COMPOSITIONAL HETEROGENEITY WITHIN A DUMBBELL-SHAPED APOLLO 15 GREEN GLASS: EVIDENCE FOR SIMULTANEOUS ERUPTION OF DIFFERENT MAGMAS;

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The Apollo 15 green glasses that occur most prominently in 15425, 15426, and 15427 consist of compositionally distinct groups [1-7]. The six groups that have thus far been defined [5-7] are thought to represent different batches of magma [1-11] that were erupted as fire-fountains, probably at different times in lunar history; although isotopic analyses of representative glasses within some of these groups have not yet found any differences in age at the ±100 Ma precision [8]. While the petrogenesis of these picritic magmas has been contentious [e.g., 1,2,4,5,6,7,9,10,11], the discovery of a compositionally heterogeneous, dumbbell-shaped green glass raises additional questions and problems about their origin.

Figure 1 shows a dumbbell-shaped Apollo 15 green glass that was handpicked from 15427,67. Its shape could be either the result of (a) spin-induced fission of a single droplet or (b) accretion of two droplets. The compositional heterogeneity observed within this sample is most readily consistent with the latter view. This sample was ground, polished, and analyzed by high-precision electron microprobe techniques involving the following conditions: 15 keV acceleration potential; 20-micron beam diameter; 50 nA specimen current; 300-second count-time per element per analysis for Fe, Al, Na, K, and S; 150-second count-time on both backgrounds for each element per analysis. At the time of writing this abstract, ***280*** 5-element analyses of this sample have been completed in order to construct the map shown in Figure 1. For the purposes of this report, the relative proportions of Fe and Al will be discussed since these two elements show the clearest evidence for compositional heterogeneity within this volcanic glass. With the operating conditions listed previously, a typical analysis for Fe and Al yielded about 370,000 and 860,000 counts above background, respectively, resulting in a relative error for Fe and Al of ±0.04 wt. % and ±0.01 wt. %, respectively.

Figure 1 shows a preliminary contour map of this green glass using observed values of the FeO/Al_2O_3 ratio (by weight). Since the values for this ratio varied typically between 2.50 and 2.63, only the last two digits are shown in Figure 1 (e.g., "50-54" means that the ratio varies between 2.50 and 2.54). However, Figure 1 is only an approximation to the actual heterogeneity within this glass since the A-A' traverse (Figure 2) displays a complex interfingering on the A-side of the major compositional boundary separating the "60-63" region from the "50-54" region. Mixing is also evident in the lower left portion of the glass where the compositional geometry is complex. This, and other, evidence for mixing between two melt compositions in this dumbbell-shaped glass suggests that two droplets of hot melt collided and were quenched before homogenization could occur. Based on a modified Stefan-Boltzmann equation [12], this 525x260-micron glass would have cooled from its liquidus temperature of about 1410°C [13] at a rate of at least 1000°C/second in a vacuum. At this high cooling rate, the complex interfingering of compositions within this glass may be due more to turbulent mixing caused by the collision of two melt droplets having low viscosity (about 5 poise) than to chemical diffusion. Less probable alternatives to this view might include: (a) collision between a soft melt droplet and a pre-existing glass; or (b) incorporation of a pre-existing piece of green volcanic glass into a later fire-fountaining event and its partial dissolution in the later magma.

The significance of this compositionally heterogeneous, dumbbell-shaped green glass lies principally in the surprise at its existence. The major-element compositions of all analyzed regions within this sample indicate that it belongs to Group A green glasses [1]. Steele and co-workers [5,6,7] have shown that the Group A green glasses, which were defined originally on the basis of major elements only [1,3], actually consists of two sub-groups that are distinguishable on trace-element abundances, principally Sm and other rare earth elements. The data of Steele [5] suggest that these two sub-divisions of the group A green glasses may also be resolvable using high-precision analyses for Fe and Al, as in the current investigation. Although currently speculative, the high ratios in Figure 1 may correspond to the high-Sm group A magma of Steele [5], while the low ratios in Figure 1 may correspond to the low-Sm group A magma of Steele [5]. Ion microprobe analyses would be capable of testing this hypothesis. Nonetheless, the current data seem to show that two volcanic melt droplets collided and merged during an eruption. Either this requires that (a) the magma being emitted from a single vent was compositionally varying on a time-scale of a few minutes (e.g., the ballistic flight-time of a spherule in the lunar vacuum ascending to an altitude of 5 km and falling back to the lunar surface is 2.6 minutes) or (b) two fire-fountaining events occurred simultaneously, and in close proximity, so that droplets from one eruption collided with droplets from another. In either instance, this sample raises questions about

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the compositional uniformity of magmas during individual eruptions. This will have importance in discussions not only for lunar volcanic glasses but also for mare basalts.

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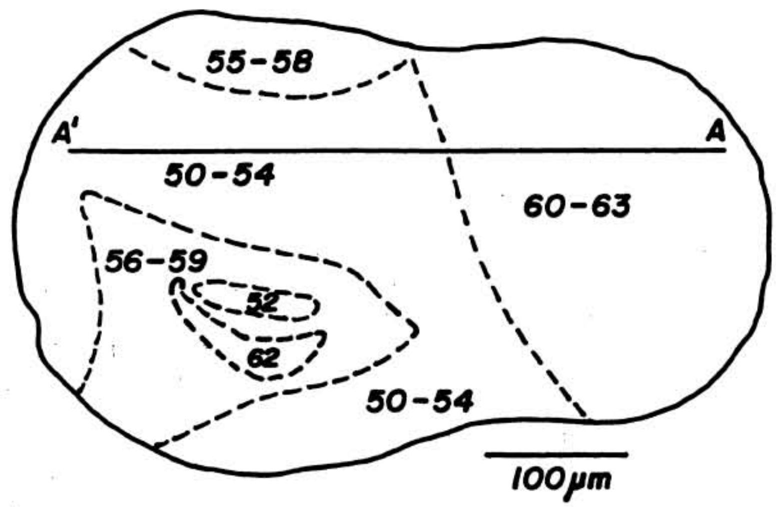

FIGURE 1
Compositional map of the Apollo 15 green glass showing values for the FeO/Al_2O_3 ratio (by weight). Within this sample, the ratio typically varies between 2.50 and 2.63. The numbers shown refer to the two digits to the right of the decimal point (e.g., "50-54" means that the ratio lies between 2.50 and 2.54). The true compositional variation within this green glass is more complex than indicated by this approximation. The map is based on analyses of 280 spots on this glass by electron microprobe.

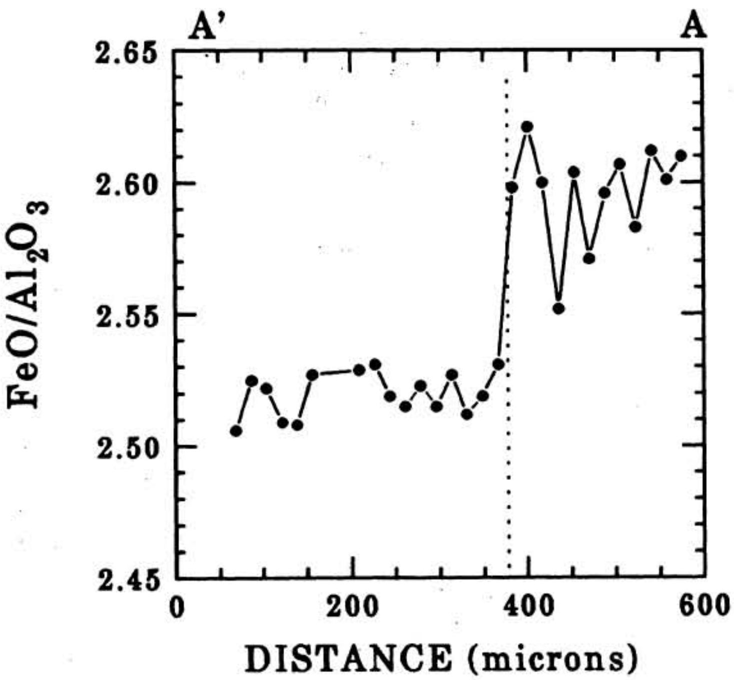

FIGURE 2
Traverse along the A-A' line (refer to Figure 1) showing the variation of the FeO/Al_2O_3 ratio in this Apollo 15 green glass. Note that the boundary between the two sides of the dumbbell-shaped glass, although prominent in this traverse, is characterized by an interfingering of compositions that becomes most apparent near the boundary. The location of the boundary illustrated in Figure 1 between the "60-63" region and the "50-54" region is indicated by the vertical dotted line in Figure 2.