PRIMARY MARE BASALTS AND GREEN GLASS. J. M. Rhodes, Lockheed Electronics Co., Inc, Houston, TX 77058.

The recent recognition of a new mare basalt type, (VLT basalts) occurring as fragments in the Apollo 17 and Luna 24 regolith (e.g. 1,2), raises several questions concerning the nature of primary lunar mare basalts and, in particular, the relationship of ultramafic green glasses to mare basalts. This abstract outlines some conclusions concerning parental and primary mare basalts that can be made from the study of large samples, and examines the VLT basalt and green glass data with respect to these conclusions.

Detailed studies of large rock and rake samples of mare basalts from individual landing sites show that in general more than one magma-type has been samples at each site, and that most samples from a given magma-type can be related to one another by assuming moderate amounts of low-pressure crystal fractionation involving the observed phenocryst assemblages (3,4,5,6,7). This is particularly true for the finer-grained, more rapidly cooled basalts. The phenocryst assemblages for low-titanium basalts include olivine (Fo72) ± Cr-spinel ± pigeonite, and olivine (Fo 68-72) + armalcolite/ilmenite ± Cr-spinel for the high-titanium basalts. These basalt types and their fractionation trends are shown in Fig. 1. Also shown, in solid symbols, are several "best estimates" of parental magma compositions from which other members of the same magma-type can be derived by crystal fractionaion or accumulation processes. All are close to liquids in composition and are characterized by high, and surprisingly similar, Mg'-values (0.50-0.52) and Cr_2O_3 contents (0.6-0.7%). These are the highest values observed for rapidly-cooled mare basalts clearly of volcanic origin (Fig. 2). Samples with higher values are either coarse-grained and could be accumulative in origin, or are glassy or vitrophyric soil particles of uncertain derivation. The forsterite content of olivine phenocryst cores in mare basalts is commonly Fo70-74 (8,9,10), with a maximum of Fo77 — in good agreement with values predicted from the Mg'-values of the proposed parental magmas (Fig. 2; KD=0.33), and within the range required by the majority of the fractionation trends (Fig. 1). The consistency of the Mg'-values, Cr_2O_3 content and olivine compositions in otherwise chemically diverse parental magmas is difficult to explain, unless they are primary melts derived from a lunar mantle significantly heterogeneous with respect to trace and minor elements, but characterized by a relatively constant Mg'-value of about 0.75-0.77. If mare basalts have evolved from more "primitive", but as yet unsampled (or identified), primary magmas one might expect to find olivine phenocryst cores more forsteritic than Fo75-77 and a wider range in the upper Mg'-values for basaltic magmas. Analagous arguments can be made for terrestrial ocean-ridge basalts. For example, the highest Mg'-values found for ocean-ridge basaltic glasses are 0.70-0.72 (Fig. 3), higher values occurring only in coarse-grained accumulative rocks. The predicted olivine composition for these magmas is Fo90 (Fig. 3, KD=0.28), in excellent agreement with the maximum forsterite content of olivine cores in ocean ridge basalts. These also, then, are good candidates for primary basaltic melts. In the terrestrial case, however, there is additional collaborative evidence for the primary nature of these magmas from ultramafic nodule and model mantle compositions (11).

Turning to the VLT basalts, both the Apollo 17 and Luna 24 samples contain

PRIMARY MARE BASALTS AND GREEN GLASS

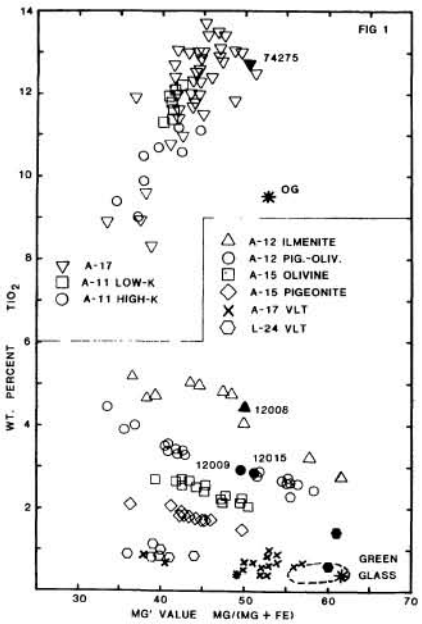
Rhodes, J.M.

vitrophyres with high Mg'-values (1,2) that may reflect primary magma compositions (Fig. 2B). Those from the Apollo 17 soil have attributes broadly comparable with the proposed primary magmas discussed above. The Mg'-values tend to be slightly higher (0.50-0.57), implying, perhaps, the existence of more "primitive" primary magmas than indicated by data for large rocks. However, this is not supported by the olivine phenocryst compositions. As in the larger samples, these attain a maximum of Fo75 (1), too low a value for olivine in equilibrium with magmas having the higher Mg'-values (Fig. 2). This problem becomes more acute with some vitrophyres from the Luna 24 soil that are compositionally similar to the Apollo 15 green glass with Mg'-values of 0.61 (2,12). The skeletal olivine microphenocrysts are too low in forsterite (Fo70-75) (2) to be in equilibrium with such a melt, and the Cr_2O_3 content is also too low relative to the well-defined Mg'-Cr_2O_3 covariance found for other rapidly cooled mare basalt compositions. In view of these inconsistencies, the presence of clasts (13), and an absence of comparable fine-grained phaneritic compositions, a volcanic origin for these fragments is questionable.

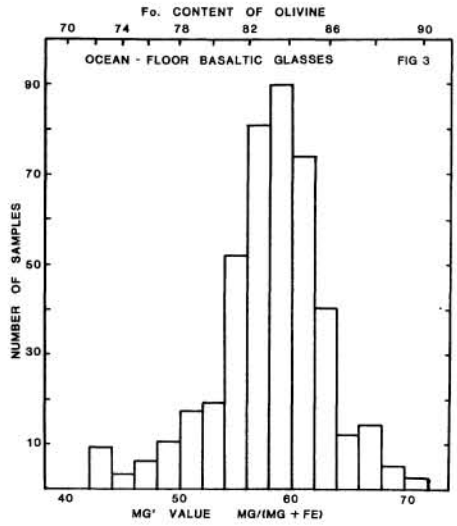
The Apollo 15 green glass (and similar glasses from other missions) have been widely regarded as the most " primitive" magmas erupted onto the lunar surface, as a result of fire-fountaining (12,14,15). As such, their low titanium content and high Mg'-values make green glass — like compositions potential parental magmas for VLT basalts (Fig. 1), and implies that other mare basalts may ultimately have been derived from analagous "primitive" liquids with Mg'-values close to 0.61. However, several observations raise questions concerning the volcanic origin of green glasses. These are: (a) Homogeneous impact glasses are not uncommon in the lunar regolith; (b) Although green glass has been found at all landing sites, fine-grained phaneritic equivalents with comparable Mg'-values have not been identified — only coarse-grained samples that are possible cumulates (Fig. 1); (c) The Cr_2O_3 content of green glasses is invariably low relative to their high Mg'-values, in contrast with the well-defined Mg'-Cr_2O_3 relationship for rapidly cooled mare basalts, but characteristic of some coarse-grained olivine accumulative rocks (7); (d) Preliminary examination of several thin sections failed to identify a single olivine phenocryst that may have formed prior to eruption: the phenocrysts are dendritic, with forsterite contents too low (<Fo75) to be in equilibrium with the melt (Fo83-84), and presumably formed during rapid undercooling; (e) Compositional variation within green glasses as a group indicates olivine control (≃Fo70) inappropriate for the melt composition (16,17); (f) Although Apollo 15 green glass is homogeneous with respect to major elements (12), trace element abundances are extremely variable (18,19). Many of the above observations suggest impact melting of olivine-rich cumulates, rather than volcanic processes. The most conclusive evidence of a volcanic origin would be the identification of equilibrium composition olivine phenocrysts that grew in the melt prior to ejection, or confirmation that the volatile-rich surface coatings are a manifestation of volcanic activity and are absent from impact-produced glasses (20). Thus, unless a volcanic origin can be firmly established, it is perhaps premature to regard these glasses as primary basaltic melts derived deirectly from the lunar interior.

PRIMARY MARE BASALTS AND GREEN GLASS

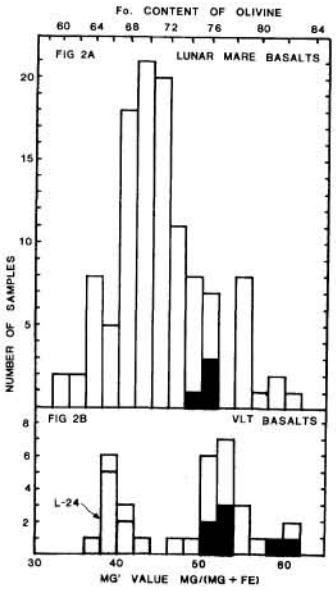
Rhodes, J.M.



Mg'-TiO_2 relationships for mare basalts.



Histogram of Mg'-values for ocean-floor basaltic glasses.



Histogram of Mg'-values for mare basalts. Potential primary compositions in black.

REFERENCES: (1) Vaniman D.T. et al., (1977) Proc. Lunar Sci. Conf. 8th, 1443-1471. (2) Ryder G. et al., (1978) The Moon (in press). (3) James O.B. and Wright T.L. (1972) Bull, Geol. Soc. Am. 83, 2357-2383. (4) Chappell B.W. and Green D.H. (1973) Earth Planet. Sci. Lett. 18, 237-246. (5) Rhodes J.M. and Hubbard N.J. (1973) Proc. Lunar Sci. Conf. 4th, 1127-1148. (6) Rhodes J.M. et al. (1976) Proc. Lunar Sci. Conf. 7th, 1467-1489. (7) Rhodes J.M. et al. (1977) Proc. Lunar Sci. Conf. 8th, 1305-1338. (8) Butler P. (1972) Geochim. Cosmochim. Acta 36, 773-785. (9) Papike J.G. et al. (1976) Rev. Geophys. 14, 475-540. (10) DUngan M.A. and Brown R.W. (1977) Proc. Lunar Sci. Conf. 8th, 1339-1381. (11) Ringwood A.E. (1975) Composition and Petrology of the Earth's Mantle, McGraw Hill. (12) Ridley W.E. et al. (1973) Phys. Earth Planet. Interiors 7, 133-136. (13) Basu A. (1977) Papers presented Luna 24 Conference, L.S.I. 14-17. (14) Green D.H. and Ringwood A.E. (1973) Earth Planet. Sci. Lett. 19, 1-8. (15) McKay D.S. et al. (1973) Proc. Lunar Sci. Conf. 4th 225-238. (16) Stolper E. (1974) B.S. Thesis, Harvard University. (17) Wood J.A. and Ryder G. (1977) Lunar Science VIII, 1026-1028. (18) Crusi A. et al. (1972) The Apollo 15 Lunar Samples, 5-9. (19) Fleisher R.L. and Hart H.R. (1972) The Apollo 15 Lunar samples, 368-370. (20) Butler P. (1978) This volume.