COMPOSITIONAL VARIATION IN LUNAR ULTRAMAFIC GLASSES.

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Analyses of ultramafic lunar glasses returned by Apollo 14 and Apollo 15 are plotted in Figures 1 and 2. Three compositional groups are recognized: Group I includes most Apollo 14 ultramafic glasses and all Apollo 15 green glasses. Group II analyses are similar to those of Group I except that TiO_2 contents are about 1.5X those of Group I analyses. Group III analyses have Fe/Fe+Mg greater than .43, lower CaO and Al_2O_3 contents, and higher TiO_2 contents than Group I.

As noted previously (Best and Minkin, 1972; Ridley et al., 1973), Apollo 15 green glasses form a homogeneous cluster that coincides with the more mafic Apollo 14 glass analyses. These Group I analyses display a trend not previously recognized. Compositional variation along this trend corresponds to addition or subtraction of olivine of composition Fo_{69}(Fig. 1 and 2). The trend is most pronounced when data from a single laboratory are considered; Figures 1 and 2 include analyses from thirteen different laboratories. Systematic interlaboratory biases on identical size fractions of the same soil samples increase the scatter of major element correlations and completely obscure related minor element trends. Group II analyses appear to show the same olivine control as Group I, but there are too few analyses to be certain of this. There are very few Group III analyses and no compositional trend is apparent.

The assumption that Group I compositional variation is indeed caused by olivine control places strong constraints on possible modes of origin. The calculated low-pressure liquidus olivine for the mafic end of the series is Fo_{83} and for the other end, Fo_{81}. Thus neither subtraction of liquidus olivine from a liquid of Apollo 15 green glass composition, nor addition of liquidus olivine to the less mafic of the Group I compositions can account for the observed variation. Such fractionation at depth is likewise inadequate, since high-pressure experiments show that pressures as high as 15 kilobars do not significantly change the composition of the liquidus olivine. We therefore conclude that theories of origin by fire fountaining (Reid et al. 1973), a lava lake (Prinz et al., 1973), and equilibrium partial melting at depth (Green and Ringwood, 1973) are incomplete in that they fail to account for the systematic compositional variation shown by Group I glasses.

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Equilibrium crystal-liquid fractionation can account for the observed trend only if olivine (Fo_{69}) is preferentially added to or removed from a mixture of olivine, pyroxene, and liquid. Alternatively, mechanical mixing of olivine (Fo_{69}) with other components (not equilibrium liquids) is required. It has been suggested (Ridley et al., 1973) that the ultramafic glasses are samples of the lunar interior excavated by cratering events. If their source is within the mafic cumulate complementary to the feldspathic crust, the REE pattern requires that accumulation of the parent rock preceded feldspar precipitation.

The vapor condensation hypothesis proposed by Cavarretta et al. (1973) to explain the major element homogeneity of Apollo 15 green glasses fails to account for the variation shown by closely similar Apollo 14 analyses. Furthermore, the correlation of the contents of certain volatile trace elements with increasing sphere size noted by Cavarretta et al. is equally well explained as a result of differential volatilization.

The ultramafic glasses are similar in major element composition (Marvin et al., 1972) and in REE pattern (Ridley et al., 1973) to howardite meteorites. In addition to the small compositional differences noted by Ridley et al., the average MnO content for howardites is about 2.5X that in the ultramafic glasses. However, the LeTeilleul meteorite and the glass spheres recently reported in Kapoeta (Brownlee and Rajan, 1973) are almost perfect matches to Group I analyses (Fig. 1 and 2). These general chemical similarities and the remarkable morphological and chemical correspondence of the green glass spheres in Kapoeta and the lunar green glasses suggest that the relationship between the howardites and the lunar ultramafic glasses may be more than coincidental. If the ultramafic glasses are remnants of howardite impacts on the moon, it would help explain the ubiquity of ultramafic glasses despite lack of equivalent lunar rock types. Whatever the green glass provenance, addition or subtraction of olivine is required to explain the compositional variation.

REFERENCES. Best and Minkin (1972), The Apollo 15 Lunar Samples, L.S.I. publ., p. 34. Brownlee and Rajan (1973), Science 182, p. 1341. Cavarretta et al. (1972), The Apollo 15 Lunar Samples, L.S.I. publ., p. 202. Green and Ringwood (1973), E.P.S.L. 19, p. 1. Marvin et al. (1972), Lunar Science III, L.S.I. publ., p. 507. Prinz et al. (1973), EOS 54, p. 605. Reid et al. (1973), EOS 54, p. 606. Ridley, et al. (1973), P.E.P.I. 7, p. 133.

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Figure 1.

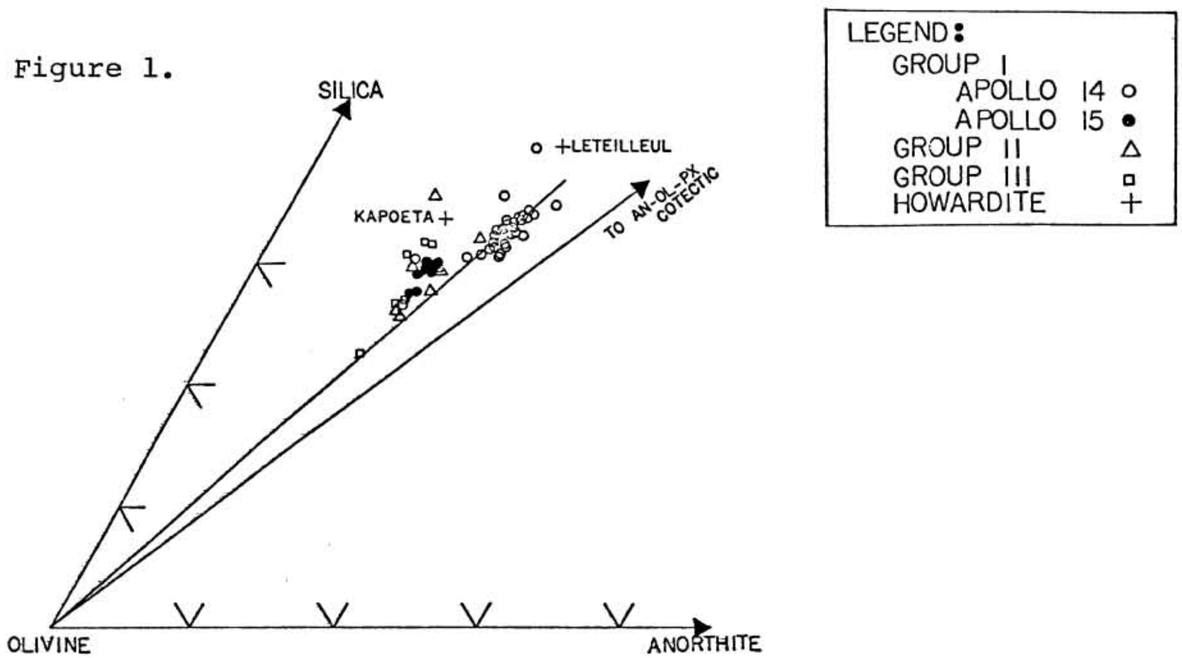

Figure 2.