( \varepsilon \) is related to the planetary radius change due to core and mantle heating or cooling). \( V \) is the seismogenic volume calculated based on the 1073 K mantle isotherm, \( \mu \) is the shear modulus varied between 30 and 70 GPa and \( \Delta t \) is the time interval set here to 1 year. We compute the cumulative seismic moment on a \( 3^\circ \times 3^\circ \) grid to filter out small scale structures since we are interested in features associated with large geologic regions such as the Tharsis and Elysium volcanic provinces, and Hellas basin.

In a previous study, [3] have shown that the structure and thickness of the crust plays an important role for the distribution and magnitude of the surface heat flow and the elastic lithosphere thickness. Here we introduce three categories of models and group our results according to the crustal thickness model used (Fig. 1).

Figure 1: Crustal thickness models used in our simulations: The model 2900_3100_DWTh2Ref1_rho which uses a 2900 kg/m\(^3\) crustal density for the southern highlands and 3100 kg/m\(^3\) for the northern lowlands (black line). The Neumann et al., [2004] model is the crustal thickness model of [5] which uses a uniform crustal density of 2900 kg/m\(^3\) (blue line), while the model 3200_1_DWTh2Ref1 [3] uses a uniform crustal density of 3200 kg/m\(^3\) (red line).

Results: In Fig. 2 we show the contributions calculated from the convective stresses and planetary contraction in panels a) and b), respectively, while panel c) shows their sum for representative cases using the crustal model of [5] (I, left column) and the 3200_1_DWTh2Ref1 model [3] (II, right column).

A different crustal structure and thickness leads to a different seismic moment distribution (Fig. 2). The crustal thickness model 3200_1_DWTh2Ref1 has a mean crustal thickness almost twice as high as the model of [5] and shows a more pronounced crustal thickness dichotomy. This leads to a long wavelength pattern of the distribution of seismic moment (Fig. 2, case II).
**Figure 2:** Distribution of the annual seismic moment release computed based on a) the convective stresses, b) stresses produced by mantle cooling and planetary contraction, c) the sum of a) and b). Case I (left panels) uses the crustal thickness model of [5] while case II (right panels) uses the 3200, J,DWTh2Ref1 model. The fault catalog from [4] (red and blue lines on each panel) is only shown for reference.

**Conclusions:** We have used the 1073 K isotherm to define the seismogenic lithosphere and hence our values represent an upper bound estimate, as smaller values would reduce the two contributions because of a smaller seismogenic volume available. Additionally, in a stagnant lid planet, convective stresses become smaller the shallower the seismogenic region and their contribution is negligible for an isotherm smaller than 800 K.

The annual seismic moment release obtained in this study lies between $10^{16}$ and $10^{19}$ Nm, similar to the values presented previously in [4, 6, 7]. Our models show similar but spatially anti-correlated seismic moments produced by convective stresses and stresses caused by mantle cooling and consequently a relatively homogeneous distribution of the sum of seismic moments. This is different from the study of [4], who used a mapping of tectonic surface faults to predict the spatial distribution of epicenters. Stresses associated with lithospheric flexure, that may impact the local distribution of seismic moment in the Tharsis region, have not been considered here.

InSight will help constrain the thickness of the seismogenic layer and thus the magnitude of the two seismic moment contributions presented here.