

THE EFFECT OF PRESSURE ON RESIDUAL LIQUID COMPOSITIONS FROM CRYSTALLIZATION OF A HUMPHREY-LIKE MAGMA: IMPLICATIONS FOR CRUSTAL STRATIGRAPHY IN MARTIAN VOLCANIC PROVINCES. W. R. Woerner¹, E. K. Coraor¹, F. M. McCubbin¹, H. Nekvasil¹, and D. H. Lindsley¹,
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Introduction: Considerable effort has been placed on trying to understand the structure and thickness of the Martian crust beneath the large volcanic structures of the Tharsis and Elysium provinces. Some crustal structure models generated from Mars Global Surveyor (MGS) topography and gravity data have revealed that the shield volcanoes are coupled with significant gravity anomalies [1,2]. The shield volcanoes were assigned a greater density than the surrounding crust to best fit the crustal structure models [1,3]. But this density correction is problematic due to the paucity of compositional data and petrologic knowledge of the shield volcanoes.

Previous studies have suggested that fractional crystallization of Martian magmas may have taken place at areas of thickened crust [4,5]. If a significant density difference exists between the base of the primary crust and the Martian mantle, mantle-derived magma could have ponded and partially crystallized at the base of the crust, followed by ascent of residual liquids to the surface. This process has been suggested in some continental intraplate magmatic regions on Earth. In this case, the cumulate material at the base of the continental crust produces an additional density interface beneath the crust while lavas reflecting residual liquids from fractionation are expressed on the surface [6-8]. Such a process has also been suggested to occur on Mars by [9].

Diverse crustal stratigraphy could arise in the Martian shield volcanoes if continuing episodes of magmatic activity resulted in residual liquids accumulating in the upper layer of the crust. As the crust would thicken due to the episodic ascent and extrusion of liquids residual to fractionation, the ponding pressure of subsequent batches of mantle-derived magma at the crust/mantle boundary would also increase. This increase in pressure may have affected both the nature of residual magmas that would reach the surface, as well as the nature of the cumulus minerals left behind at the crust/mantle boundary. This process could induce significant temporal changes in crustal stratigraphy of the large volcanic provinces.

As a first step in assessing possible compositional and structural stratification of the crust beneath Martian volcanic provinces, we are investigating the crustal stratigraphy that could arise from multiple fractional crystallization events of a primary mantle derived magma at the base of a thickening crust. The Gusev

Crater microbasalt Humphrey (Analyzed by the Mars Exploration Rover (MER) Spirit) was chosen as the starting composition since it is thought to be a primitive basalt that has not undergone fractionation [10-12]. Experiments elucidating the nature of potential residual liquids and cumulus assemblages from ponding of a Humphrey-like liquid at the base of a ~70 km crust were conducted by [13]. In order to assess how significantly pressure affects this system, we conducted additional experiments at 16 kbar (~120 km). These experiments allow us to constrain residual liquid and solid compositions of the youngest magmatism that could have arisen by fractional crystallization beneath the crust of large volcanic structures on Mars.

Experimental/Analytical Details: The Humphrey composition used in the experiments was based on the Humphrey RAT 1 composition reported by [14] with the addition of 1500 ppm Cl (as NaCl) and 5000 ppm F (as CaF₂) as was done by [13]. Since these experiments simulated the late stages of extensive magmatism, it was assumed that little water was left in the source region. Experiments conducted by [13] were "dry" experiments that contained only 0.07 wt% bulk water. The water content was determined by micro-FTIR spectroscopy at the American Museum of Natural History. To achieve this, the mix was loaded into graphite capsules and dried under vacuum at 800°C in the presence of an oxygen getter to prevent oxidation of the starting material. The water content of the 16 kbar experiments has yet to be determined, however, the same drying procedure was used as that reported by [13]. The dried assemblies were placed in extra dense BaCO₃ cells for piston-cylinder experiments. Crystallization experiments were conducted at 16 kbar by first melting for 2.5 hours at pressure and then rapidly cooling to the desired temperature; the runs were left to crystallize for a minimum of 2.5 days.

The compositions of all phases were analyzed by the Cameca Camebax electron microprobe with an acceleration voltage of 15 kV and nominal beam current of 10 nA at Stony Brook University. Additional analysis of the F-bearing glass was conducted at the American Museum of Natural History using the Cameca SX100 microprobe. All analyses were checked for consistency using mass balance calculations of the IgPet Program Suite of [15]. These calculations also yielded phase abundances for each experimental temperature.

Results: Figure 1 shows the residual liquids from crystallization at 16 kbar compared with those produced at 9.3 kbar [13]. At both pressures, a Humphrey parent produces residual liquids that remain basaltic. Furthermore, at both pressures residual liquids evolve along a silica depletion trend, eventually becoming silica-undersaturated (ne-normative). The most significant compositional differences in the evolution of the residual liquids are the decrease in CaO and increase in alumina at the higher pressure, reflecting the dominance of pigeonite and the absence of olivine in the higher pressure assemblage.

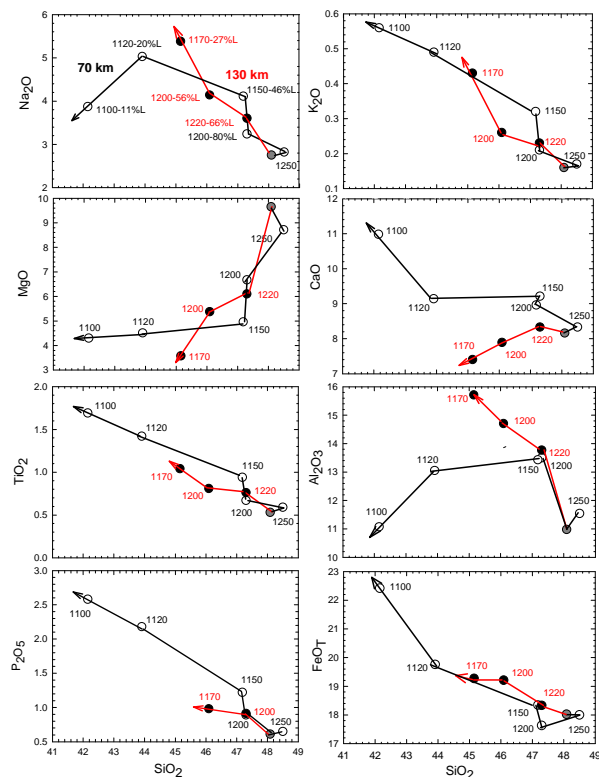


Figure 1. Residual liquid compositions from crystallization of a Humphrey composition parental magma (gray circle) at 16 kbar (black circles) compared with those produced at 9.3 kbar by [13] (open circles). Arrows indicate the down-temperature direction. Temperatures are in °C. The percentage of liquid at each high pressure point is indicated in the Na₂O diagram and given in wt%.

Figure 2 shows the total solid composition at each temperature of the 16 kbar experiments compared with those at 9.3 kbar from [13]. For similar degrees of crystallization, the solid residue at the higher pressure is lower in alkalis and aluminum, and higher in silica and iron than the lower pressure cumulates. Ongoing efforts include further experimentation at 16 kbar under “dry” conditions as well as “wet” and “dry” experiments at 4 kbar (base of a ~30 km thick early crust). Taken together, these data on the compositional evolu-

tion of lavas and deep cumulates provide new insights into crustal stratigraphy and density profiles in regions containing large volcanic structures.

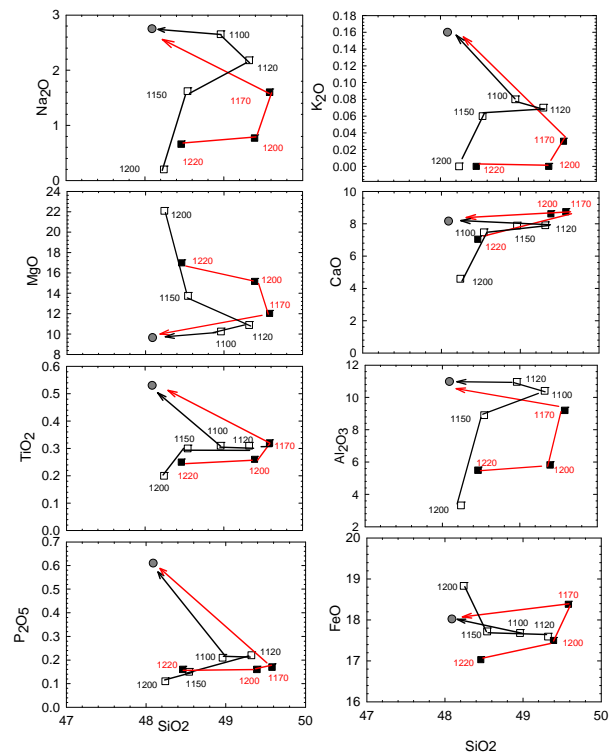


Figure 2. Total solid composition from the crystalline assemblages forming at 16 kbar (black squares) and left at the base of the crust compared with those formed at 9.3 kbar from [13]. Arrows indicate the down-temperature direction. Temperatures are in °C. For clarity, the earliest dunitic solid from crystallization experiments at 9.3 kbar has been omitted.

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