COMPARATIVE COMPOSITIONAL STUDIES OF SILICATE MELT INCLUSION, BULK CHEMICAL, AND EXPERIMENTAL DATA ON MARE BASALT.


Although the mare basalts are texturally complex, relatively simple chemical classifications have been developed (1). These provide the basic criteria for sample selection for experimental and trace element studies (2 & 3), as well as studies which use the major element and textural data to assess the significance of certain variations in composition between and within different classes of basalts (4 & 5). Such studies provide constraints on models of lunar mantle compositions, magma generation, eruption, cooling, and subsequent impact history of mare basalts (2,3 & 6 - 9). The validity of these models depends strongly on selection of appropriate rock compositions for experimental studies (8) and whether representative samples of all the significant possible parent magma compositions have been recognized (10). The investigation of soil and rake samples is also important in this respect (11). Silicate melt inclusions provide a further, and as yet relatively untapped, source of data for these studies as well as a source of data on eruption and cooling history of individual samples. Silicate melt inclusions in olivine (ol) are of particular importance because they represent the earliest melts sampled (12 & 13). The difference between the compositions of these inclusions and the bulk rocks provides insight into the problem of the nature and extent of fractionation processes. In our studies of this problem we have found that a normalization of the melt inclusion data of the type used in REE studies is very informative (Fig. 1). The method provides: (a) A systematic method for comparison of the melt inclusion data with chemical classifications; (b) An efficient method for assessing the effect of ol crystallization on each melt inclusion composition (analogous to correcting for the iron capsule effect in experimental studies); and (c) A more complete graphic representation of the total compositional variation of melt inclusions than is possible with variation diagrams (13) or projections onto appropriate phase diagrams (14).

With the normalization plots we can demonstrate the following: (A) Analytical error can be evaluated; (B) The distinctive major element differences between and degree of uniformity of bulk compositions within the classes of basalts presently recognized (1) can be succinctly illustrated; (C) Plots of Apollo 11 low-K and some 17 rocks show a striking similarity, suggesting only minor precipitation of ol, ilmenite (ilm), and to a lesser extent plagioclase (pl), from a closely related parent(s); the possible role of pyroxene is being investigated; (D) Melt inclusion data on 10020 (12) can be related by fractionation of <10% ol, Fe-Ti oxide and pl (all three of which are actually found as daughter minerals), to low-K Apollo 11 mare basalts; (E) Apollo 12 & 15 inclusions show a broad spectrum of compositions and, furthermore, no Apollo 12 or 15 rocks have been found with compositions comparable to the "fractionated" inclusions in these rocks; (F) Aluminous mare basalt compositions (10) are represented by melt inclusions in ol of basalt clasts in Apollo 14 breccia 14321; (G) Fractionation of observed early phases (as demonstrated by others (2)) cannot produce the K differences between Apollo 11 low- and high-K
basalts; similarly, fractionation cannot produce the Ti differences between Apollo 12 or 15 basalts and Apollo 11 or 17 high-Ti basalts.

Point C above agrees with the conclusions of Shih et al. (3) from trace element data that near-surface fractionation of ol, ilm, and pl could produce the variation found in Apollo 17 basalts. Perhaps the fractionation suggested by the inclusion data mentioned in E above had occurred on a broad scale, samples of cumulates corresponding to various proportions of the crystals that were fractionated out should occur. They have not been found. Thus we conclude from the available samples and data that extensive fractionation probably did not occur during mare volcanism.


Fig. 1. Plots of normalized major element data on rocks and silicate melt inclusions in ol for Apollo 11, 12, 14, 15 & 17 mare basalts. Data in wt. % have been divided by that of the 1965 Makaopuhi lava lake pumice (16) (as wt. % oxides Si 50.37, Al 13.36, Fe 11.16, Mg 8.14, Ca 10.87, Na 2.33, K 0.53, Ti 2.65, P 0.28, Mn 0.17). Most data (including avg's.) from Proc. of the Lunar Sci. Conf. 1-6 and all melt inclusion data from Roedder and Weiblen in these volumes are plotted. The lowest Mg ratio in Fig. 1C is from the melt inclusion in 10020 (12). Apollo 12 ilm basalts (Fig. 10) differ from Apollo 12 ol basalts principally in having a lower Mg content and higher Fe/Mg ratio. Data for these parameters in Apollo 12 pigeonite basalts (not shown) fall between Apollo 12 ilm and Apollo 12 ol basalts. Most Apollo 15 ol basalts are higher in Mg and have a lower Fe/Mg ratio than Apollo 15 pigeonite basalts (Fig. 1G & H). Apollo 17 basalts (Fig. 1J) show an olivine (and Fe-Ti oxide)-controlled variation similar to that illustrated in Fig. 1C where the effects of adding 10 increments (each 2.5%) of the host olivine to the melt inclusion composition are shown. The melt inclusion analyses in Apollo 14 breccia 14321 (triangles and circles, Fig. 1I) resemble aluminous mare basalt compositions (10), whereas the bulk composition of 14321 (crosses on Fig. 1I) is very different.
MARE BASALT COMPOSITIONAL STUDIES

Weiblen, P.W.

Fig. 1.

A. APOLLO 11 HIGH K VS. MAPOPHI

B. APOLLO 11 LOW K VS. MAPOPHI

C. APOLLO 11 MELT INCL. OL VS. MAPOPHI

D. APOLLO 12 ILMenITE VS. MAPOPHI

E. APOLLO 12 OLIVINE VS. MAPOPHI

F. APOLLO 12 MELT INCL. IN OL VS. MAPOPHI

G. APOLLO 15 OLIVINE VS. MAPOPHI

H. APOLLO 15 PIGEONITE VS. MAPOPHI

I. APOLLO 15 MELT INCL. IN OL VS. MAPOPHI

J. APOLLO 17 TI VS. MAPOPHI

K. APOLLO 16 ALUMINOS HARE BASALTS

L. APOLLO 14 MELT INCL. IN OL VS. MAPOPHI