

**COMPOSITIONAL RANGE OF PRIMARY MAGMAS OBSERVED AMONG THE APOLLO 17 ORANGE VOLCANIC GLASSES (74220);** J. W. Delano, Department of Geological Sciences, State University of New York, Albany, NY 12222

**Introduction:** In addition to being a primary magma from the lunar mantle [1-3], the Apollo 17 orange volcanic glasses are the best-sampled deposit of a lunar fire-fountain. As a continuation of previous work [4,5], additional analyses of high-Ti, volcanic glass spherules handpicked from soil sample 74220,680 have been made by electron microprobe in order to acquire more information about processes associated with melt generation and melt eruption on the Moon. The present work has developed microprobe procedures for making high-precision analyses [6] of the major- (Si, Ti, Al, Fe, Mg, Ca) and minor- (Cr, Mn) elements. The JEOL 733 electron microprobe was operated at a 15-keV accelerating potential with a counting time of 300-seconds per element per analysis at a beam current of 75 nanoamps. One homogeneous spherule of Apollo 17 orange volcanic glass was used as a working standard throughout the investigation to assess analytical precision and to fine-tune the calibration. The precisions ( $\pm 2$  sigma) that follow are based on 21 replicate analyses of this working standard: SiO<sub>2</sub> ( $\pm 0.11$  wt%); TiO<sub>2</sub> ( $\pm 0.08$  wt%); Al<sub>2</sub>O<sub>3</sub> ( $\pm 0.02$  wt%); Cr<sub>2</sub>O<sub>3</sub> ( $\pm 0.02$  wt%); FeO ( $\pm 0.09$  wt%); MnO ( $\pm 0.01$  wt%); MgO ( $\pm 0.06$  wt%); CaO ( $\pm 0.03$  wt%).

*Was the 74220 magma compositionally homogeneous throughout the conduit?* If the magma spent some time in a pre-eruptive magma chamber, it would have been homogenized by diffusion and mixing. Alternatively, complex processes associated with dynamic melting may have caused the magma to be compositionally heterogeneous on a large length-scale. To address this latter possibility, which appears to have occurred in the Apollo 14 green 'A' glasses [see accompanying abstract], high-precision analyses were made on 33 spherules of Apollo 17 orange glass. Quenching of the mist of melt droplets during the fire-fountain eruption makes these glass spherules ideal for preserving any primary compositional variations that might have existed within the magma conduit (i.e., each glass bead is a sample of primary melt). While 1.8E08 glass beads (with median diameter of 150 microns [7]) occur in each kilogram of 74220, even *one* vitrophyric sample per lava flow is often not available within the present collection of crystalline mare basalts.

**Two magmas:** High-precision analyses suggest that 74220,680 contains two compositional groups of high-Ti volcanic glass. Although they differ by only 0.4 wt% SiO<sub>2</sub>, the analytical precision is sufficient to resolve '*high-Si*' and '*low-Si*' groups (Figure 1). The fact that these two magmas (a) are compositionally similar and (b) occur in similar proportions within the same pyroclastic-rich soil suggests that these magmas (a) are petrogenetically related and (b) may have been erupted from the same vent (or adjacent vents) at different times (at the same time). Current models for magma petrogenesis involve dynamic melting processes [8-11]. Although equations exist for modelling those processes [9,10], the problem is underconstrained at present due to uncertainties in at least four variables: fraction of partial melting; composition of the lunar mantle; mass fraction of each mineral phase in the source-region as a function of partial melting; fraction of melt remaining in the residue during each melting increment. Since magma heterogeneity is a memory of melt generation and melt segregation processes, the ability to estimate solutions to these complex processes is enhanced by these high-precision analyses.

Both of these magmas define subtle fractionation trends (Figure 2) that in detail are not due to either olivine fractionation or disequilibrium growth of quench crystals within each glass spherule. Although Figure 2 does not allow the '*high-Si*' and '*low-Si*' groups to be independently confirmed, they are nonetheless systematically offset in this plot.

**Redistribution of Na, K during the eruption:** While Na<sub>2</sub>O and K<sub>2</sub>O vary by >20% among the 119 spherules analyzed for these two elements (Figure 3), the ratio remains at  $4.5 \pm 0.3$ . This >20% variation is not a result of low-pressure, crystal/liquid fractionation, but could reflect heterogeneities among the different increments of accumulated melt that segregated from a compositionally heterogeneous volume of lunar mantle. There is also an inverse correlation between Na<sub>2</sub>O and spherule diameter. Within six glasses that were profiled, the Na<sub>2</sub>O abundances were highest near the edges and steadily decreased toward the sphere centers. This distribution indicates that Na was being gained, *not lost*, from these individual melt droplets during the time between eruption of the melt droplet in a fire-fountain and quenching to glass. Diffusion profiles for Na suggest times of 3-5 seconds at the liquidus temperature of 1370°C.

**Constraint on the Moon's origin?** Ratios of alkali elements have been suggested as providing constraints on the Moon's origin [12,13]. Relative to the chondritic Na<sub>2</sub>O/K<sub>2</sub>O ratio of 10 [14], the values measured in four varieties of lunar picritic volcanic glasses range from 10 to 4.5 (Figure 4). Furthermore, since the average highlands crust has a value of about 6 [15], and KREEP has a value of about 1 [16], the bulk Moon value is

## COMPOSITIONAL RANGE OF PRIMARY MAGMAS: Delano J. W.

uncertain. Statements about the origin of the Earth/Moon system based on estimates of alkali ratios for the bulk Earth and the bulk Moon should be viewed with caution owing to the large observed *ranges*. While it is easy to find examples of differences involving a factor of 2 in alkali ratios between lunar and terrestrial samples, there are some notable similarities: (a) the Na<sub>2</sub>O/K<sub>2</sub>O and Rb/Cs ratios in KREEP [16] are comparable to the average continental crust of Earth [17,18]; (b) the Na<sub>2</sub>O/K<sub>2</sub>O ratios in picritic volcanic glasses (Figure 5) are similar to those in Hawaiian basalts [e.g., 19]. However, recent K-isotopic measurements [20] suggest that the alkali fractionations observed in devolatilization experiments [20] have no relevance to planet-forming processes.

**References:** [1] Delano J. W. (1986) PLPSC 16, p. 201-213. [2] Shearer C. K. et al. (1994) *Geochim. Cosmochim. Acta*, 58, p. 5349-5362. [3] Longhi J. (1987) PLPSC 17, p. 349-360. [4] Delano J. W. and McGuire J. (1992) LPI Tech. Rpt. 92-09, p. 7-9. [5] Delano J. W. et al. (1994) LPS-XXV, p. 325-326. [6] Hanson B. et al. (1996) *Amer. Mineral.*, in press. [7] Arndt J. and von Engelhardt W. (1987) PLPSC 17, p. 372-376. [8] Eggins S. M. (1992) *Contrib. Min. Pet.*, 110, p. 398-410. [9] Kinzler R. J. and Grove T. L. (1992) *J. Geophys. Res.*, 97, p. 6907-6926. [10] Langmuir C. H. et al. (1992) *Geophys. Mono.* 17, p. 183-280. [11] Longhi J. (1995) *Geochim. Cosmochim. Acta*, 59, p. 2375-2386. [12] Kreuzberger M. E. et al. (1986) *Geochim. Cosmochim. Acta*, 50, p. 91-98. [13] Norman M. D. et al. (1994) LPS-XXV, p. 1009-1010. [14] Anders E. and Grevesse N. (1989) *Geochim. Cosmochim. Acta*, 53, p. 197-214. [15] Taylor S. R. (1982) *Planetary Science: A Lunar Perspective*. LPI, Houston. [16] Warren P. H. (1989) LPI Tech. Rpt. 89-03, p. 149-153. [17] Rudnick R. L. and Fountain D. M. (1995) *Rev. Geophys.*, 33, p. 267-309. [18] Taylor S. R. and McLennan S. M. (1985) *The Continental Crust: Its Composition and Evolution*. Blackwell. [19] Rhodes J. M. (1983) PLPSC 13, p. 869-879. [20] Himayun M. and Clayton R. N. (1995) *Geochim. Cosmochim. Acta*, 59, p. 2131-2148.

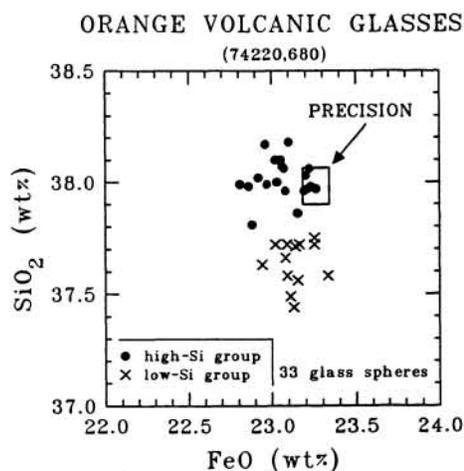


Figure 1

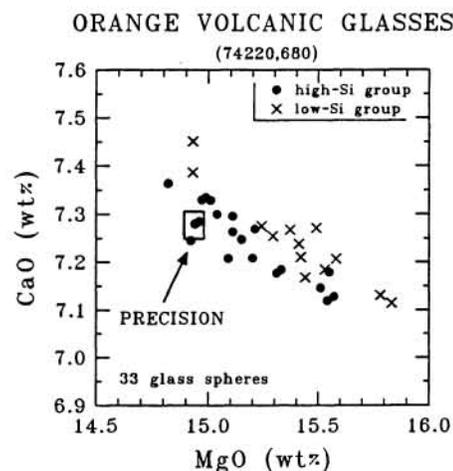


Figure 2

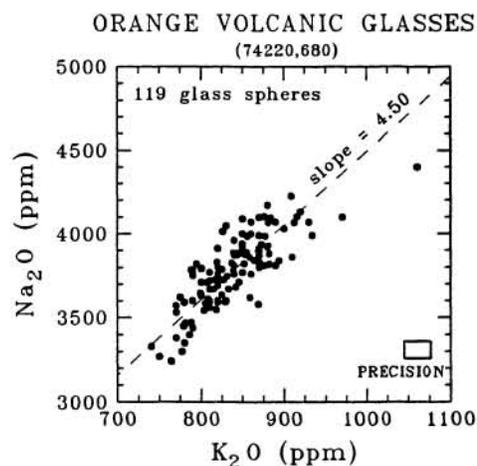


Figure 3

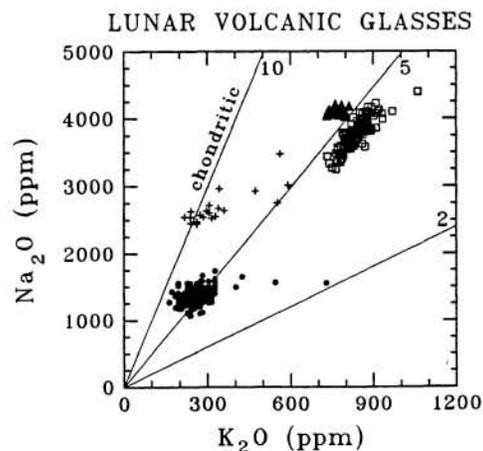


Figure 4. Apollo 15 green glasses (solid circles); Apollo 17 VLT glasses (+); Apollo 15 yellow glass (solid triangles); Apollo 17 orange glass (open squares).