IMPLICATIONS OF VOLCANIC EDIFICE SHAPES AND STRUCTURES FOR THE VOLCANOLOGICAL AND THERMAL EVOLUTION OF VENUS. P. J. McGovern[1] and M. E. Rumpf[2], [1]Lunar and Planetary Institute, 3600 Bay Area Blvd., Houston, TX, 77058, USA (mcgovern@lpi.usra.edu), [2]Department of Geology, State University of New York at Buffalo, Buffalo, NY 14261, USA (rumpf@buffalo.edu).

Introduction: Large volcanic edifices comprise a significant portion of the geologic record of Venus, as revealed by radar-based imaging and ranging of the surface of that planet [1]. These edifices display a range of shapes from conical to dome-shaped. Furthermore, the class of large volcanoes on Venus overlaps with a class of features, called coronae, that are typified by annular-shaped tectonics, topography, or both [2]. In a companion abstract [3], we demonstrate that lithospheric flexure can exert a strong influence on the shape of a volcanic edifice via the effects of flexural stresses on intrusive magma ascent pathways (dikes). In particular, the thickness of the elastic lithosphere (T_e) modulates stresses magnitudes and flexural wavelengths of the response, such that each particular edifice shape (conical, domical, and annular) has a corresponding range of T_e (high, moderate, and low, respectively) that favors volcanic construction of that shape [3].

The link between lithosphere thickness, magma ascent, and edifice shape has several implications. First, it provides a new scenario for construction of a subset of coronae, namely, those with substantial annular topography and lava flows associated with such relief. The structure and surficial geology of such coronae may then result from volcanic construction (by effusion and intrusion) rather than from surface deformation induced by subsurface flow (usually diapiric) in the crust and mantle, as posited by a class of popular models for corona formation [4-7]. Second, since T_e can be considered a proxy for the thermal gradient in the lithosphere [e.g., 8], the discovery of the lithosphere-shape link raises the exciting prospect of using spatial variations in volcanic edifice morphology to map the thermal state of the lithosphere (corresponding to the time of volcanic construction).

Data and Models: Synthetic aperture radar (SAR) images collected from the Magellan mission [9] reveal flows, faults, and vents used to identify volcanoes and coronae. The shapes and sizes of the features can be determined using Magellan altimetry data. More than 150 large volcanoes [1,10] and 500 coronae [2,11] have been identified. Image data are draped over topography for two large volcanic structures in Figure 1.

Kokyanwuti Mons (Figure 1a) exhibits a domical profile, with a nearly flat summit region and gently sloping outer flanks. The summit has a fairly uniform radar-dark surface, whereas the outer flanks are draped with numerous digitate units of varying brightness, consistent with the presence of relatively young lava flows. Models of lithospheric flexure with T_e in the range 20-30 km result in a shutoff of magma ascent beneath the summit plateau but allow ascent beneath the outer flanks [3], consistent with the pattern of flow units seen at Kokyanwuti Mons.

Aruru Corona (Figure 1b) displays an annular topographic profile, with associated circumferential fracturing. Numerous lava flows appear to have resurfaced the outer slope of the annulus. Some flows appear to have emanated from the inner slope as well, covering the interior low region. Models with low T_e (<= 15 km) produce two narrow zones of predicted magma ascent on the inner and outer slopes of the annulus [3], in accordance with the observed distribution of flows. For both Kokyanwuti Mons and Aruru Corona, models with T_e outside the ranges given above predict magma ascent patterns that are at odds with the observed topography and flow distributions [3].

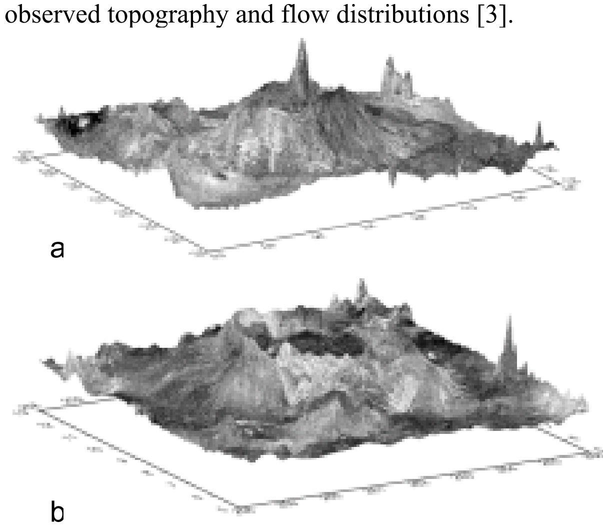

Figure 1. Synthetic aperture radar (SAR) images superposed on Magellan altimetry data for (a) Kokyanwuti Mons, centered at 35.5°N 212°E with approximate vertical exaggeration of 93:1 and south to lower left, and (b) Aruru Corona, centered at 9°N 262°E with approximate vertical exaggeration of 80:1 and south to the lower right of image. Magellan radar images collected from the USGS Map-a-Planet website [12].

Some Coronae are Strangely Shaped Volcanoes: In [3], we found that annular loads (e.g., Figure 1b) produce a distinct effect on the flexural stress state within the lithosphere, such that for thin lithospheres the annular shape tends to be reinforced by the resulting pattern of magma ascent. This finding yields a new model for corona formation via stress-regulated volcanic construction. Here we suggest that the subset of coronae that have significant annular ridge topography, abundant lava flows associated with that topography, and a gravity signature consistent with low T_e are formed primarily via volcanic construction. In other words, such coronae are essentially strangely-shaped volcanic edifices. This model is in principle similar to previous models of surface corona loads [e.g., 4, 13-14], but is the first to explicitly account for the interactions of lithospheric flexure, magma ascent and edifice growth.

Coronae lacking substantial positive relief, exhibiting negative relief, and/or lacking evidence for areally significant lava flows are not likely to have formed by this constructional mechanism. Such coronae constitute a large fraction of the total number. Inferences of large values of T_e at specific coronae from gravity measurements [e.g., 15] are also inconsistent with this mechanism (although gravity-based inferences are non-unique).

Volcanically constructed coronae may have more in common with more conventional volcanic edifices than with corona formed by deformation from subsurface flow mechanisms [e.g., 4-7]. Of course, there is likely a continuum of processes that contribute to the wide range of corona morphologies seen on Venus, and a given structure may be the result of combined construction and subsurface flow. Unfortunately, it is often assumed (implicitly or explicitly) in the literature that all features termed "corona" formed by one mechanism. This assumption is then applied as a criterion with which to evaluate models for corona formation, along the lines of "A successful theory of corona formation must explain X", with X being some global property (or even range of properties) of the entire set of coronae. In light of the diversity of potential corona formation mechanisms [including 4-7, 13-14], the prevailing (and often unspoken) assumption that "There can be only one" [16] may lead to the improper dismissal of corona formation models which only apply to a subset of corona (like the one proposed here). It may also skew analyses of coronae that formed by viscous flow or other mechanisms.

Application to Eistla Regio: Eistla Regio on Venus encompasses several concentrations of volcanic activity (Fig. 2). Western Eistla Regio consists of a broad topographic rise superposed by the conical shield volcanoes Sif and Gula Montes [17]. In Central Eistla Regio, the volcanoes Anala Mons and Irnini Mons lie in close proximity. While Anala has a domical profile, Irnini Mons exhibits an annular topographic ridge with associated circumferential tectonics. An early name for the center of Irnini Mons is Sappho Patera, for which the map quadrangle is named [18], and which was listed as a corona [2].

Edifice shapes in Eistla Regio appear to systematically change with distance to the east. The Western Eistla edifices Sif and Gula Montes have conical edifices that are consistent with emplacement on lithosphere with high T_e. The domical shape of Anala Mons in Central Eistla suggests emplacement at moderate T_e, and the annular Irnini Mons edifice is consistent with emplacement at low T_e. This trend can be accounted for in several ways. If volcanic edifice construction in Eistla Regio is more or less coeval, a gradient in lithospheric thickness (decreasing to the east) is indicated. Alternatively, in the context of a planet cooling down after a more or less catastrophic resurfacing event, the edifices may get younger toward the west. Such a hypothesis is difficult to test on a broad scale, since Eastern and Central Eistla are too far apart to have direct stratigraphic contact, and the cratering record is too sparse to constrain ages of individual constructs. However, mapping of Central Eistla indicates that Irnini Mons is older than Anala Mons [18]. Our findings support the idea that lithospheric cooling helped to bring on a transition between emplacement of annular edifices (e.g., Irnini Mons) and younger domical or conical ones [10, 18].

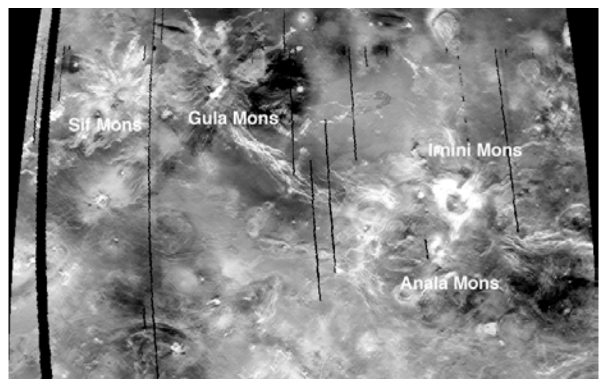

Figure 2. Magellan SAR Image of Western and Central Eistla Regio, from [11]. Sinusoidal projection: image bounds are –15° to 25° E, 2.5° to 27.5° N.

References: [1] J. W. Head et al., JGR, 97, 13, 153, 1992; [2] E. R. Stofan et al., *JGR*, 97, 13,347, 1992; [3] M. E. Rumpf and P. J. McGovern, *LPS, XXXVIII* (this volume), 2007; [4] D. M. Janes et al., JGR, 97, 16,055, 1992; [5] D. M. Koch and M. Manga, *GRL, 23*, 225, 1996; [6] S. E, Smrekar and E, R. Stofan, *Science, 277*, 1289, 1997; [7] T. Hoogenboom and G. A. Houseman, *Icarus, 180*, 292, 2006; [8] P. J. McGovern et al., *JGR, 107*, doi 10.1029/2002JE001854, 2002. [9] Saunders et al., JGR, 97, 13,067, 1992; [10] P. J. McGovern and S. C. Solomon, *JGR, 103*, 11,071, 1998; [11] E. R. Stofan et al, GRL, 28, 4267, 2001; [12] USGS: Map-a-Planet, http://pdsmaps.wr.usgs.gov; [13] K. E. Cyr and H. J. Melosh, *Icarus, 102*,175, 1993; [14] D. M. Janes and S. W. Squyres, JGR, 100, 21,173, 1995; [15] T. E. Hoogenboom et al., *JGR, 109*, doi:10.1029/2003JE002171, 2004; [16] C. MacLeod, in *Highlander*, 20th Century Fox, 1986; [17] R. E. Grimm and R. J. Phillips, *JGR, 97*, 16,035, 1992. [18] G. E. McGill, Geologic Map of the Sappho Patera Quadrangle (V-20), Venus, *USGS Map I-2637,* 2000.