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MODELING MELT FRACTIONATION IN THE VENUSIAN MANTLE AND IMPLICATIONS FOR BASALT COMPOSITION.

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Introduction: Surface measurements of the Venera and Vega landers [e.g., 1] and terrestrial crystallization experiments [2] record compositional differences in Venusian basalt. This magmatic diversity can derive from variations in melting depth and volatile content in the source rocks [2] but also be a result of melt fractionation. Constraining the influence fractionation on melt composition is hence crucial to better understand melting processes of the venusian mantle and to establish a link to the compositions of basaltic surface rocks.

Here, we use petrological modeling to determine the effect of melt fractionation on melt compositions and mineralogy of the restitic mantle for a range of thermal gradients and compare them to surface basalt analyses.

Methods: The Gibbs free energy minimization software Perple_X 6.9.1 [3] and an internally consistent thermodynamic dataset [4] was used to model phase equilibria and extract melt compositions. We used a terrestrial peridotite [5] as starting composition since the venusian mantle is assumed to be compositionally similar to Earth's [6]. Phase diagrams were computed for temperatures of 450–2050 °C and pressures of 0.001-8 GPa. The oxidation state was assumed to be reducing by adding 0.01 wt % O_2. We used solid solution models for olivine, orthopyroxene, clinopyroxene, garnet, spinel, melt, [7] and plagioclase [8]. Phase proportions and melt compositions were extracted on thermal gradients of 5, 10, 15, 20 and 25 °C/km with and without melt fractionation.

Results: Figure 1 shows modal proportions of solid phases and melt plotted against depth for three thermal gradients. Only the relatively low thermal gradient of 10 °C/km passes through the plagioclase, spinel, and garnet stability fields (Fig. 1a). The onset of melting is shifted towards shallower depths with increasing thermal gradients and is >100 km for the 10 °C/km and ~ 38 km for the 20 °C/km thermal gradient. In the models where the melt is fractionated (dotted lines in Fig. 1), olivine and orthopyroxene proportions increase in the restite.

The modeled melt compositions for non-fractionated and fractioned melts are shown as oxide plots: SiO_2 vs MgO (Fig. 2a) and FeO vs MgO (Fig. 2b). On the low thermal gradient of 5 °C/km no significant compositional difference is observed between batch and fractionated melts. On higher thermal gradients (15-25 °C/km), the fractionated melt can be significantly more enriched in SiO_2 and FeO.

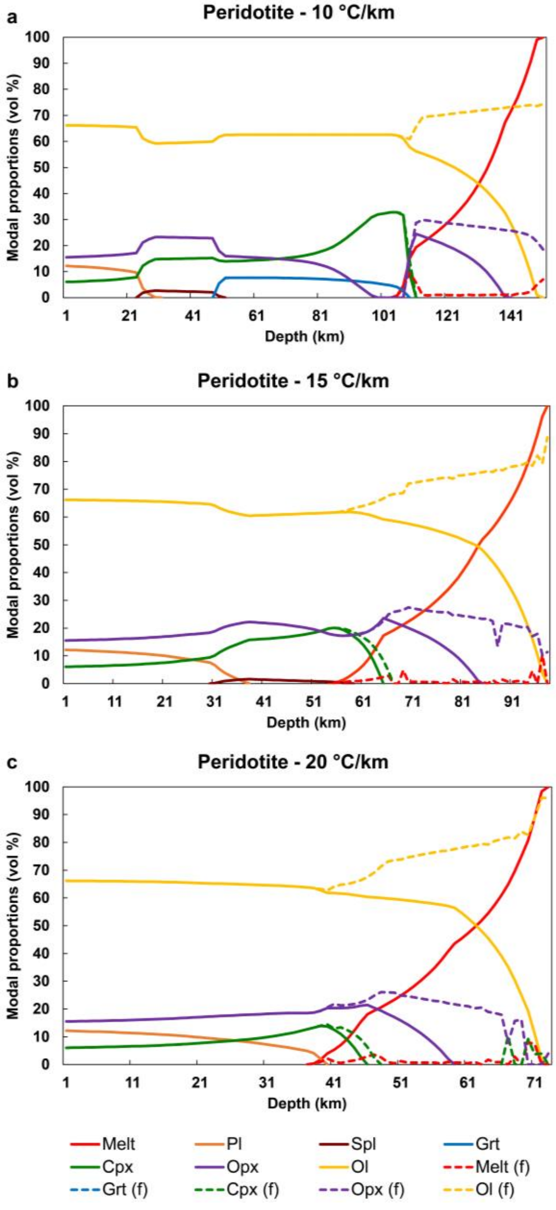

Figure 1: Phase proportions plotted versus depth for 10 (a), 15 (b) and 20(c) °C/km thermal gradients. Abbreviations: Pl – plagioclase, Spl- spinel, Grt – garnet, Cpx – clinopyroxene, Opx – orthopyroxene, Ol – olivine. Solid lines represent batch melting, while dotted lines show phase proportions with melt fractionated along each thermal gradient.

The SiO$_2$ and FeO contents for Venera 13 and Vega 2 analyses plot within the range of non-fractionated and fractionated melt. The Venera 14 composition has higher SiO$_2$ and lower MgO, which overlaps with some of the fractional melts but also ~8.8 wt % FeO, which does not match any of the modeled melt compositions.

Discussion: Large uncertainties of the geochemical data from Venera and Vega analyses and the low total of the Vega 2 analyses either due to missing elements or alteration make the derivation of conclusions difficult. The Venera 14 and Vega 2 basalt have been interpreted as tholeiites suggesting relatively shallow melting of a hydrous lherzolite or peridotite [2], which is supported by the modeled melts. The higher silica content of the Venera 14 composition may be due to fractional melting of a slightly depleted mantle source. Alternatively it could derive from a basaltic source [9]. The Venera 13 basalt was interpreted to be an alkali basalt which could have formed by deep partial melting of a carbonated source region [2] to account for the high K$_2$O content. Due to the low amount of melting, fractional melts can also contain significant amounts of K2O (not shown in Fig. 2) and the Venera 13 basalt may have formed by fractionation processes. However, the proportion of fractionated melt in our models is relatively low (<5 vol 5), and these melts may therefore not be transported to the surface.

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References: [1] Surkov, Y.A. et al. (1984), *JGR, 89*, B393-B402. [2] Filiberto, J. (2014), *Icarus, 231*, 131-136. [3] Connolly J.A.D. (2005), *EPSL 236*, 524-541. [4] Holland T.J.B. and Powell R. (2011), *JMG 29*, 333-383. [5] Davis F.A. et al. (2009), *Am Min*, *94*, 176-180. [6] Fegley B. (2014) *in Venus, Treatise on Geochemistry*, 127-148. [7] Holland, T.J.B. et al. (2018). *J Pet 59*, 881-900. [8] Jennings, E.S. and Holland, T.J.B. (2015), *J Pet 56*, 869-892. [9] Semprich J. and Filiberto, J. (2023) 54th LPSC, Abstract #1468.

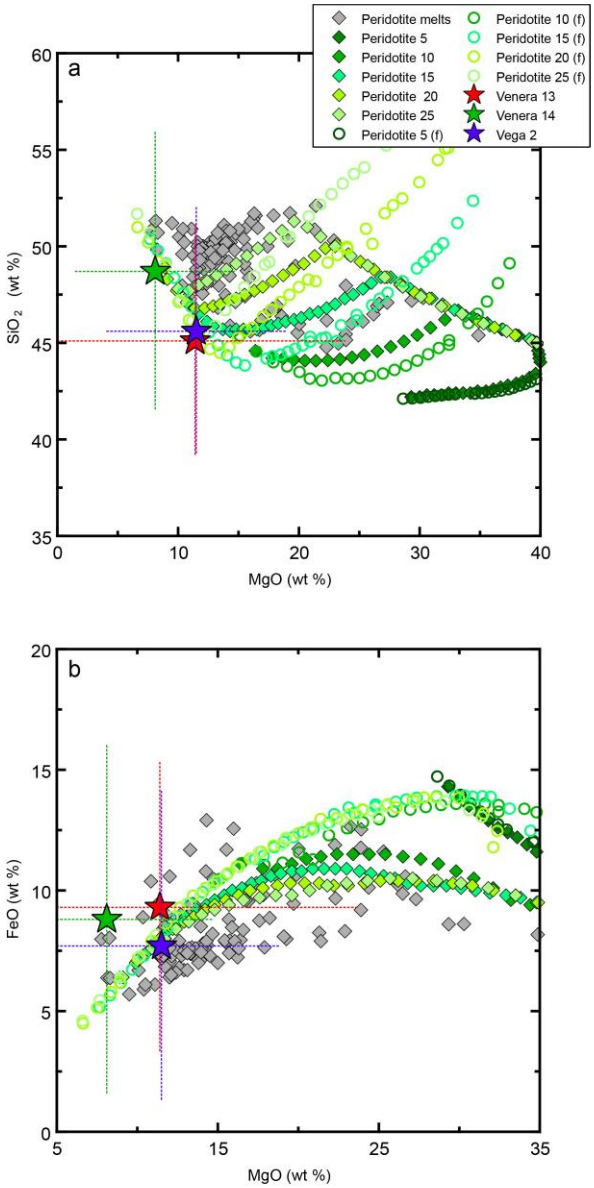

Figure 2: SiO$_2$ (a) and FeO (b) vs MgO for modeled melt compositions derived from peridotite during batch (diamonds) and fractional (open circles) melting on thermal gradients of 5, 10, 15, 20 and 25 °C/km. Stars represent Venus surface compositions.