ELASTIC THICKNESS ESTIMATES FOR CORONAE ASSOCIATED WITH CHASMATA ON VENUS.
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Introduction: Coronae are large-scale circular tectonic features surrounded by annular ridges (Figure 1). They are generally considered unique to Venus and may offer insights into the differences in lithospheric structure or mantle convective pattern between Venus and Earth. 68% of all coronae are associated with chasmata or fracture belts. The remaining 32% are located at volcanic rises or in the plains [1]. Chasmata are linear to arcuate troughs, with trough-parallel fractures and faults which extend for 1000's of kilometers.

Estimates of the elastic thickness of the lithosphere (T_e) have been calculated in a number of gravity/topography studies of Venus and for coronae specifically [e.g. 2]. None of these studies, however, have explored the dependence of T_e on the tectonic history of the region, as implied from the interpretation of relative timing relationships between coronae and surrounding features. We examine the relationship between the local T_e and the relative ages of coronae and chasmata with the aim of further constraining the origin and evolution of coronae and chasmata systems.

Methods: In this study, coronae closely associated with chasmata are classified according to their time of formation relative to chasmata formation. These interpretations are then compared with T_e estimates derived from admittance spectra [3].

Admittance and T_e*:* The admittance (ratio of free-air gravity to topography in the spectral domain), is sensitive to bending of the elastic lithosphere in response to a load from above/below. We used a spatio-spectral localization method [4] with a global admittance map [5] to calculate the local admittance for individual coronae. By comparing the observed admittance to the predictions of 2 loading models of the lithosphere, T_e is estimated. We assume the Venusian lithosphere has 2 laterally homogenous layers: crust of thickness Z_c overlying mantle to an apparent depth of compensation Z_L. Loaded by surface topography (top-loading) or by internal loads at depth Z_L (bottom-loading), the model lithosphere attains static equilibrium by elastic flexure of the uppermost elastic layer.

Error Analysis: Data noise, method biases and the occurrence of other processes contribute to the uncertainty in the estimated T_e [2]. We account for these following [6] and assume that for each corona, the variation in admittance is representative of the uncertainty in admittance and is equal to 1.5 x RMS_{MIN} misfit between model and observed values.

Relative Timing of Corona Formation: Magellan SAR images are used to interpret whether individual coronae formed prior to, during or after chasmata formation on the basis of superposition and cross-cutting relationships between coronae and regional fractures and volcanism [7]. If regional (chasmata) fractures terminate against the fracture sets associated with corona formation, the corona-related fractures are presumed to be pre-existing fractures that provide a structural barrier to the propagation of regional fractures. If regional fractures are deflected around a corona, the corona is also presumed to have formed first (pre-tectonic). If regional fractures cut corona flows, and corona fractures or flows also superpose regional fractures, the corona is presumed to have formed at the same time (syn-tectonic) as the chasmata (Figure 1). If regional fractures are clearly cross-cut by corona fractures, or hidden by corona flows, then the corona is classified as post-tectonic. Two intermediate categories (syn/post-tectonic, syn/pre-tectonic) are also included.

While previous mapping studies describe stratigraphic relationships between coronae and their surrounding geology [e.g. 8], these studies used pre-Magellan or non-stereo data. Stereo imaging allows the relationship between the chasmata trough and corona topography to be observed more clearly.

Results: The relationship between T_e and the relative timing of corona formation is shown in Figure 2. For the data available, the average T_e of each group correlates with the relative timing of coronae formation. Examples of coronae with small T_e (<5km) are found, however, in all groups.

Syn/post-tectonic coronae (4 in total) exhibit T_e estimates between 0 and 39km (ave. 26±6km) with best fit Z_c estimates from 6 to 69km (30±30km). Syn-tectonic coronae (7 in total) display T_e values up to 52km (10±18km) with Z_c estimates from 30 to 69km (53±13km). T_e estimates for syn/pre-tectonic coronae (12 in total) range between 0 and 56km (33±17km). For the 8 coronae that are best fit by a top-loading model, Z_c ranges from 39 to 61km (48±8km). For the other 4 that are best fit with a bottom-loading model, Z_L ranges from 37 to 63km (51±11km). The 4 post-tectonic coronae display small T_e values less than

19km (6±7km) with Z_c values ranging from 4 to 63km (44±28km). Pre-tectonic coronae (4 in total), display the largest range of T_e values between 0 and 56km (29±22km). The 3 that are best fit by a top-loading model have Z_c values between 21 and 64km (41±22km). The other, best-fit by a bottom-loading model, has a Z_L of 60km.

Discussion: 74% of the coronae analyzed formed synchronously with chasmata formation. This abundance of synchronous activity suggests that the two formation processes are related.

T_e and chasmata formation: Chasmata have previously been interpreted as extensional rift zones similar to terrestrial rifts [9]. However, rifting on Venus appears to be predominantly related to convective upwelling in the mantle [9] rather than plate motion. Impingement by a plume puts the lithosphere under stress [10] and weakens it [11]. Injection of plume-related magma into the crust may then create a localized zone of weakness in which rifting occurs. Coronae that form subsequent to rifting (chasmata formation) therefore would develop in hotter, weaker lithosphere, and be associated with smaller values of T_e. A similar explanation for the smaller T_e values found in studies of the East African rift is described by [12] who attribute the small values (21 to 36km) found in the vicinity of severely faulted rift valleys to mechanical weakening of the lithosphere due to heating involved in the rift formation process. Stable (colder) cratonic regions were found to be underlain by relatively thick T_e (64 to >90km).

Conclusions: For the limited number of coronae examined, smaller T_e values (0 to 19 km) are found for coronae that formed after chasmata formation. Coronae that formed before chasmata formation display larger T_e values (0 - 56 km). These results suggest that coronae that form before chasmata formation may form on colder and stronger lithosphere and those that form after chasmata formation may form on weaker, less stable lithosphere. This interpretation is comparable with the interpretation of the East African rift [13]. While the results indicate a correlation between T_e and relative timing of the coronae examined, there remains no clear causal relationship between the formation and evolution of coronae and chasmata.

Although only a small number of coronae were examined (due to low resolution of the Magellan gravity data in regions of interest), the relationship between the local elastic thickness of the lithosphere and the relative ages of coronae does appear to be valid. Improving the confidence of this result awaits a higher resolution more complete model of the Venusian gravity field.

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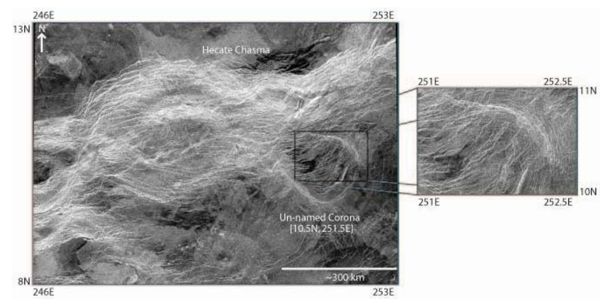

Figure 1: Magellan (left-looking) SAR image (sinusoidal projection, image resolution: 1.2 km/pixel) of unnamed corona [10.5N 251.5E] located on Hecate Chasma (http://pdsmaps.wr.usgs.gov). The corona is classified syn-tectonic as chasmata-related fractures cut the corona flows, and some of the concentric corona fractures (in the N-NE of the corona) also superpose chasmata fractures.

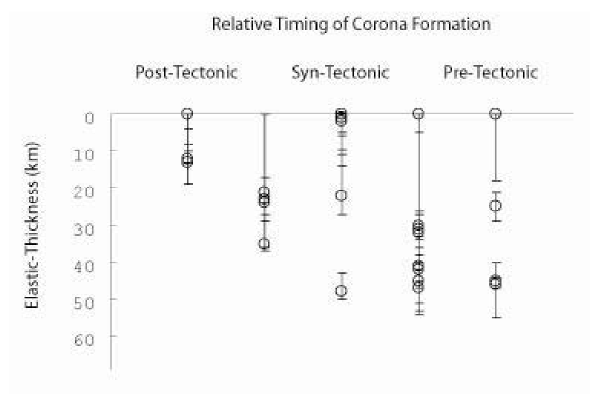

Figure 2: T_e as a function of the relative age of corona formation relative to chasmata formation. Each individual corona is represented by a circle. Error bars represent the range of T_e values that provide an RMS misfit within a factor of 1.5 times the minimum data misfit of the spectral admittance function.