USING MAP-DERIVED HOOP STRAIN AND ELASTIC MODELS OF RESERVOIR INFLATION TO QUANTIFY THE DEGREE OF DIKE EMPLACEMENT AT GIANT RADIAL LINEAMENT SYSTEMS ON VENUS. E.E. Barry[1], A. Deurlington[2], S. Yin[1], M.J. Wucher[1], E.B. Grosfils[1], [1]Pomona College, Claremont, CA. [2]Claremont McKenna College, Claremont, CA. (egrosfils@pomona.edu)

Introduction: Over 150 giant radial lineament systems characterized by extensional structures were first identified on Venus via a C1-MIDR resolution (225 m/pix) reconnaissance survey [1]. On morphological grounds, most radial systems (~3/4) appear to require shallow dike emplacement, with the remainder more plausibly related to domical uplift or a combination of the two [1]. Augmenting previous efforts to test this inference quantitatively [2-4], here we investigate the relative contribution of each mechanism to surface dilation by comparing mapping-derived hoop strain at 8 radially fractured systems (15S, 215E; 28.5S, 232E; 14N, 39E; 6S, 262E; 8S, 243.5E; 13.5N, 291.5E; 39.5S, 296.5E; 34N, 21.5E) with the strains produced in an axisymmetric elastic model as a magma chamber inflates to produce the observed topography. Using different strain-per-lineament values, and exploring different edifice construction/uplift ratios when accounting for the observed topography, we quantify the minimum degree of dike involvement. Our results indicate this technique is quite useful for assessing strain on pre-nova domes and on the flanks of the many mature structures where the strain per lineament is more likely to be of low magnitude [5].

Methods & Results: Following [4] we quantify hoop strain associated with radial lineaments mapped in ArcGIS and compare them with strains produced by COMSOL models of uplift under different starting conditions. Pre-uplift topography is quantified by

$$z(r) = \frac{f^2 d}{r^2 + f^2},$$

where d is the apex height of the edifice (varied from 0-75% of an edifice's topography, representing different degrees of edifice construction prior to uplift) and f denotes the angle of slope as a function of width [6]. The solid volcanic edifice, like the host, is assigned basaltic properties [7]. However, while the subedifice lithosphere is subjected to lithostatic pre-stress, the edifice is assumed to be constructed rapidly and therefore no pre-stress is used in the model [cf. 8]. A body load $-\rho g$ (ρ = 2900 kg/m^3, g = 8.89 m/s^2) is applied in the z direction, and the model's bottom and lateral boundaries are assigned roller conditions to create the desired state of stress. Once the edifice height d is set, magmatic inflation produces uplift until observed existing topography is matched. The resulting strain is compared to mapping-derived values for strains per lineament ranging from 5-100%, with 100% dilation translating to a lateral displacement across each lineament of 75 m (FMIDR image resolution) [4]. After assessing what percentage of the observed hoop strain can be produced by magmatically-driven elastic uplift, we propose that the remainder of the strain is likely caused by shallow subsurface dike emplacement.

Discussion: To maximize the potential for explaining radial lineament deformation without invoking subsurface dike emplacement, we first assume the topography at each of our eight features is a product solely of uplift (i.e., d = 0). Modeling-derived strains fit the mapping-derived strains for all features when strain-per-lineament values are 5-15%, similar to [4]. If all topography is due to uplift, then strain-per-lineament values would need to be higher than the value matched by the uplift to require dike involvement (Fig. 1).

It is unlikely, however, that existing edifice topography is due purely to uplift because surface eruption and construction are also expected to contribute significantly. To account for various degrees of pre-uplift construction, we build edifices with d set to 25, 50 and 75% of observed existing topography prior to applying magmatic uplift. Strain values for these initial conditions are calculated, normalized and compared (Fig. 2).

By optimizing the case against dike injection (d = 0) and then examining three additional construction/uplift scenarios, our strain quantification method shows that, even if uplift plays a role in the formation of a volcanic edifice, lateral dike injection is necessary to produce observed degrees of hoop strain. Greater initial construction/uplift ratios yield proportionately smaller strains due to uplift. Dikes or other forms of construction are then increasingly necessary to explain map-derived strain. Even in a case where only 25% of the existing topography is explained by construction, dike emplacement is necessary to account for ~50% of the flank deformation for all features analyzed.

A limitation of our method, which accounts consistently for flank strains via the assumption of an established strain per lineament, is that strains near the focus of a given lineament system are often accommodated by a small number of large grabens [2] produced by inelastic deformation [5], leading to a sharp underestimation of strain in these areas when our method is employed (Fig. 3). To compensate, we assessed strains only beyond a radial cut-off distance denoting the observed extent of the larger graben plexi (Figs. 1,3). In addition, while variable from feature to feature, late-stage eruptions often obscure portions of a lineament system; while quantification of strain via mapping can adjust for such obscuration in various ways [4], we have not done so here to maximize reproducibility. Taking flooded areas into account will increase the mapped strain at a given radius, elevating the degree of dike emplacement required at any affected system.

References: [1] Grosfils, E.B. and Head, J.W. (1994), *GRL*, *21*, 701-704. [2] Grindrod, P.M. et al. (2005), *JGR*, *110*, E12002. [3] McGovern, P.J. et al. (2014), *Geology*, *42*, 59-62. [4] Grosfils et al. (2014), *LPSC*, Abstr. #1506. [5] Gerya, T.V. (2014), *EPSL*, 391, 183-192. [6] Currenti, G. and Williams, C.A. (2014), *PEPI*, 226, 14-27. [7] Schultz, R.A. (1993), *JGR*, 98, 10883-10895. [8] Galgana, G.A., McGovern, P.J. and Grosfils, E.B. (2011), *JGR*, 116, E03009.

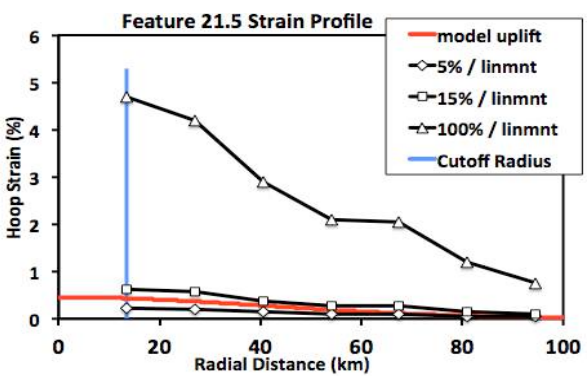

Fig. 1a

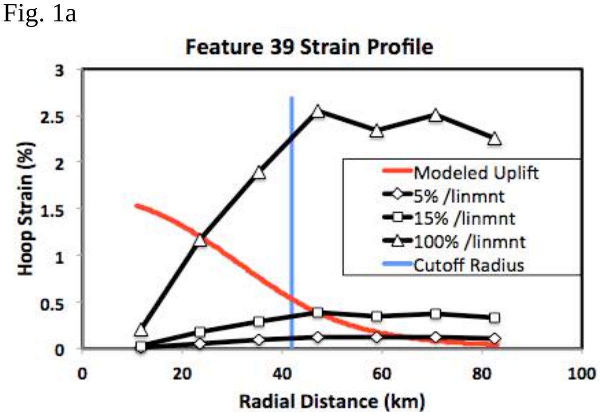

Fig. 1b

Figure 1. *Model- and map-derived hoop strain for features (a) 21.5 and (b) 39. Red line is strain from uplift model with d = 0. Black lines depict strain assuming 5% (4m), 15% (11m) and 100% strain per radial lineament. Blue line depicts cut-off distance, interior to which our assumptions are violated by the strain accommodated by strain occurring at unusually large grabens.*

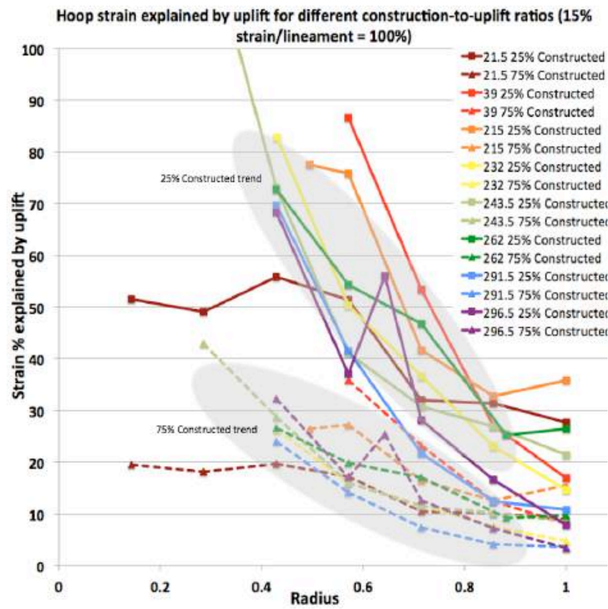

Figure 2. *Model-derived hoop strains for each of 8 features analyzed; radius is normalized to 1. Construction/uplift ratios of 25 (solid) and 75% (dashed) are shown. The 25% cases exhibit higher strain for any given feature, and both existing construction values exhibit general downward trends as radial distance increases. The case displayed here assumes 15% strain/lineament, and strain not explained by uplift is attributed to dike emplacement, with typical values of ~50% or more.*

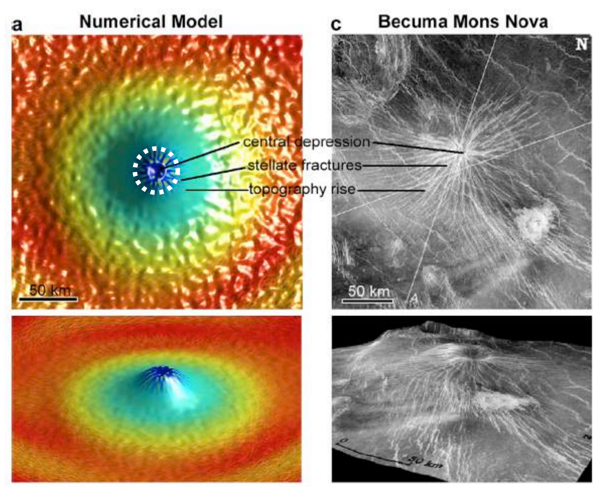

Figure 3. *Topography derived from thermomechanical models of plume-induced crustal convection, including concentrated inelastic deformation near the apex of the domical rise; case shown is Becuma Mons (Feature 21.5). Dashed white line schematically depicts cut-off distance within which strain is accommodated by a small number of large grabens, whereas beyond this distance strain is accommodated by regularly distributed radial lineaments. Adapted from Figure 7 of [5].*