

COMPOSITIONAL VARIATION OF VENUSIAN MELTS AS A FUNCTION OF THERMAL GRADIENT AND PROTOLITH. J. Semprich¹ and J. Filiberto², ¹AstrobiologyOU, The Open University, Walton Hall, Milton Keynes, MK7 6AA, UK (julia.semprich@open.ac.uk), ²ARES Division, XI3, NASA Johnson Space Center, Houston, TX 77058, USA.

Introduction: Average surface pressure and temperature conditions of 92 bars and 460 °C and thermal gradients in the range of 5-25 °C/km [e.g., 1,2] and up to 50 °C/km for specific cases [3] on Venus suggest that the lower crust and upper mantle are exposed to conditions suitable for partial melting. Further, constraints from terrestrial crystallization experiments are indicative of magmatic diversity on Venus due to variations in melting depths and volatile content [4]. Here, we use phase equilibria modeling to determine the melt compositions resulting from partial melting of a mantle protolith and two mafic crustal compositions for several Venusian thermal gradients. The modeled melt compositions are then compared to experimental eclogite and peridotite melt compositions and analyses from the Venusian surface to further constrain melting processes.

Methods: We modeled equilibrium assemblages and partial melting using the thermodynamic software package *Perple_X* which calculates phase equilibria by means of Gibbs free energy minimization [5] using an internally consistent thermodynamic dataset [6]. The following three whole-rock compositions were used in our models: a peridotite [7], a basalt [4,8] and an alkali basalt [9]. We used a terrestrial peridotite since the bulk density of Venus implies a peridotitic composition of the Venusian mantle [10]. The basalt composition is based on analysis of the Venera 14 lander [8, 11] and terrestrial analogs [4]. The alkali-rich composition was taken from Svalbard [9], which is chemically similar to the Venera 13 analysis [8].

Models were calculated in the dry SiO₂-TiO₂-Al₂O₃-Fe₂O₃-FeO-MgO-CaO-Na₂O-K₂O-system. Fe₂O₃ was set to 0.3 wt% for the peridotite and to 10% of total iron in the mafic crustal compositions. We used solid solution models for olivine, orthopyroxene, clinopyroxene, garnet, spinel, melt [12], plagioclase [13,14] and ilmenite [15]. We extracted melt compositions at >10 vol% and the melt was not fractionated.

Results: Figure 1 shows major oxides versus MgO for the modeled melt compositions on thermal gradients in the range of 5-25 °C/km, experimental peridotite [16-20] and eclogite [21-24] melt compositions and the geochemical data from the Venera 13, Venera 14, and Vega 2 missions [4,8]. Most calculated melt compositions for peridotites are in the range of the experimentally derived melt compositions, except for the melt on the 5 °C/km thermal gradient, where the first

melt is formed at depths of ~270 km. For all other geotherms, MgO is lowest at shallow depth and increases with depth and melt volume and can therefore be used as an indicator for melting conditions. Most melts derived from the basaltic protolith are within the range of experimental eclogite compositions, while melts formed from the alkali basalt only partially overlap with experimental results due to compositional differences of the starting compositions. The Venera 13 and Vega 2 analyses generally plot in the range of modeled and experimental peridotite melts although they both show lower CaO and Venera 13 has unusually high K₂O. The composition of Venera 14 consistently plots at the transition between eclogite and peridotite melts.

Discussion: Large uncertainties of the geochemical data from Venera and Vega landers and the low total of the Venera 2 analysis either due to missing elements or alteration [8] make the derivation of a conclusive formation depth and protolith challenging. However, our models indicate that compositions comparable to those analyzed on the Venusian surface can either form by low amounts of melting of peridotite in the upper mantle at ~33-62 km depth depending on thermal gradients, or by high amounts of melting of a metamorphosed basaltic protolith in the deep crust (~30-50 km). Venera 14 and Vega 2 have been identified as tholeiites suggesting relatively shallow melting of a hydrous lherzolite or peridotite [4], which is corroborated by our models although a crustal origin for Venera 14 cannot be excluded. Venera 13 was interpreted to be an alkali basalt which could have formed by deep partial melting of a carbonated source region [4] that could explain the high K₂O. Since our dry model calculation cannot reproduce these high amounts, further modeling including volatile components, as well as fractionation during melting and crystallization could provide further constraints. Our models can hence contribute to a better understanding of formation mechanisms of the Venusian crust once the upcoming Venus missions return more precise data from surface rocks.

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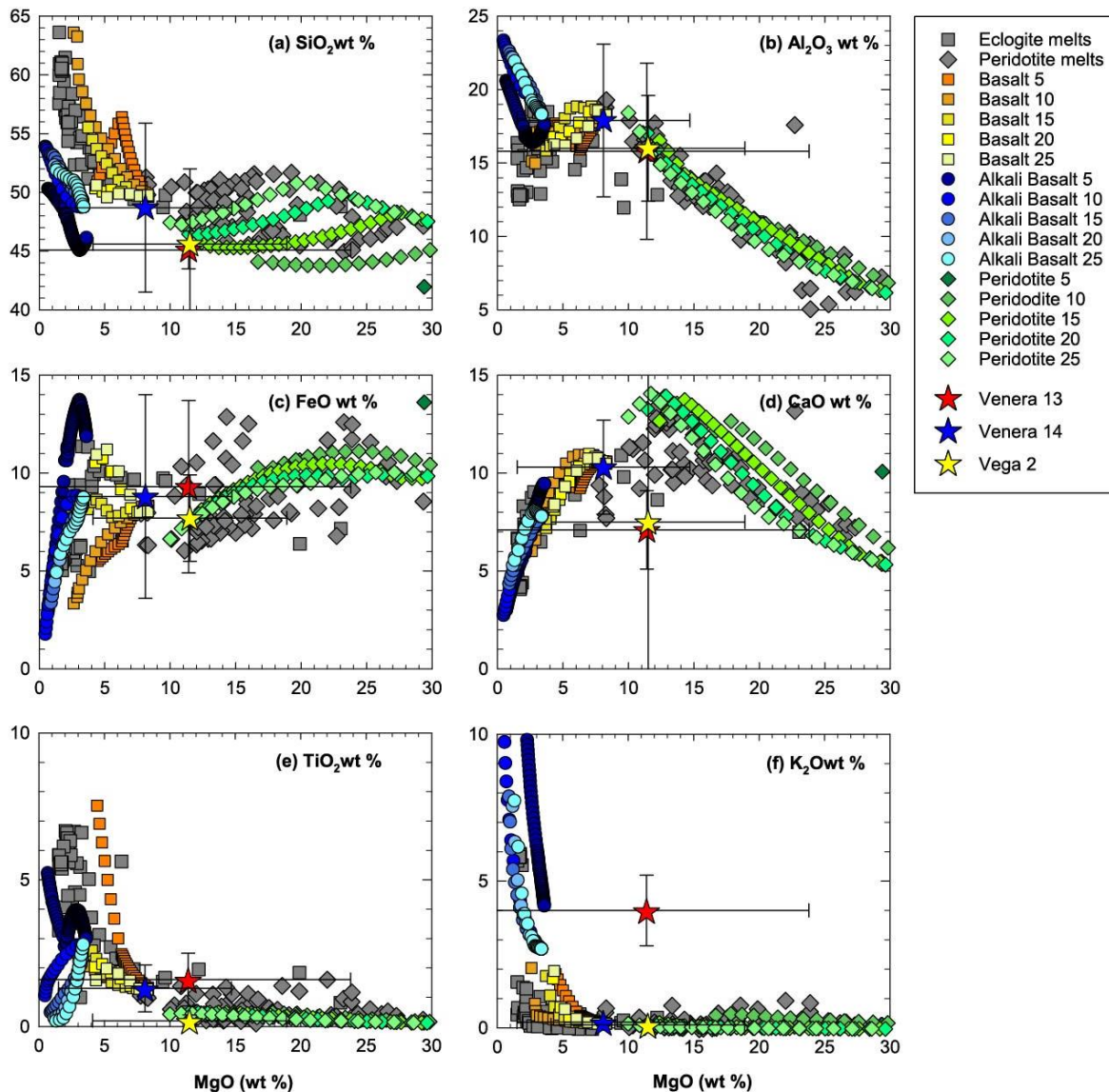


Figure 1: Major oxides vs. MgO for the modeled melt compositions derived from peridotite (green diamonds), basalt (orange and yellow squares) and alkali basalt (blue circles). Numbers represent the thermal gradients ranging from 5 to 25 °C/km. Gray diamonds and squares show experimental peridotite and eclogite melts, respectively. Stars represent Venus surface compositions.