VENUS VARIABLE LITHOSPHERIC THICKNESS AND IMPLICATIONS FOR ACTIVE RIFTING AND NEW INSIGHTS ON CONVECTIVE REGIME S. E. Smrekar[1], C. M. Ostberg[3], J. G. O'Rourke[1], [1]Jet Propulsion Laboratory/California Institute of Technology, Pasadena, CA, 91024 USA; (ssmrekar@jpl.nasa.gov), [2]University of California, Department of Earth and Planetary Sciences, Riverside, CA, [3]School of Earth and Space Exploration, Arizona State University, Tempe, AZ.

Introduction: Venus lacks terrestrial style plate tectonics. Yet is has ~40,000 km of major rift zones [1], and numerous minor fracture belts. The length of these rift zones approaches that of Earth's mid-ocean ridges, but Venus' rifts differ in many respects. They have no corresponding compressional zones, many branches, and, perhaps most significantly, ~350 coronae occur in association with rifts. The link between rifts and coronae (many coronae likely form above small scale upwelling) and interior dynamics is a critical question in Venus' overall evolution.

We estimate elastic thickness (Te) for 65 new coronae derived from topographic profiles. We compare these and prior Te values [1-4] to estimate Fs. We also compare our results to a near-global Te map derived from gravity and topography [5], resulting in new interpretations for both data sets.

Methodology: *Elastic thickness.* Here we estimate Te using a well-established method to model bending of the elastic plate in response to a load. These analytic models are purely elastic, but in locations where curvature can be derived from topography, estimating the total mechanical strength of the lithosphere, which includes viscous strength, is straight forward [65].

Heat Flow (Fs) and Thermal Lithospheric Thickness. Based on terrestrial seismic and Fs 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 [4]. Using the surface temperature (460°C) and elastic thickness, one can estimate thermal gradient. Fs is the product of the thermal gradient and thermal conductivity (k = 3 Wm^{-1} C^{-1}). Absent in-situ data, Te is a valuable means of estimating Fs. The thermal lithospheric thickness, which is important for convection models, can be derived using the thermal gradient and an assumed mantle temperature of 1300°C.

Te from admittance. Admittance is the transfer function between gravity and topography in the spectral domain. Modeling of the flexural bending wavelength provides a Te estimate. [10] apply a spatio-spectral method to calculate global admittance. They find that ~50% of Venus has a Te <20 km. They interpreted these values as either indicating isostatic compensation, meaning that Te is not well constrained, or as regions of high Fs and active geology. Other regions, many of which occur in areas of low gravity resolution, have Te >20 km, up to 100 km, with very large uncertainty.

Results: We obtain 75 new Te estimates at 65 coronae ranging from ~1–45 km, with most <20 km. Incorporating 14 prior coronae Te estimates yields an average of 11±7 km, and a derived average Fs of 101±88 mWm^{-2}. Derived Fs values and thermal lithospheric thickness overlap with terrestrial values, including those of actively extending regions (Fig. 1).

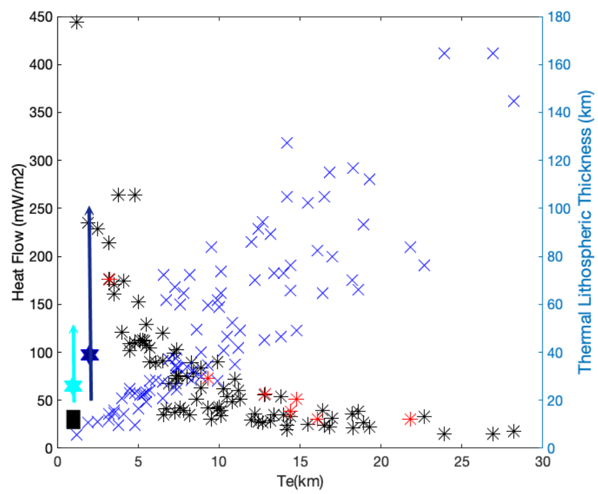

Figure 1. Measured Fs for terrestrial continental and oceanic regions, where highest values located in active extensional regions, overlap with Venusian estimates and point to likely active regions. Estimated values for each corona are shown both as black stars for elastic thickness (Te) versus Fs and as blue crosses for Te versus thermal lithospheric thickness (Tt). The coronae that have been proposed as subduction sites are shown as red stars. The range in values for Fs and lithospheric thickness for a given Te value are a result of different curvatures. Measured average Fs values for terrestrial oceanic (dark blue star) and continental Fs (light blue star) and modeled values of stagnant lid Fs for Venus (black bar) are shown for comparison. Dark blue arrow shows the range of oceanic Fs measurements, with those closest to the ridge showing the largest values, including in excess of 250 mWm^{-2} [7]. The light blue arrow shows the range of continental Fs, with larger values associated with extensional regions. Artemis Coronae, with Te of 45 km and Tt of 112 km is not shown.

Te Comparison: We compare Te from flexure to those derived from admittance, taking into account the local gravity resolution and assuming an error of ±10 km. We find good to reasonable agreement at most (73 of 89) locations (Fig. 2), indicating that Te estimates from admittance are largely accurate but not precise.

Implications: Numerous Fs values exceed 75 mWm^{-2}, similar to values at Earth's actively extending regions. On Venus, high Fs is common in the ~10,000 km-long Parga Chasma rift zone and at other minor fracture zones (Fig. 2). The agreement between local and global Te values leads to new interpretation of both global maps and local values from flexure at coronae. For the global Te map, agreement with Te from flexure indicates that many non-tesserae areas (~40% of Venus) are best interpreted as present day thin lithosphere, rather than isostacy. The agreement between global Te values and local flexural values at coronae indicates that many coronae form on thin lithosphere, rather than creating locally thin lithosphere due to plume interaction [4]. Overall, Te and Fs are variable on Venus, most consistent with average values similar to Earth. Geodynamic models commonly predict average surface Fs of <40 mWm^2 with spikes of 60+ mWm^2 during regions of greater activity [e.g. 8.9]. In particular, some stagant lid models predict higher Te values and are consistent with variability in Te and Fs, such as the 'squishy' lid model dominated by intrusive volcanism [12]. A full understanding of Venus' Te and Fs await future missions.

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References: [1] Schubert, G. & D.T. Sandwell, Icarus. 117, 173–196, 1995. [2] Sandwell D.T. and G. Schubert (1992) Science, 257, 766-770. [3] Johnson, C.L. & D.T. Sandwell, Geophys. J. Int. 119, 627–647, 1994. [4] O'Rourke, J. & S.E. Smrekar, J. Geophys. Res., doi:10.1002 /2017JE005358, 2018. [5] Anderson, F.S. and S.E. Smrekar, JGR-Planets, 111, doi:10.1029/2004JE002395, 2006. [6] McNutt, M.K. JGR, 10.1029/ JB089iB13p11180, 1984. [7] Jaupart, C., et al. Treatise on Geophysics, doi:10.1016/B978-044452748-6.00114-0, 2007. [8] Solomon, S.C. and J.W. Head GRL, doi:10.1029/GL017i009p01393, 1990. [9] Gillmann, C. and Tackley, P.J. JGR-P, 10.1002/2013JE0045052014 [10] Arman, M. and Tackley P.J., JGR, 10.1029/2012JE004231, 2012. [11] Bilotti, F. &J. Suppe, Icarus. 139, 137–157, 1999. [12] Lourenço, D.L. et al., Nat. Geosci. 11, 322–327, 2018.

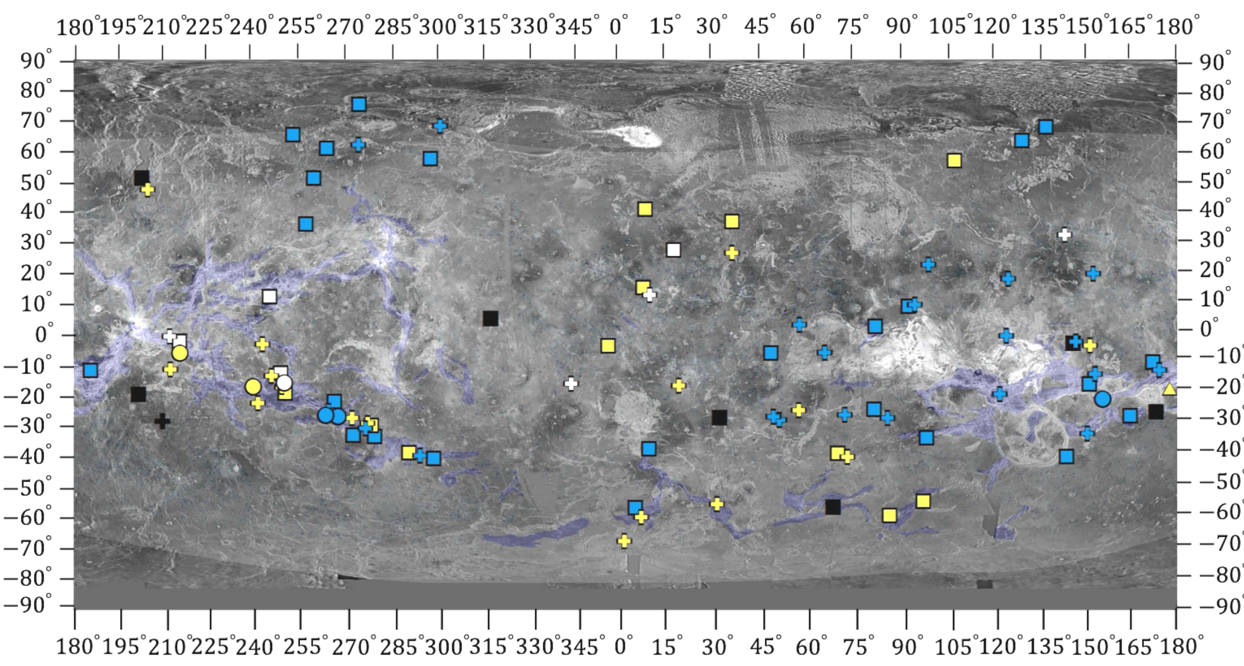

Figure 2. Fs estimates greater than the average value of 77 mWm^{-2} (+ symbols) occur around the globe, with a major concentration in Parga Chasma (lat. 20-35°S, lon. 75-130 E). Most locations with local Te estimates are in good (blue) or reasonable (yellow) agreement with the regional values from gravity and topography; no agreement is show in black, and locations with no derived regional value are shown in white. Rift locations [11] are shown in navy blue. In addition to coronae, we show 8 Te estimates from rift flank flexure as circles for those with Te > 75 mWm^{-2} or a triangle for one with Te < 75 mWm^{-2}. The background map is Magellan radar imagery; rough areas appear bright and smooth appear dark (radar wavelength ~12 cm).