**EFFECTS OF DENSITY, ROOT THICKNESS, AND TERRAIN ELEVATION ON ISOSTATIC COMPENSATION OF TESSERAE.** A. R. Baker[1], J. Semprich[1], S. P. Schwenzer[1], J. Filiberto[2], and R. C. Greenwood[1], [1]The Open University (Milton Keynes, MK7 6AA, Aedan.baker@open.ac.uk), [2]ARES Division XI3, NASA Johnson Space Center, Houston, TX 77058, USA.

**Introduction:** The composition and formation mechanisms of tesserae on Venus are still a matter of debate but are of great importance in understanding the history and development of early Venus [1].

Here, we use thermodynamic modeling to compute phase diagrams and extract rock densities for several potential compositions for tesserae. We discuss the initial results of isostasy calculations using densities extracted from a range of possible geotherms [2] and implications for the stability of tesserae of various elevations.

**Methods:** The bulk compositions used for the models are given in Table 1. The basalt used in our model was taken from [3], which is based on Venera 14 measurements [4]. The granitic composition used is a terrestrial granite from the Bad Vermillion Lake greenstone belt collected by [5]. This granite was chosen as greenstone belts are among the oldest remnants preserved on Earth, making for a good comparison to see if Venus could have had a similar tectonic regime to early Earth. Furthermore, Venusian Tesserae resemble Archaean terrain, both featuring high densities of tectonic structures [1]. The alkali basalt was chosen, as it has been used in previous literature [6] to represent a mantle plume setting, as opposed to the more general plains setting represented by the Venera 14 basalt. Finally, the granodiorite was chosen for similar reasons to the granite, as it originates from a greenstone belt [7].

Calculations of the water-free phase diagrams and resulting densities were performed using the Perple_X 6.9.1 Gibbs free energy minimization software [8] and an internally consistent thermodynamic data base [9]. Diagrams presented here were calculated with divalent iron only and the oxides $Cr_2O_3$, MnO, and $P_2O_5$ were excluded as they had little effect on the outputs.

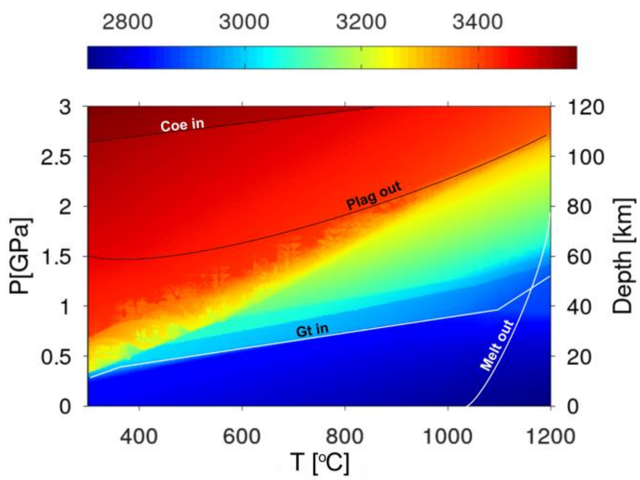


Figure 1: Diagram showing the density changes for a basalt within a range of Venus-like temperature and pressures. Abbreviations used are as follows: Gt – garnet, Plag – plagioclase, Coe – coesite.

The solid solution models used in the calculations included those for clinopyroxene, orthopyroxene, garnet, olivine, and spinel as well as a melt model from [10] and an ilmenite model from [11].

In the basalt model (Figure 1), quartz, kyanite, coesite and rutile were assumed to be pure phases. Corundum was excluded from the basalt calculation as it is not a phase usually found in metabasic rocks.

Densities were extracted along three geotherms of 5°C/km, 10 °C/km and 20 °C/km, assuming a maximum crustal depth of 70 km [12], and a surface temperature of ~470 °C. These geotherms were then used to perform Airy isostasy calculations modelling the thickness of a crustal root of a particular composition that would be required to support tessera of different elevations (Figure 2), as well as the maximum average density of tessera with distinct elevations that could be supported by a uniform crustal root composition of variable depth.

**Results:** Fig 1 shows the densities extracted for the basaltic composition. Close to the surface at temperatures of ~470°C and pressures of ~9 MPa, the

Table 1: rock compositions used in models; component amounts are in wt%

| **Rock** | **$SiO_2$** | **$TiO_2$** | **$Al_2O_3$** | **FeO** | **CaO** | **MgO** | **$K_2O$** | **$Na_2O$** |
|---|---|---|---|---|---|---|---|---|
| Basalt | 48.7 | 1.30 | 17.9 | 8.80 | 10.3 | 8.10 | 0.20 | 2.40 |
| Granite | 73.5 | 0.140 | 14.7 | 1.44 | 1.45 | 0.33 | 3.74 | 4.46 |
| Alkali basalt | 47.9 | 2.80 | 18.0 | 9.60 | 7.70 | 3.30 | 2.70 | 6.00 |
| Granodiorite | 66.1 | 0.656 | 15.8 | 4.68 | 2.78 | 2.01 | 2.12 | 4.83 |

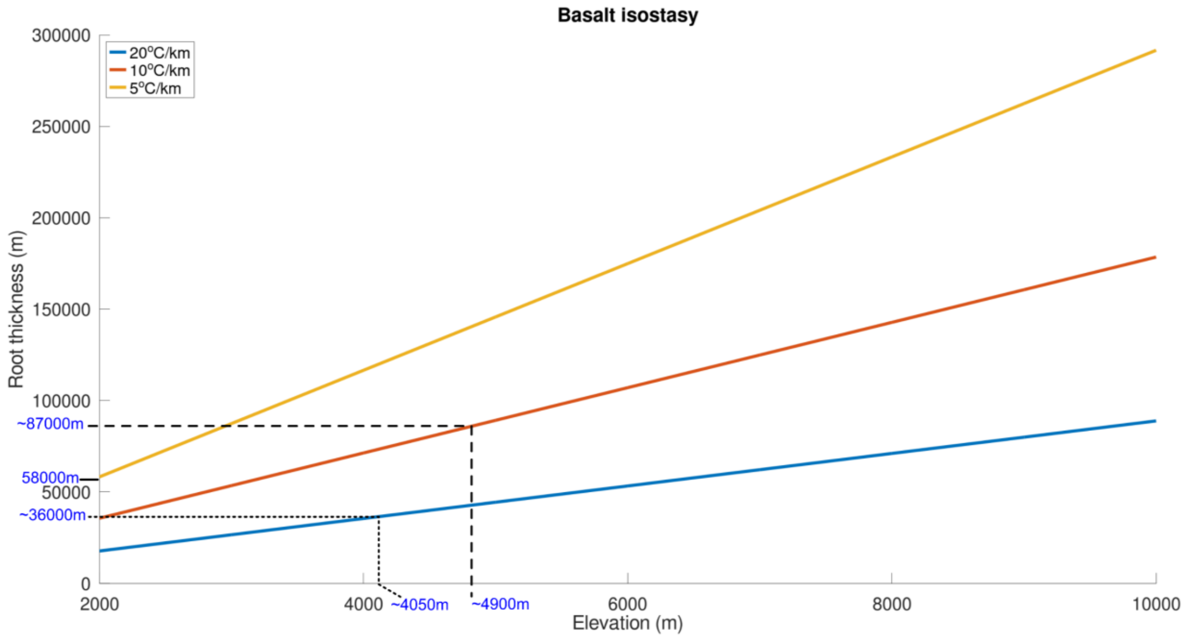


Figure 2: Isostasy plot showing the crustal root thickness required to support a basaltic tessera. Black dotted and dashed lines show the maximum crustal root thickness that can be supported on each geothermal gradient and the corresponding elevation which could be supported. The approximate thickness where a 5°C/km geotherm crustal root would begin to delaminate is marked on the y axis.

densities are in the range of 2900-3000 kg/$m^3$, while at high pressure the densities increase significantly to 3500kg/$m^3$ or more, depending on the temperature.

Major changes in density are caused by garnet forming in a granulite transition, plagioclase being replaced during an eclogitic transition (although the transition is more gradual than is visible in the figure), and coesite formation. Garnet is formed from olivine at relatively low pressures. Plagioclase becomes unstable at around 1.5-2.5 GPa and is replaced by sodic clinopyroxene and kyanite, while coesite forms as a high-pressure polymorph of quartz.

Figure 2 shows the crustal root thickness, which would be required to support a purely basaltic tesserae and root of varying elevations and geotherms. A root with a 20°C/km geotherm is limited by melting beginning at approximately 36km, while roots with 10 and 5°C/km geotherms are limited by delamination when the density exceeds 3300 kg/$m^3$, (used here as an approximation for the Venusian mantle density), at ~85km and 58km respectively.

**Discussion and Outlook:** From previous work [2], it has been deduced that there are different factors that limit the maximum thickness of a crustal root depending on the composition and geothermal gradients.

Assuming a uniform composition of the tesserae and root, these maximum root thickness values would be unable to support tesserae exceeding 4900m in height with a 10°C/km geotherm. A root with a 20°C/km geotherm would have a maximum supported elevation of 4050m and a 5°C/km would be unable to support any tesserae above 2000m. As such, it is unlikely that tesserae of any significant elevation, such as Maxwell Montes, could have a basaltic composition.

Ongoing work is investigating the maximum elevation supported by the other crustal compositions, as well as the effects on density and isostatic compensation of fractionating the melt from the geotherm paths and adding water to the compositions.

**References:** [1] Byrne, P. K. et al. (2020) *Geology*, 49(1), 81-85. [2] Baker A. R. et al. (2022) LPSC abstract #1426. [3] Filiberto, J. (2014) *Icarus*, 231, 131-136. [4] Surkov, Y. A. et al. (1984) *JGR*, B393-B402 [5] Wu, T. et al. (2016) *Precambrian Research*, 282, 21-51. [6] Teffeteller H. et al. (2022) Icarus, 384, 115085. [7] Papunen H. et al. (2009) *Geological survey of Finland.* [8] Connolly, J. A. D. (2005) *EPSL*, 236, 524-541. [9] Holland, T.J. B. and Powell, R. (2011) *J. Met. Geol*, 29, 333-383. [10] Holland, T. J. B. et al. (2018) *Journal of Petrology*, 59, 881-900. [11] White, R. W. et al. (2007) *Journal of Metamorphic Geology*, 25, 511-527. [12] James, P. B. et al. (2013) *JGR:Planets*, 118, 859-875.