HIGH PRESSURE PHASE RELATIONS AND TRACE ELEMENT PARTITIONING IN APOLLO 14 BLACK GLASS. R. E. Dwarzski, D. S. Draper, C. K. Shearer, and C. B. Agee, Institute of Meteoritics, 1 University of New Mexico, MSCO3-2050, Albuquerque, NM 87131,(dwarzski@unm.edu).

Introduction: Picritic lunar glasses act as probes into the petrologic processes that occurred within the lunar interior, since they were delivered to the surface of the moon from depth as liquids with little to no modification or fractionation. Understanding the phase equilibria and trace element partitioning of phases stable in the picritic glass compositions at high pressure provides a unique insight into the structure of the moon and lunar differentiation processes.

Recent work [1,2,3,4] re-examines whether garnet might be present in the source regions of some of the lunar glasses. Neal and Shearer [4] suggested that the high titanium picritic glass compositions Apollo 12 Red (A12R) and Apollo 14 Black (A14B) retained garnet in the residue after melting. These picrite glasses show elevated values of Zr/Y, Zr/Yb, and $(Sm/Yb)_N$ when compared with mare basalts and KREEP. They suggested that those ratios, in addition with lower Sc/Sm than mare basalts and KREEP, are evidence of retention of garnet in their source regions. However, use of such element ratios requires knowledge of whether lunar picritic liquids saturate with garnet and how the elements of interest will partition between those garnets and liquids. Recent work on garnet partitioning in an ordinary chondrite bulk composition [5] showed different partitioning behavior from work on more magnesian compositions appropriate for terrestrial magmatism. Partitioning between the most Ti-poor lunar glass (Apollo 15 green C) and coexisting garnet [3] is also substantially different for some key elements than in terrestrial compositions.

This study examines the possibility of whether garnet was retained in the source region of the high titanium pyroclastic glass Apollo 14 Black. To assess this question, experiments to characterize high pressure phase relations of A14B were carried out, the trace element partitioning between garnet and melt was measured, and non-modal batch melting was modeled based on those D-values, where D is the weight ratio of a given element between crystal and melt.

Experimental and Analytical Approaches: Experiments on A14B were performed in the High Pressure Laboratory at the Institute of Meteoritics. The experiments ranged in pressure from 3.5 to 7.0 GPa and were carried out using a Walker-style multi-anvil press. The starting material for these experiments was a synthetic A14B oxide mixture prepared by [6] for melt density experiments. All experiments were run in graphite capsules under nominally anhydrous conditions. A14B is the most Ti-rich of the lunar picritic glasses (16.4 wt %), and has 34.0 wt % SiO_2, an Mg# (molar Mg/Mg + Fe) of 0.49 and CaO/Al_2O_3 = 1.5 [7].

The starting composition was doped with Sc, Sr, Y, Zr, Ba, Hf, Nd, Sm, Dy, Yb, and Th at ~300 times chondritic abundance, in order to analyze via ion microprobe. Major elements were analyzed by the JEOL 8200 Electron Microprobe at the University of New Mexico. Trace elements were analyzed by the Cameca 4f Secondary Ion Mass Spectrometer, also at UNM.

Results: Table 1 displays run conditions and the resulting phase assemblages of high pressure experiments.

Run no.	P, GPa	T, °C	Assemblage
A105	3.5	1600	Liq
A80	5.5	1850	Liq
A82	5.5	1750	Liq
A85	5.5	1650	Liq, gt, ilm
A97	5.5	1675	Liq, gt
A98	5.5	1660	Liq, gt
A119	6.3	1700	Liq, gt
A103	7.0	1650	Liq, gt
A120	7.0	1700	Liq
A129	7.0	1675	Liq
A132	7.0	1650	Liq, gt
A134	7.0	1625	Liq, gt

Table 1. Phase Assemblages from high pressure experiments on Apollo 14 Black. Liq = liquid, gt = garnet, and ilm = ilmenite.

Phase relations. From 5.5 to 7.0 GPa the liquidus phase in all experiments is garnet. This complements the low pressure experiments executed by [8]. They found the liquidus was saturated with Cr-spinel at 1 atm, with olivine between 0.5 and 1.5 GPa, and with low calcium pyroxene and Cr-spinel above 1.5 GPa. Our results show no evidence for a multiple saturation point at high pressure. There is no majorite component to the garnets grown in this study, unlike the small majorite contents of those grown from Apollo 15 Green C [3]. Similar to [8], ilmenite is not a liquidus phase as only one high pressure experiment resulted in crystallation of that mineral. Phase relations presented here are preliminary, and further experimentation will elucidate the high pressure phase equilibria of this composition.

Trace element partitioning. Although D-values measured in this study fall in the general range of literature values for partitioning between garnet and melt, D_{Sc}, D_{Nd} and D_{Yb} differ significantly from terrestrial garnets. Partition coefficients for trivalent cations (REE, Sc, Y) were then fit to the lattice strain partitioning model of Blundy and Wood [9] and resulted in E = 159 ± 58 GPa, r_o = 0.879 ± 0.044 Å, and D_o = 2.27 ± 0.40 (r^2 = 0.957). D values for heavy REE were significantly lower, and those for light REE somewhat higher, than those from more magnesian systems. From this we conclude that the garnets grown from A14B appear to have a lessened ability to fractionate the light from the heavy rare earth elements compared to garnets grown in terrestrial magmas. It is unclear whether iron, titanium, or chromium is exerting the strongest effect, but experiments are underway to further constrain the crystal chemical controls on partitioning between garnet and melt at high pressure.

Discussion: The D-values from this study were used to model non-modal batch melting of the A14B composition using identical formulations to those of [4] but substituting our D-values for the literature values used in that work. Our results allow the possibility that garnet was retained in the source for the high titanium picritic glass. In Figures 1a-1c, the shaded pink regions demark where the actual A14B and A12R data from [4] plot. All mare basalt data are taken from [1] and KREEP data from [4]. Three different sets of D-values were used to model non-modal batch melting of the Apollo 14 Black composition. All three calculations resulted in identical trends, therefore, only the one trend using data from Run A85 is shown. In Figure 1a, the A85 trend results in elevated $(Sm/Yb)_N$ and Zr/Y when compared with mare basalt and KREEP data, which [4] has suggested to be indicative of retention of garnet in the source region. Although the A85 model and actual picrite data in Figure 1b do not overlap, the Zr/Y and Zr/Yb are larger than those ratios for the mare basalts and this is nearly the same trend [3] produced using D-values obtained from A15C experiments. A second mechanism may be required to produce such trends, for example shallow-level assimilation [10]. Finally, in Figure 1c, our modeling predicts Sc/Sm ratios lower than those of the mare basalts, which is exactly where the actual A14B and A12R data plots. Therefore, this modeling supports the hypothesis of [4] that garnet could have been retained in the source region for those high titanium lunar glasses after melt segregation.

References: [1] Neal C. R. (2001) *JGR 106*, 27865. [2] Shearer C. K. et al. (2003) *LPS XXXIV*, Abstract #1456 [3] Draper D. S. et al. (2004) *LPS XXXV*, Abstract #1297. [4] Neal C. R. and Shearer C. K. (2004) *LPS XXXV*, Abstract #2135. [5] Draper D. S. et al. (2003) *PEPI 139*, 149. [6] Circone S. and Agee C. B. (1996) *GCA 60*, 2709. [7] Delano J. W. (1986) *JGR 91*, D201. [8] Wagner T. P. and Grove T. L. (1997) *GCA 61*, 1315. [9] Blundy J. D. and Wood B. J. (1994) *Nature 372*, 452. [10] Neal C. R. et al. (2005) *LPS XXXVI*, this meeting.

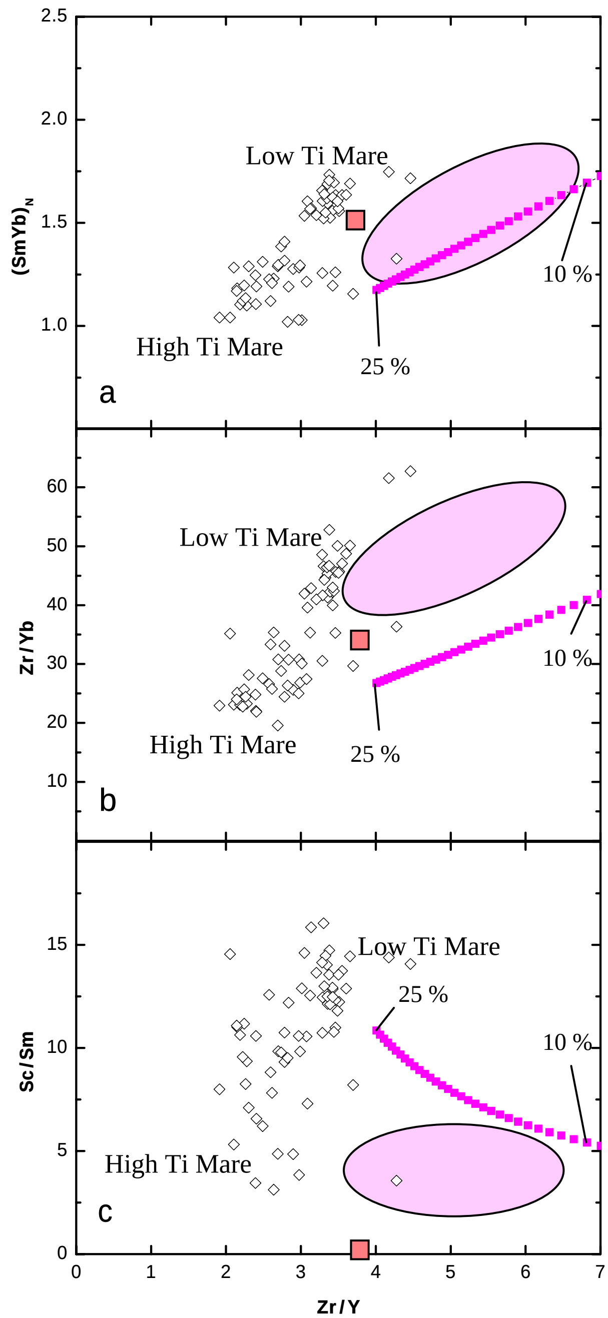

Figure 1. Mare basalt data (open diamonds) from [1]. KREEP (filled square) and region where actual A14B and A12R plot (pink shaded ovals), data from [4]. Elevated Zr/Y, Zr/Yb, and $(Sm/Yb)_N$ signifies garnet retention in the source region after melt segregation according to [4].