AN ADMITTANCE SURVEY OF LARGE VOLCANOES ON VENUS: IMPLICATIONS FOR VOLCANO GROWTH. A. W. Brian[1,2], S. E. Smrekar[3], E. R. Stofan[1, 2], [1]Proxemy Research, 20528 Farcroft Lane, Laytonsville, MD 20882 (awb@star.ucl.ac.uk), [2]Dept. Earth Sciences, UCL, London, [3]Jet Propulsion Laboratory, Pasadena, CA.

Introduction: Estimates of the thickness of the venusian crust and elastic lithosphere are important in determining the rheological and thermal properties of Venus. These estimates offer insights into what conditions are needed for certain features, such as large volcanoes and coronae, to form. Lithospheric properties for much of the large volcano population on Venus are not well known. Previous studies of elastic thickness (Te) have concentrated on individual or small groups of edifices [e.g. 1,2,3], or have used volcano models and fixed values of Te to match with observations of volcano morphologies [4]. In addition, previous studies use different methods to estimate lithospheric parameters meaning it is difficult to compare their results. Following recent global studies of the admittance signatures exhibited by the venusian corona population [5,6], we performed a similar survey into large volcanoes in an effort to determine the range of lithospheric parameters shown by these features. This survey of the entire large volcano population used the same method throughout so that all estimates could be directly compared. By analysing a large number of edifices and comparing our results to observations of their morphology and models of volcano formation, we can help determine the controlling parameters that govern volcano growth on Venus.

Method: Using the latest 180 degree and order gravity strength map [7], we examined all large volcanoes (>100 km diameter) from a new global database [8] with a topographic-edifice diameter greater than half the local degree strength at their location. Degree strength provides an approximate gauge of data resolution equivalent to the spherical harmonic degree (wavelength) at which the power in the gravity field equals the power in the noise. Of the 51 volcanoes that were large enough, 18 were eliminated because their admittance spectra were too noisy (usually below a degree strength of 65) or so flat that it couldn't be determined if a best fitting model was isostatic, bottom-loading or top-loading. The admittance signatures of the remaining 33 large volcanoes were examined using the spatial spectrum method described below.

The wavelet admittance spectrum is derived directly from the spherical harmonic gravity and topography fields, averaging wavelength power beginning at a central point and moving outward in annuli of variable width [9]. From a global admittance map created by moving the central point of the computational area over a 1º by 1º grid [10], we extracted the region that encompassed the volcano of interest using the commercial spectral analysis package ENVI. The mean admittance spectrum for that region covered by the volcano was then fit with compensation models. An automated routine calculates the best-fit between the observed average admittance and the compensation model, over a specified wavelength range (generally 40-80). The upper bound of the range depends on the local degree strength. The lower bound is chosen based on arguments described by McKenzie [11], which suggest that convective processes in the mantle dominate admittance below degree 40. For each large volcano, we have determined values of crustal thickness (Zc), elastic thickness (Te) and apparent depth of compensation (Zl) using the admittance signature. Model fits were iteratively compared to the observed spectra, and the minimum misfit found by varying Te and Zc by increments of 5 km and Zl by increments of 10 km.

Compensation Models: Following previous works [12,13], we use two simple top and bottom loading mechanical models to interpret the observed admittance. We assume that the lithosphere comprises of two laterally homogenous layers: crust of thickness Zc and mantle lithosphere of thickness Zl, which are loaded by a harmonically varying topography, either at the surface (top loading) or at a compensation depth below the crust-mantle interface (bottom loading). The lithosphere is assumed to be in static equilibrium with stresses supported by the elastic layer, thickness Te. The shape of the admittance spectrum as a function of wavelength is sensitive to whether the elastic lithosphere is flexing in response to a load applied at the surface (e.g. the mass of a volcano – top load), or at depth (e.g. a plume – bottom load).

Results: Of the 33 volcanoes we analysed, the admittance signatures of 22 features were fit with top-loading models and 11 with bottom loading models. A further 3 of the top loaded edifices were also fit with bottom loading models as the exhibited bottom loading characteristics in the admittance signatures. 13 (59%) of the top loaded volcanoes have a Te of <25 km. For these features an elastic thickness of 0 km provides an equally good fit to the data and they are therefore most likely to be isostatically compensated. The remaining 41% have elastic thicknesses that vary from 34 to 79 km. Zc is fixed at 30 km for the bottom loading models but ranges from 0 to 60 km from top loading models. Of the bottom loaded volcanoes, only 2 (7%) have a Te of <25 km. Te ranges from 28 to 91 km for the other 13 (93%). The depth of compensation Zl ranges from 36 to 197 km.

The acceptable ranges for Te, Zc and Zl are those for which the RMS misfit is within 1.5 times the RMS variation of the observed admittance. For top loading models, the mean uncertainty for Te is 12 km and that for Zc is 17 km. Bottom loading models display a mean uncertainty of 13 km for Te and 14 km for Zl. The range of bottom loading models may be larger because any error in the assumed value of Zc will influence the inferred value of Zl.

Implications: Our results show some similarities to previous estimates of Te for various volcanoes around Venus. Keifer and Potter's [2] results for 8 edifices fall within our ranges for the same features; most of these have a Te of <25 km and therefore most likely indicate isostacy. A third of volcanoes in our study are bottom loaded which indicates they are being supported (wholly or partially) from below. This may also indicate that they are currently active. McGovern and Solomon [4] suggested that the largest 25% of volcanoes should have a Te >32 km. We see very large features with low Te's (close to 0 km) and more moderate sized volcanoes with large (55 km) Te's. We do not find a correlation of Te with diameter nor a relationship between Zc and diameter suggesting that small elastic thickness does not inhibit volcano growth to such an extent. We also do not see any correlation with geologic setting, similar to that found for Type 1 and 2 coronae [5,6]. Zl and Zc have large ranges. Variations in Zc may imply either differing densities by region or actual variations in crustal thickness. The large range shown by Zl may be due to dynamic processes still active under the volcano.

Conclusions: This survey provides a quantitive assessment of the lithospheric properties associated with the population of large volcanoes on Venus. We find some correlation with previous studies [e.g. 1,2] but see large volcanoes formed in areas of both thick and thin elastic lithosphere in contrast to the models of McGovern and Solomon [4]. This suggests that elastic thickness is not the sole factor in governing volcano growth on Venus. A third of volcanoes have bottom loading signatures which suggest that some features may still be dynamically supported and currently active. We are in the early stages of analysing the results of this study in comparison to the morphological features of each edifice and therefore hope to further constrain more factors that affect volcano location, formation and evolution on the surface of Venus.

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