NEW CONSTRAINTS ON THE ELASTIC THICKNESS OF VENUS AND IMPLICATIONS FOR GEODYNAMIC EVOLUTION S. E. Smrekar, Jet Propulsion Laboratory/California Institute of Technology, Pasadena, CA, 91024 USA (ssmrekar@jpl.nasa.gov).

Introduction: Size, density and surface measurements of U and Th [1] all point to Venus having a similar interior thermal engine to drive surface geology. Earth loses most of its heat at present though plate tectonics. Venus does not support terrestrial style plate tectonics, and has been proposed to experience a range of possible convective styles such as episodic, sluggish, and stagnant lid [e.g. 2-4]. A key constraint on such models is present day heat flow. Here we show that new estimates of elastic thickness [5, 6], a proxy for heat flow, at smaller coronae are in good agreement with regional estimates of elastic thickness from gravity suggest that heat flow is high (>95 mWm^{-2}) over at least 40% of the planet. This value is similar to terrestrial oceanic heat flux [7]. This result implies Venus is a tectonically active planet.

Background: The elastic thickness is the brittle portion of the lithosphere that supports earthquakes. Based on terrestrial seismic and heat flow data, ductile flow takes over at a temperature of ~ 750°C, assuming a strain rate of 10^{-16} s^{-1} for dry olivine or diabase [5,8,9]. Thus given the surface temperature (460°C) and elastic thickness, one can estimate thermal gradient. Heat flow is the product of the thermal gradient and thermal conductivity, which is estimated to be k ≈4 Wm^{-1} C^{-1}. Absent in-situ data, elastic thickness is a valuable means of estimating heat flow.

Predictions of heat flow from geodynamic models. Thermal and geodynamic models of the convective state of Venus commonly assume either no plate tectonic processes or episodic plate tectonics. Episodic models are motived by both an interpretation of surface impact craters as indicting catastrophic resurfacing and the inferred need to lose heat more rapidly than at present. Most models predict average surface heat flow of <40 mWm^2 with spikes of 60+ mWm^2 during regions of greater activity [e.g. 2-4].

Estimation of elastic thickness. One method of estimating is modeling the admittance – the transfer function between gravity and topography in the spectral domain. The thickness of the elastic lithosphere determines the flexural wavelength of the bending. The resolution of Magellan gravity field ranges from degree and order (d&o) 40 to 100, with a median value of 70. The required resolution for obtaining a reasonable error estimate in the admittance is ~d&o of 70 [10]. Anderson and Smrekar [10] applied a spatio-spectral method to calculate admittance on a global grid, and used a classification method to group similar spectra. They found less precise estimates of elastic thickness for regions with a d&o somewhat below 70 by doing model fits to regions with higher resolution and similarly shaped spectra. These limitations motivated a relatively loose criteria of <±20 km for fits for elastic thickness. Their global map of elastic thickness shows that roughly half the planet has an elastic thickness <20 km. They interpreted these values as either indicating isostatic compensation, meaning that the elastic thickness value is not well constrained, or as regions of high heat flow and active geology.

New Constraints: Another method of estimating elastic thickness is to model bending of the topographic surface of the lithosphere in response to a load. Our recent study [8] used both stereo topography (resolution of ~1 km horizontal) and Magellan topography (resolution of 10-25 km horizontal) to estimate elastic thickness at coronae. As shown previously [e.g. 11], large coronae tend to have larger values of elastic thickness, typically > 25 km. O'Rourke and Smrekar [5] estimated elastic thickness for 18 coronae, with the most estimates in the range of 5-15 km, providing heat flow estimates of > 95 mW/m^2. Following the same methodology, [6] produced elastic thicknesses estimates for 18 additional coronae (with no prior elastic thickness estimates) fall into this same range. [5] interpret these low values as likely to be due to localized heat flow above small scale mantle plumes that maybe responsible for the formation of coronae.

Interpretation and Implications: The low resolution of gravity and topography data result in large error bars for elastic thickness estimates. Our comparison between independent elastic thickness estimation methodologies suggests a higher confidence than the formal errors. These results have the following implications:

1. The presence of flexural bending in many locations invites a non-isostatic interpretation of the gravity modeling results.
2. The agreement between elastic thickness estimates from the regional and local estimates indicates high heat flow is likely in large regions, not just at coronae or other volcanic features. Exceptions: Tessera are likely isostatically compensated as they would be highly unstable to relaxation in the presence of very high heat flow.

3. Surface heat flow is apparently highly variable. Assessing whether the variability reflects regional variations at present or whether the variability reflects either an increase or decrease in heat flow over time is limited by our knowledge of the relative age of different terrains.
4. Interpretation of elastic thickness in terms of heat flow is a function of assumptions about composition, strain rate, and volatile content [e.g. 5]. These assumptions should be broadly assessed. If the rheology is significantly weaker (wetter, more silica-rich) than typically assumed, the elastic thickness is larger and the heat flow smaller.
5. Overall the implication is that heat flow on Venus, over at least 40% of the surface is significantly higher than estimates of heat flow from thermal evolution models. Both the variability and high values need to be considered in evolution models.

Work to go: We will continue to investigate agreement between elastic thicknesses from gravity/topography-derived and analysis of topographic features the regional versus local heat flow. We will also compare validated regional heat flow estimates with relative surface age models, resurfacing models, evidence for relatively recent volcanism, and geodynamic models.

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