CONSTRAINING CORONA FORMATION ON VENUS. D. Piskorz[1], L. T. Elkins-Tanton[2], S. E. Smrekar[3], [1]California Institute of Technology, Pasadena, CA 91125 (dpiskorz@gps.caltech.edu); [2]Carnegie Institution for Science, Department of Terrestrial Magnetism, Washington, DC 20015 (ltelkins@dtm.ciw.edu); [3]Jet Propulsion Laboratory, Pasadena, CA 91109 (suzanne.e.smrekar@jpl.nasa.gov).

The thermal history of Venus remains an enigma. As Venus and Earth have similar radii and radiogenic abundances, we assume they have a similar internal structure and composition [1]. Venus does not appear to have plate tectonics, and its surface displays a range of volcanic and tectonic features, including those that are both similar and dissimilar to those on Earth [2, 3]. Here, we study coronae at Parga Chasma with the goal of understanding how Venus loses its heat. At the conclusion of our study, we find that the data required to make a full comparison between models and observations is lacking.

Session: From Orbit.

Target: High resolution altimetry, SAR imaging, spectroscopy, and gravity for coronae in Parga Chasma.

Science Goals: II.A.1, II.A.3.

Background: The Magellan mission observed quasi-circular volcano-tectonic features called coronae dotting the surface of Venus [4]. (See Figure 1 for an image of a corona.) There are over 500 observed coronae on Venus [5]. There are 50 coronae associated with Hecate Chasma and 131 with Parga, the two largest rift systems on Venus. The coronae form at different times relative to the rifts, making it difficult to determine a genetic relationship. At Parga Chasma, there are 55 off-rift coronae located 150 to 1500 km from the rift, meaning that their stratigraphy relative to the rift cannot be determined. These off-rift coronae are generally smaller and less volcanic than the average corona and tend to have negative topographies [6].

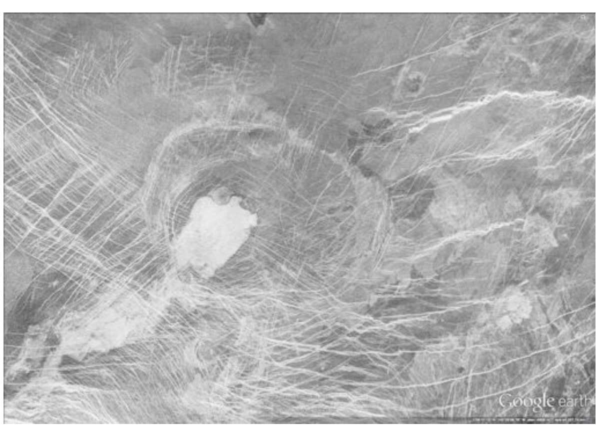

Figure 1. *Magellan radar image of a corona located at 1.2N, 145.6S. This corona is roughly 120 km across and is in topographic group 7 (rim only), according to [6].*

Motivation: In the absence of plate tectonics, the origin of major rift systems like Parga is unclear. Are coronae important in the formation of rifts, or vice versa? How do they contribute to planetary heat loss? Are they sites of upwelling, delamination, or both? How much extension has occurred across the rift zones? In other locations, such as the Dali-Dianna fracture zone, the fractures have been proposed to be subduction zones (e.g., [7]). Are there different types of fracture zones that represent multiple types of heat loss such as upwelling, volcanism, or subduction?

By characterizing the connection between rifts and coronae, we may be able to better understand heat loss on a single-plate planet.

Proposed methods of corona formation: There are many proposed corona formation mechanisms, including mantle upwelling or downwelling with associated lithospheric drips [4] and Rayleigh-Taylor instabilities at the lithosphere-mantle boundary [8]. Another theory suggests that the interaction between the edge of a plume head and a depleted mantle layer can produce the full range of corona topographies [9].

This study. We propose that a mantle plume or upwelling associated with a rift mobilizes eclogite [10, 11] in the lower lithosphere off-axis of the rift, causing lithospheric dripping into the upper mantle, leading to extension, surface stresses, melting, and the creation of off-rift coronae.

Experiments: Numerical models are run in Cartesian coordinates with Conman [12] to simulate the rift geometry and in spherical, axisymmetric coordinates with SSAXC [13] to simulate coronae formation. These are finite-element codes that solve equations for the conservation of heat, momentum, and mass given initial temperature and compositional profiles. Our models consist of a conductive lithosphere and a convective mantle with a rift, plume, and density contrast representing eclogite at the lithosphere-mantle boundary. We perform resolution tests and account for edge effects.

We vary lithospheric thickness, or the non-rifted region with a conductive temperature profile, (75, 88, and 100 km), as well as rift half-width (50 and 100 km) and plume temperature (1400 and 1500°C). We use a mantle temperature of 1300°C, mantle density of 3300kg/m^3, and reference viscosity of 10^{20}Pa·s. The composition varies from 120% to 100% of the mantle density.

Results: For the models that produce substantial lithospheric dripping, we calculate topographies, melt volumes, and gravity anomalies. Figure 2 shows a comparison between the topography of a corona simulated by the above method and a real corona on Venus.

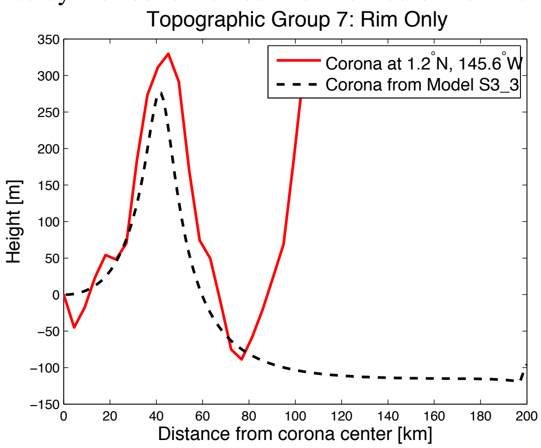

Figure 2. Topography comparison of data and model. Shown by the red solid line is the topographic profile of a corona located at 1.2N, 145.6W. Shown by the black, dashed line is the topographic profile resulting from the model with a lithospheric thickness of 88 km, plume temperature of 1500°C, and rift half-width of 100 km.

To first order, our topographic profiles agree with observed topography, though they have a higher curvature than that seen in the Magellan topography. This disagreement is often more pronounced than is shown in Figure 2 and could be due to the lack of a crustal layer in our models, the resolution of the Magellan topography, or both. We are not able to compare our predicted gravity profiles for coronae as the horizontal resolution of the gravity data is about ~475 km in Parga Chasma.

Discussion: Here we discuss observations required to determine if extension and lithospheric instability is a viable method for producing true off-rift coronae.

High-resolution altimetry. Coronae display both highly variable and extremely complex topographic deformation and fracture patterns [6]. Magellan topographic resolution is 8-15 km along track and 12-27 km across track. In areas of steep topography, the altimetry is often in error, as can be seen by the anomalous pits and peaks in the topography. This means that details of the topographic morphology are difficult to determine for most coronae, which have typical diameters of 200-300 km. The topographic shape of most coronae appears to vary radially. Is this an artifact of the resolution or a characteristic of coronae and thus a clue to how they form?

Similarly, the relationship between coronae and rifts and other fractures that extend beyond the coronae are enigmatic, with multiple hypotheses for their origin; this work details only one such hypothesis. High-resolution topography (e.g. horizontal: 500 m, vertical 20 m) would allow these relations to be unambiguously determined and would estimate the amount of extension across rifts.

SAR imaging. High-resolution imaging (e.g. 30 m or better) would help further determine the stratigraphy of fractures, topography, and volcanism.

Spectroscopy. In some cases, the volcanic flows associated with coronae are large enough (>50 km, e.g. Fig. 1) to allow spectral observations from orbit. If delamination is occurring at coronae, the composition of melts may be distinct [14].

Gravity data. The diameter of corona in our model agree well with observations. Variations in the gravity associated with topography and subsurface structure can only be observed at larger coronae, such as Furachoga at Parga. Ideally, global gravity data with a resolution of 100 km or better would allow resolution of both radial variations in density and estimates of elastic thickness for a majority of coronae. In reality, the dense Venusian atmosphere prohibits long-term operation at low enough altitude. However, higher resolution gravity (e.g. < 300km) would be a major improvement over the irregular Magellan gravity field and allow dozens more coronae to be resolved.

Conclusions: Our models have shown that it is possible to produce reasonable off-rift coronae resulting from the interaction between a rising plume associated with a rift and a pre-existing layer of dense material at the lithosphere-mantle boundary. This is only one possible formation mechanism for corona on Venus. Together, the data sets discussed above would allow for better determination of the origin of coronae (upwelling and/or delamination?) and associated fracture zones (rifts and/or subduction zones?). This determination has major implications for understanding how Venus loses its heat.

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