THE EFFECTS OF INTRUSIVE MAGMATISM ON THE MECHANICAL LITHOSPHERE THICKNESS OF VENUS. A.-C. Plesa[1] and D. Breuer[1], [1]Institute of Planetary Research, DLR (ana.plesa@dlr.de).

Introduction: On Venus, elastic lithosphere thickness estimates range between 0 and 100 km, with 20 km or less representing a best fit for more than the half of the planet [1]. Such small values might be indicative of a high heat flow if such areas are isostatically uncompensated [2]. Specifically, coronae, a class of volcano-tectonic features which have been associated with various stages of magmatic activity on Venus [3,4] show thin elastic lithosphere thicknesses [5] that are likely representative for present-day Venus [6]. Since the elastic thickness is an indicator of the thermal state of the lithosphere, as it describes its response to long-term geological loading, such low values would suggest a warm lithosphere that may indicate that enough heat is available today to produce partial melting in the interior of Venus.

In this work we investigate the thermal history of Venus using geodynamical models. We estimate the effects of melt intrusions on the thermal state of the lithosphere and compare our results with recent elastic lithosphere thickness estimates to provide implications for the present-day magmatic style on Venus.

Methods: We use the mantle convection code GAIA [7] in a 2D spherical annulus geometry to compute the thermal evolution of Venus. GAIA solves numerically the Navier-Stokes and heat transfer equations to obtain the spatial and temporal distribution of the temperature field in the interior Venus. We consider the decay of radioactive elements and core cooling, and assume a stagnant lid, although surface mobilization may occur due to the weakening of the stagnant lid by melt intrusions similar to [8].

Our models employ a temperature and depth dependent viscosity and thermal conductivity. For the depth dependence of the viscosity, we use a depth-dependent activation volume [9] while for the thermal conductivity we adopt the parametrization of Tosi et al. [10].

In our simulations we include the effects of intrusive magmatism. When melt is being generated in the interior by mantle plumes, it is instantaneously extracted and placed at the surface and in the lithosphere with a predefined ratio of extrusive to intrusive magmatism. On Earth, the ratio of extrusive to intrusive magmatism varies significantly depending on location [11]. In our models we systematically vary this ratio between purely extrusive and purely intrusive magmatism.

The depth of magmatic intrusions is poorly constrained, and therefore we vary this depth between ~45 km and ~135 km below the surface. The former value is representative for the base of the crust or lower crust, while the latter is suggesting that melt remains trapped deeper within the lithosphere.

We estimate the mechanical thickness of the lithosphere using a strength envelope formalism [e.g., 12], similar to [13, 14] and parameters relevant for an olivine rheology. The mechanical thickness is identified with a rheological boundary that is associated with ductile failure, given the bounding stress, below which the lithosphere loses its mechanical strength. The mechanical thickness is larger or at most equal to the elastic thickness, and for geological structures on Venus the mechanical thickness is suggested to be about 1.2 – 3.7 times larger than the effective elastic thickness [5]. Thus, the results provided in this work represent upper bound estimates for the elastic lithosphere thickness.

Results: We have tested the effects of the extrusive to intrusive ratio and the influence of the depth of intrusive magmatism on the mechanical lithosphere thickness.

In Fig. 1a we show the evolution of the mechanical lithosphere thickness considering a purely intrusive case, where all generated melt is being trapped at 45 km depth below the surface, a case where 20% of the produced melt reaches the surface, while 80% remains trapped at 45 km depth, and a case where the entire amount of melt generated in the interior is being placed at the surface (i.e., extrusive melt). The largest mechanical thickness (136 km average present-day value) is obtained for the purely extrusive case, where all melt reaches the surface and instantaneously cools to the surface temperature. This is justified by the fact that the cooling time of lava flows is significantly shorter than the time-step used in the global evolution model. The extruded melt leads to the downward advection of cold material that is efficiently cooling the lithosphere and, hence, producing a large mechanical thickness.

The thinnest mechanical thickness (43 km average present-day value) is obtained for the purely intrusive case, in which all produced melt is placed at 45 km depth. In this case, the subsurface temperature increases locally in the regions, where melt intrusions remain trapped, and, therefore, leads to a thinner lithosphere. The difference between the purely intrusive case and a case, where both intrusive and extrusive melt are

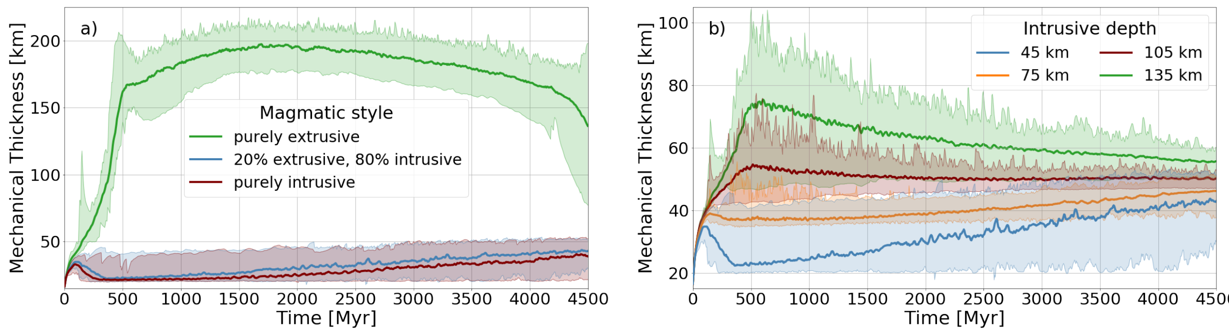

Figure 1: a) Evolution of the mechanical lithosphere thickness for various extrusive to intrusive ratios. The depth of intrusive melt was set to 45 km. b) Evolution of the mechanical lithosphere thickness for various intrusive depths. For all cases in panel b) 20% of the melt reaches the surface, while 80% remains intrusive. The solid lines show the average mechanical thickness, while the shaded areas present the mechanical thickness variations over the thermal history. For the mechanical thickness calculations, we used a dry olivine rheology, a bounding stress of 10 MPa [21], and a strain rate of 1e-17 s^{-1}, this value being representative for mantle convection time scales.

considered, are small due to the large fraction of intrusive melt in the latter.

The effect of the depth of intrusions on the mechanical lithosphere thickness is presented in Fig. 1b. For these models we assumed that 20% of the produced melt reaches the surface, while 80% remains intrusive. Shallow melt intrusions lead to a thin mechanical thickness with an average present-day value of 43 km and local values between 30 and 51 km. Conversely, deep intrusions (i.e., at ~135 km depth) lead to the thickest mechanical thickness of 56 km on average at present day and with local values ranging between 51 and 60 km.

The convergence of the mechanical lithosphere thicknesses to more similar values towards the present day indicates the decline in magmatic activity. The effect of extrusive melt is most pronounced for cases where the mechanical thickness is larger and decreases towards present day, while cases, where intrusive magmatism is dominant, show an increase of the mechanical thickness over time.

Conclusions and Outlook: In this study we investigate the effects of melt intrusions on the mechanical lithosphere thickness of Venus. A low amount of extrusive magmatism and a shallow intrusive depth are consistent with a thin mechanical lithosphere thickness and, hence, can be better reconciled with low elastic lithosphere thickness estimates available for Venus. Additionally, variations of the mechanical thickness are about a factor of 2 larger for intrusions that remain trapped deep in the lithosphere (~135 km depth) compared to intrusive depths located in the lower crust or at the base of the crust (~45 km depth).

In a future step, we will perform a detailed comparison between our mechanical thickness estimates and values obtained from lithospheric flexure modeling on Venus [e.g., 5]. Systematic variations of the extrusive to intrusive ratio, the depth of melt intrusions, the rheological parameters used in computing the mechanical thickness, various tectonic regimes (i.e., mobile, stagnant, and squishy lid [8]), as well as estimates of the efficiency of melt migration [15] can help us to place constraints on the magmatic style on Venus.

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