TOPOGRAPHIC CHANGE AT CORONAE ON VENUS RECORDED BY LAVA FLOWS. W.S. Tucker & A.J. Dombard, Dept. of Earth & Environ. Sci., Univ. of Illinois at Chicago, Chicago, IL 60607 (wtucke5@uic.edu).

Introduction: Coronae are volcano-tectonic features on Venus initially characterized by their concentric fractures and ridges [1]. Magellan data have shown coronae surface characteristics to be varied in the amount of concentric faulting, topographic signatures, diameters, and extent of associated volcanism [2]. Geophysical models of corona formation have been able to reproduce only some of the features associated with corona, and most have difficulty capturing more than one or two characteristic observations. One interpretation produces coronae from a buoyant mantle diapir with a diameter approximately equal to that of the resulting surface expression [3, 4]. Other models argue for downwelling of the lithospheric mantle [5], crustal loading from partial melt at the head of an impinged thermal [6], or stress-regulated volcanic construction [7].

A "standard model" of corona evolution that results from a thermally buoyant diapir has three main stages [8]. First, a rising mantle diapir causes an initial domical uplift. Then, as the diapir impinges on the lithosphere, it flattens and spreads radially creating a plateau. Last, as the diapir cools, the surface relaxes forming an interior depression. The various topographic signatures observed among coronae are thus evolutionary stages from domal to circular to calderic with two transitional stages [9]. Additionally, detailed mapping of coronae in Guinevere and Sedna Planitia has shown a complex evolution with multi-stage annulus formation [10].

The role of volcanism in corona formation and evolution is unclear, and only a limited number of coronae have any associated volcanism [e.g., 11]. For those coronae with associated volcanism, the scale is often comparable to that of terrestrial flood basalts [12]; therefore, intrusive and extrusive magmatism has the potential to be significant during and after the formation of coronae [e.g., 6, 7]. Volcanism is thought to occur during the domical uplift stages before shifting to extra-annulus volcanism as the concentric fractures form and again shift towards the interior during the last evolutionary stage [8]. Although the degree of volcanism for each stage is difficult to discern, exterior volcanism during annulus formation appears to be more extensive than the interior volcanism of the first and final stages [9].

Coronae are clustered in the Beta-Atla-Themis (BAT) region [e.g., 2], but are markedly absent from highlands. They appear to be anticorrelated with areas of supposed upwellings and downwellings [13]. The absence of coronae from lowlands is likely caused the suppression of transient plumes beneath active downwellings. This is in agreement with lowland coronae being older than BAT coronae [14]. While coronae are absent from the immediate vicinity of volcanic highlands, they are concentrated towards these regions of broad scale upwelling (e.g., the BAT region). Upwelling regions may "consume" approaching thermals allowing for the concentration of adjacent coronae [15].

The relationship between volcanism and corona evolution might be revealed by comparing flow directions to modern topography, as lava flows have the ability to inform how topography has changed since the flows were emplaced. The downhill direction of a lava flow is recorded in its morphology and the relationship among flow units, irrespective of any topographic data [e.g., 16, 17]. Any topographic change that has occurred since the time of flow emplacement will be recorded in the difference between the topographic and flow directions. In this study, we briefly assess the degree of volcanism within coronae, and apply paleotopographic techniques to lava flows associated with the coronae, focusing on Atete Corona (16°S, 243.5°E), with particular attention paid to its intra-annulus flow units.

Methods: Using Magellan SAR images (75 m/pixel), a global survey of corona volcanism is conducted from catalogs of Type 1 and Type 2 coronae [2] and those recognized in the USGS corona nomenclature database. Favorably stretched SAR data allow for identification of discrete lobate and digitate flows [e.g., 18]. Where sufficient corona associated lava flows are identified, individual flow units are mapped, and their azimuthal orientation is calculated from their geographic start and end points. A buffer with a 15 km radius is processed at the midpoint of each flow unit, and a mean regional slope direction is calculated from an aspect raster derived from altimeter data. The differences between the regional slope direction and the flow-unit direction record the topographic change since emplacement flow.

We also use spherical harmonic analysis to examine the distribution of locations [e.g., 15, 19] of subsets of coronae from the survey described above. We find the spectral power and correlations between the full corona database, corona that have undergone topographic change since emplacement, and unchanged coronae where no post-emplacement deformation is observed.

Results: A total of 545 unique coronae are identified in the two corona databases, of which 13% have discernable volcanic flows within their fracture annuli. However, only 7% have lava flows with mappable units. For the 40 coronae with mappable flows, 19 have topographic change along flow paths.

The normalized power spectra of changed and unchanged coronae show relatively white spectra at degrees 4 and higher. The full corona data set has a red spectrum at degrees lower than 10, and white for the shortest wavelengths. All data sets are correlated at low

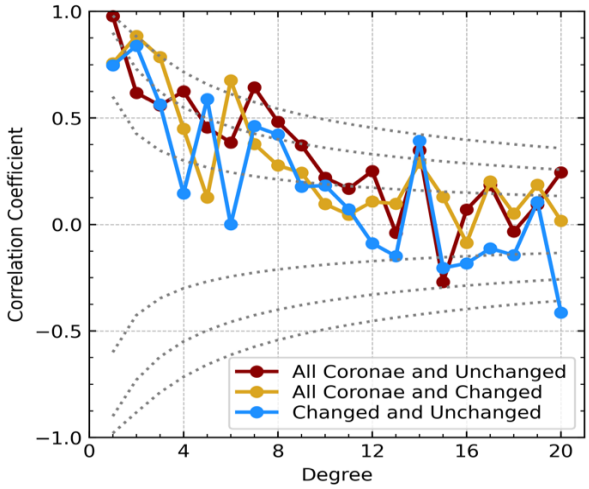

Figure 1. Power correlations between all coronae and coronae with no change (red), all coronae and coronae that show change (yellow), and coronae that show change and those with no change (blue). Confidence lines are 80%, 95%, and 99%.

degrees with significant confidence. At shorter wavelengths (l > 8), there is no significant correlation between any of the spectra (Fig. 1).

Atete Corona (16°S, 243°E) is the clearest example topographic change and has extensive lava flows both within and outside of its annulus. Mapping of the interior flows show most lava flows appear to flow uphill (Fig. 2). Flows are seen radiating from an edifice in the southern part of the corona extending to the northern limit of the concentric fractures. Exterior lava flows at Atete Corona also indicate topographic change since the emplacement of some flows.

Discussion: The strong power and correlation at higher degrees between coronae that are changed, unchanged, and the full corona data set suggests that the same mantle processes are affecting these subsets. The lack of correlation at high degrees is likely a product of the small sample numbers, as at those degrees the distributions cannot be distinguished from random.

Mapped lava flows within the fracture annulus of Atete Corona show clear difference between their original flow direction and the current topographic gradient. The source of these interior flows appears to be a region of radial fractures near the southern rim. Many corona models indicate domical uplift and radial fracturing as an early or first stage of evolution [e.g., 3]. This early stage is consistent with the results found here, where the formation of the fracture annulus and topographic rim led to the current orientation of the slope face and uphill lava flows. Notably, this early center is not in the geographic middle of Atete.

The flows on the exterior of Atete show less change of the topography than is observed in the interior. Here, redirected flows intermingle with flows that follow the modern slope. This finding suggests multiple volcanic events with younger flows found on the flanks of the corona. All interior flows being redirected while only some on the exterior suggests the interior flows are relatively old, while the exterior flows show a range of ages, though cross-cutting relationships are generally lacking to test this hypothesis directly. The progression of volcanism to the annulus is consistent with lithospheric loading via constructive edifice growth [20].

These findings suggest why models have difficulty capturing more than one or two characteristic observations: coronae, like most geological features, are messy and do not exactly follow textbook models of formation and hence show a range of deviations from these schematic models. The northward surface inflation and extension of the annulus from an initial center violates the axisymmetry of these simple models. What is clearer is that volcanism played a significant role in this evolution, though improved imagery and topography are needed to test these ideas further.

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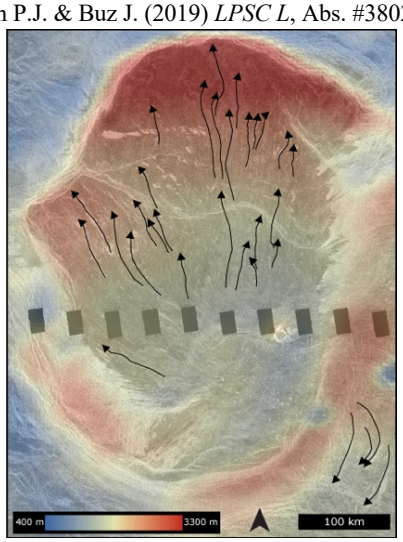

Figure 2. Topography of Atete Corona overlying SAR image. Arrows indicate apparent flow direction of mapped lava flows.