MULTI-ELEMENT ABUNDANCES OF INDIVIDUAL MARE VOLCANIC GLASSES BY COLLABORATIVE ELECTRON MICROPROBE AND NEUTRON ACTIVATION ANALYSES: INTERIM REPORT #2. J. W. Delano*, S. S. Hughes*, P. L. Verplanck* and R. A. Schmitt*; *Dept. of Geological Sciences, State University of New York, Albany, NY 12222; †Depts. of Chemistry and Geology and the Radiation Center, Oregon State University, Corvallis, OR 97331.

Multi-element chemistries of individual pristine mare volcanic glass (MVG) spheres from Apollo 14, 15 and 17 soil samples have been obtained using combined EMP and INAA procedures. The intentions of this on-going collaborative effort [1] are to establish not only the trace element patterns and petrologic histories of various MVG types, but also the possible petrologic associations of lunar volcanic glass ejecta and mare basalts (MBs). When possible, trace element patterns have been determined by analyses of several glass samples from each MVG group. These chemical signatures, which can be incorporated into petrogenetic models, represent a compilation of the best values appropriate to separate MVG groups as determined by EMP analyses [2-6].

Several MVG samples analyzed are as small as \( \sim 6 \) pg. Thus, errors in weighing and especially in counting geometries result in up to 50% error factors during INAA of samples weighing less than \( \sim 20 \) pg. Such deviation is avoided somewhat by using data statistically weighted in favor of heavier MVG samples; however, some MVG groups are represented only by samples less than \( \sim 20 \) pg and yield inherently large error margins during INAA counting. Because Fe is easily determined by INAA and EMP, the INAA data for very small MVGs are therefore systematically adjusted to yield FeO values consistent with those obtained by EMP.

Trace element abundances of Apollo 14 VLT and green-A and Apollo 17 VLT (all Array II) MVGs are shown normalized to bulk moon values [7] in Fig. 1. The nearly identical Sc values suggest similar sources and residual pyroxene acting as a Sc buffer during partial melting. This is consistent with liquidus phase relations determined for Apollo 14 and 17 VLT glasses [3,4] which indicated that these VLT magmas came from depths of \( \sim 400 \) km. Negative Eu anomalies, similar to those obtained for lunar mare basalt compositions, are related to plagioclase extraction prior to source cumulate deposition from the lunar magma ocean (LMO) and support a petrologic relation between these MVGs and lunar mare basalts. The \( \sim 16X \) range in LREE abundances possibly relates to large differences in the degree of partial melting and/or amount of LMO magmatic liquid trapped in the source cumulates.

A single Apollo 17 VLT MVG (7.1 pg) falls within the range of four large (2.2-916 mg) Apollo 17 basalt samples [8-10] shown in Fig. 1. Large errors in our La, Yb and Lu counting justify the use of mass weighted abundances in all these samples for the best Apollo 17 VLT MVG composition.

Apollo 15 HT (high Ti) and VHT (very high Ti) MVG patterns compared to Apollo 11 and 17 HT MBs (Fig. 2) indicate some similarities in magma genesis among these types. However, the two nearly identical MVG patterns have Sc = 2.3-2.5X and 20-30% higher LREE relative to the HT MBs having Sc = 4.3-4.5X and a steeper positive LREE slope. The near equivalence of the two Apollo 15 MVG patterns argues for a common magmatic source for HT and VHT MVGs. An equivalent relation may be possible for HT MBs from the Apollo 11 and 17 sites which would justify a regional uniformity in processes affecting their cumulate sources.

Figure 3 illustrates the Apollo 17 orange MVG pattern compared to the
74220 orange glass pattern derived from literature data. The equivalent trace element (and bulk element) signatures indicate that the two orange MVG samples used in this study are coeval with the more accurately analyzed abundant 74220 samples. The Sc ≈2.5X in orange glass is consistent with other HT and VHT MVG compositions, all of which exhibit an ≈20-25% higher Sc relative to Sc in VLT MVG samples.

These new trace element and bulk element data enable the delineation of chemical signatures appropriate for petrogenetic modeling [e.g. 11]. Moreover, the presence of negative Eu anomalies and trace element patterns similar to MB patterns support the lunar magma ocean concept as well as the derivation of MVG magmas from cumulate sources [12-14] and a degree of uniformity in the petrogenesis of similar MVG types. While further constraints will be applied as the EMP/INAA data are refined, research in Sr and Nd isotopic systematics is needed and should enhance such constraints on early LMO-cumulate petrologic evolution.


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