GEOCHEMISTRY OF VENUS BASALTS WITH CONSTRAINTS ON MAGMA GENESIS. J. Filiberto[1] and A.H. Treiman[2], [1]Geology Dept., Southern Illinois University, MC 4324, Carbondale, IL 62901 Filiberto@siu.edu, [2]Lunar and Planetary Institute, USRA, Houston, TX 77058.

Introduction: The chemical diversity of planetary basalts has been used to constrain the processes of planetary accretion and evolution; however, without recent mission to Venus to analyze compositions *in situ*, models for Venus rely on Venera and Vega measurements which lack the precision of modern instruments [1-5]. Venus basalts are thought to be similar in composition to terrestrial basalts, and therefore models of terrestrial magma formation and evolution have been used to understand Venus' interior [1, 2, 4, 6-8]. With renewed interest in this data and with understanding the Venus interior, and with the NASA New Frontier's call for a Venus *in situ* mission, we will review what is know about the chemistry of Venus magmas, constraints on their petrogenetic history, and discuss the uncertainties in these models.

Data Source: Seven Soviet lander missions provided chemical analyses of rocks on the surface of Venus (Venera 8, 9, 10, 13, and 14 and VEGA 1 and 2). Venera 13, 14, and VEGA 2 provided the only major element bulk chemistry of these rocks; while the other missions provided a subset of elemental analyses [1, 2, 6, 23, 24].

Venus Geochemistry:

Trace Elements. The Venera & VEGA spacecraft determined the local abundances of U, Th, and K from their intrinsic radioactivities [1]; these elements are expected to behave similarly in igneous melting and fractionation processes. The U/Th abundance ratios of all analyses are consistent with that of CI chondrites [1], Fig. 1a. However, K/Th (and K/U) values are far below CI (Fig. 1b): ~0.1 x CI for all analyses except Venera 8 at ~0.3x CI. Sadly, no abundances of U or Th are available for the Venera 13 & 14 sites. Calibrations of these analyses are not certain, and it is reasonable (and mostly within uncertainty) that Venus' K/Th (and K/U) ratio is similar to but somewhat smaller than the Earth's.

Abundances of K, Th, and U from Venera 8 are much greater than for the other sites, and suggested that they represent granitic rock or highly alkaline basalt. Unfortunately, no major element analyses are available for Venera 8, and one cannot know why the rock is so enriched nor why the K/Th is greater than other rocks.

Major Elements. The Venera 13 major element analysis is consistent with that of an alkali basalt, while the Venera 14 and Vega 2 analyses are consistent with those of terrestrial olivine tholeiites (Figure 2; [1, 4]).

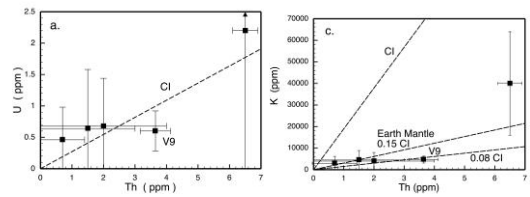


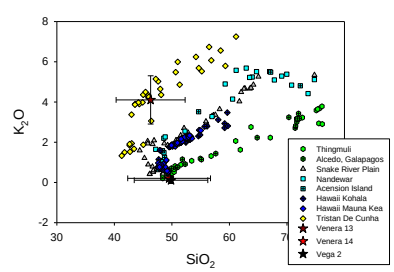
Fig. 1. Abundances of Th, U, and K from Venera and VEGA analyses. Th/U is essentially chondritic (Fig. 1a), while K/Th is distinctly sub-chondritic (Fig. 1b) [1]. For Venera 8 (highest Th, U, K) and 9 and VEGA 1, no major element analyses are available.

Importantly, the interpretation of the Venera 13 analysis as an alkali basalt suggests deep partial melting of a water-poor, carbonated source region; while the Venera 14 and Vega 2 tholeiites suggest relatively shallow melting of a lherzolitic or peridotitic source region [4, 8, 25]. However, Venus basalts (both Venera and Vega analyses) have super chondritic Ti/Al ratios [1] and are enriched in incompatible elements compared with those of terrestrial mid-ocean ridge basalts [26] which suggests similarity to terrestrial ocean island alkalic basalts rather than mid-ocean ridge basalts [1, 4].

Results from petrologic modeling and experimental petrology showed that crystallization of a Venus basalt at shallow crustal levels can produce phonolitic and rhyolitic/granitic compositions [4, 27]. Such evolved compositions in the Venus crust have been suggested based on recent analyses from the Galileo mission [28].

Magma Genesis Conditions. Despite the large uncertainties in the elemental compositions of Venus' basalts, recent work has relied on those analyses in petrologic calculations of the physical and chemical

Fig. 2. K_2O vs. SiO_2 (wt%) for terrestrial rocks for five suites of rocks compared with VEGA and Venera analyses from [4] with data from: [1, 9-22].



conditions of magma genesis [3, 5, 29]. Average pressures and temperatures for genesis of the Venera 13 and 14 basalts are both ~2.4 GPa and ~1410°C; the two estimates for Vega 2 are ~1 GPa and 1370°C or 1778°C. Interestingly, there is no significant (within uncertainty) difference in the P-T formation conditions between the Venera 13 and 14 basalts, even though their compositions (specifically K-content) suggest differences in origin. However, the uncertainty (when reported) for most of the temperature and pressure calculations are >100 °C and >1 GPa [29]. Therefore, the temperature of basalt genesis is consistent with both a ridge system (at lower pressure; [3]) and Hawaii-style volcanism (at higher pressure; [4, 29]) (Figure 3).

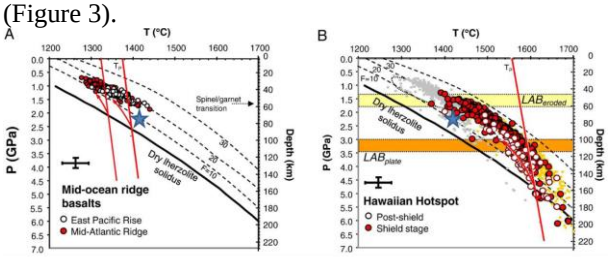


Fig. 3. Pressure and Temperature of magma generation for terrestrial MORBs and Hawaii from [5] with average data for Venus (blue star) from [3, 5, 29].

For Venus *in situ* lander missions, several sorts of elemental analytical systems have been proposed, each with different accuracies and precisions. Treiman and Filiberto [30] showed that, in order to distinguish magma genesis conditions as above, major element analyses with precisions and accuracies like those of MER APXS and those suggested for a Venus lander [31] are adequate to distinguish among varieties of basalts, and to provide adequately precise values for some geophysical parameters of their origins. However, other instruments (such as LIBS) may not be precise enough to constrain magma genesis conditions, but would provide information about the potential diversity of the Venus crust [30].

Conclusions: The available elemental abundance data from Vega and Venera hint that Venus has Earth-like chemistry and magma genesis conditions. Other, remote sensing, data suggest that rhyolites and granites may even be present in the crust, which would suggest that water (or other volatile elements) is present in the mantle of Venus. However, given current uncertainties in the compositions of Venus' crust, it is impossible to distinguish different methods of formation (MORB vs. OIB style melting). Precise geochemical data for Venus basalts, as proposed for a Venus In-Situ Explorer (VISE) lander spacecraft [31, 32], are required to understand both the geochemical diversity and magma genesis conditions for Venus magmas.

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