SOME OBSERVATIONS ON MARE BASALT GENESIS; M.-S. Ma, A. V. Murali and R. A. Schmitt, Department of Chemistry and The Radiation Center, Oregon State University, Corvallis, OR 97331.

Data of Apollo 11, 12, 15 and 17 mare basalts from our laboratory and others (1) are used to determine any existing correlations among the elements in these samples. Basalt data from the Apollo 15 deep-drill-core (2) and our work are distinguished by their REE, FeO, Sc, V, and Cr_2O_3 contents.

Correlation plots of La/Sm and Sm/Eu versus La of Apollo 12, 15, 11 and 17 mare basalts are shown in Figs. 1-3, respectively. Due to the low D(s/l)'s of La in ol (∿0.01), opx (∿0.01) and cpx (∿0.1), La is used instead of Sm as an index of the degree of partial melting or fractional crystallization. The correlations of La/Sm and Sm/Eu versus La of Apollo 11, 17 and 15 samples possibly resulted from cpx and pl fractionation, respectively (3). However, weak La/Sm -La correlations (neglecting 12038) and no Sm/Eu-La correlations are observed in Apollo 12 samples. This could possibly be attributed to pl crystallization from an oceanic magma after the Apollo 12 cumulates were laid down and during crystallization of the Apollo 15 cumulates (We assume that partial melting of cumulates (4) was the principal mechanism for mare basalt genesis).

Data of fine grained samples are scattered among the coarse grain samples which indicate no serious problems due to sampling of Apollo 17 mare basalts (Fig. 3). A mare basalt clast found (5) in the highland breccia 60639 has been analyzed by us and found to be similar to the eastern mare basalts.

The Sm/Eu-La and La/Sm-La correlations (Fig. 3) for both the Apollo 11 low and high alkali and Apollo 17 basalts suggest a common genetic link for their genesis and these correlations place additional constraints on the fractionation history of the Apollo 11 high alkali basalts as indicated by their lower model ages (6).

The average La abundance is 5-6 ppm in Apollo 12, 15, and 17 basalts while La is ∿10 ppm and ∿26 ppm in the Apollo 11 low and high alkali basalts, respectively (Fig. 4). This may indicate that Apollo 12, 15 and 17 cumulate source materials lie close in a stratigraphic column while the Apollo 11 cumulates are higher in the column. If La and Sm are mainly present in cpx cumulates, different cpx contents in the close cumulate levels will not explain the significant differences of average La/Sm ratios among these basaltic groups. However, the differences of the average La/Sm ratios in these basalts may be explained by similar degrees of partial melting of close cumulate levels which contain similar amounts of trapped liquid but different amount of cpx. During partial melting of cumulates with cpx, essentially all the cpx must be melted to satisfy the stringent Lugmair constraint (7), i.e., < 2% Sm/Nd fractionation may occur during the partial melting episodes. We assume that this constraint, obtained so far for only Apollo 17 mare basalts, applied to the partial melting for all lunar cumulates that yielded mare basalts. To test the cpx effect we have plotted the La/Sm versus Sc fields (D_{Sc}(s/l) ∿ 3 at 1100° C in cpx (8) and D_{Sm}(s/l) ∿ 0.5) for Apollo 11, 17, 12 and 15 basalts (Fig. 4). The lower Sc contents in Apollo 12 and 15 basalts relative to the low alkali Apollo 11 and 17 basalts may reflect a third to a half as much cpx in Apollo 12 and 15 cumulates relative to Apollo 11 and 17 cumulates. This is consistent with higher La/Sm in Apollo 12 and 15 mare basalts relative to Apollo 17 basalts if the cumulates lie close together and contain similar amounts of

Some observations on mare basalt genesis

M.-S. Ma

trapped liquid. The Apollo 11 high alkali basalts may have been derived from the partial melting of even higher level cumulates or represent an open system for LIL contamination. The same Sc content in both the Apollo 11 low and high alkali basalts indicates comparable amounts of cpx in the cumulate source material.

Many investigators have suggested that the olivine basalts of Apollo 12 could have been derived by the addition of olivine to "pigeonite and ilmenite" basaltic magmas. The La-TiO_2-MgO data are quite in agreement with this suggestion. A corresponding La-MgO correlation curve for Apollo 15 basalts does not permit such a simplified interpretation if all the basalts are considered. If we disregard the three basalts with La < 2.3 ppm and the two with La > 8 ppm, then the slope will not be as steep and permit olivine dilution of a "basic magma" with La ∿6.0 ppm and MgO ∿7%. The correlation slopes for both Apollo 12 and 15 basalts will then be parallel, indicating similar petrogenetic mechanisms. These correlation plots will be shown at the conference.

Neglecting the lower four and upper two La data abundances for the Apollo 15 La-TiO_2 correlation, we find that the correlation curve for Apollo 15 basalts will parallel the Apollo 12 basalts. These correlations may indicate that both La (a representative LIL element) and Ti (behaves as a LIL in low Ti basalts (9)) are apparently diluted by olivine addition. However, simple olivine dilution does not explain the strong La/Sm-La and Sm/Eu-La correlations (Fig. 2) for the Apollo 15 basalts. No La-MgO-TiO_2 correlations are observed for Apollo 17 basalts (Figs. 5 and 6). This could be attributed to five or more magma flows resulting from the partial melting of cumulates with varying quantities of trapped liquid (10). We have observed the overlap of the field of the Apollo 11 low alkali basalts with the fields of the two apparent clusters of Apollo 17 low alkali basalts in the La-MgO-TiO_2 correlation diagrams. The similar bulk contents in these basalts could again be generated from stratigraphic levels not too far apart.

We have confirmed the positive Eu anomaly in the 15388 mare basalt previously observed by (11).

(1)Data, principally obtained via ID and NAA techniques, were taken from the five Proc. Lunar Sci. Conf. (1970-1974). (2)Drake M. J. and Lindstrom M. M. (1975) Preliminary report on the petrology and geochemistry of lithic fragments from the Apollo 15 deep-drill-core. In "Lunar Science VI" p. 202-204. The Lunar Science Institute, Houston. (3)Shih C.-Y., Haskin L. A., Wiesmann H., Bansal B. M. and Brannon J. C. (1975) Proc. Lunar Sci. Conf. 6th, in press. (4) Philpotts J. A. and Schnetzler C. C. (1970) Proc. Apollo 11 Lunar Sci. Conf., p. 1471-1486. (5)Dowty E., Keil K. and Prinz M. (1974) Proc. Lunar Sci. Conf. 5th, p. 431-445. (6)Papanastassiou D. A. and Wasserburg G. J. (1971) Earth Planet Sci. Letts. 11, 37-62. (7)Lugmair G. W. (1975) Sm-Nd systematics of some Apollo 17 basalts. Origins of Mare Basalts, p. 107-110, The Lunar Science Institute, Houston. (8)Goles G. G., Hering C. and Leeman W. P. (1974) private communication. (9)Shih C.-Y. (1975) Origin of Mare Basalts, p. 149-153, The Lunar Science Institute, Houston. (10)Warner R. D., Keil K., Prinz M., Laul J. C., Murali A. V. and Schmitt R. A. (1975) Proc. Lunar Sci. Conf. 6th, in press. (11)Laul J. C. and Schmitt R. A. (1972) Bulk and REE abundances in three Apollo 15 igneous rocks and six basaltic rake samples. The Apollo 15 Lunar Samples, p. 225-227, Lunar Science Institute, Houston.

Some observations on mare basalt genesis

M.-S. Ma

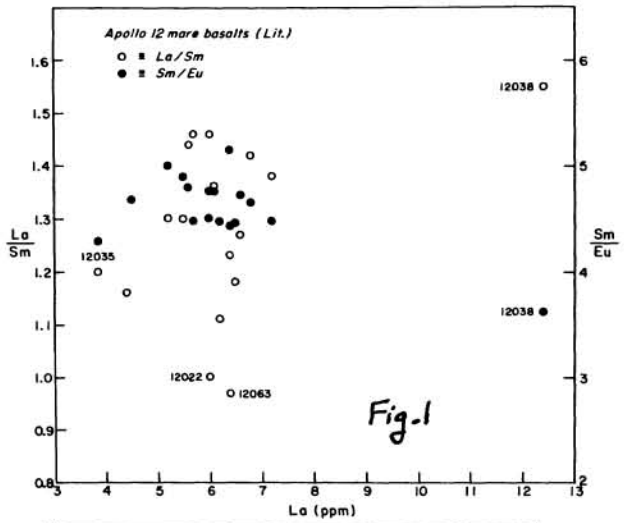

Fig.1

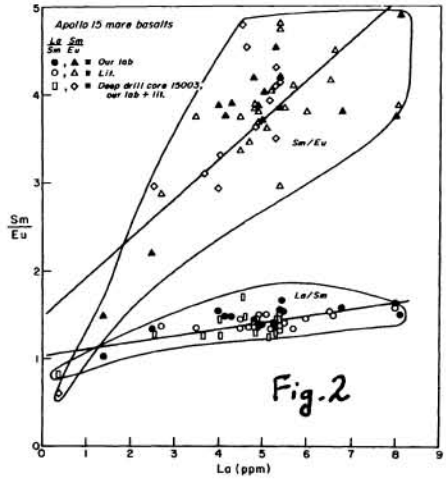

Fig.2

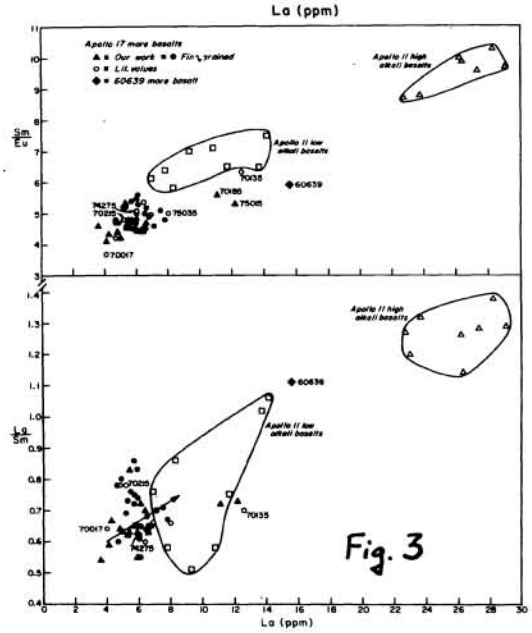

Fig. 3

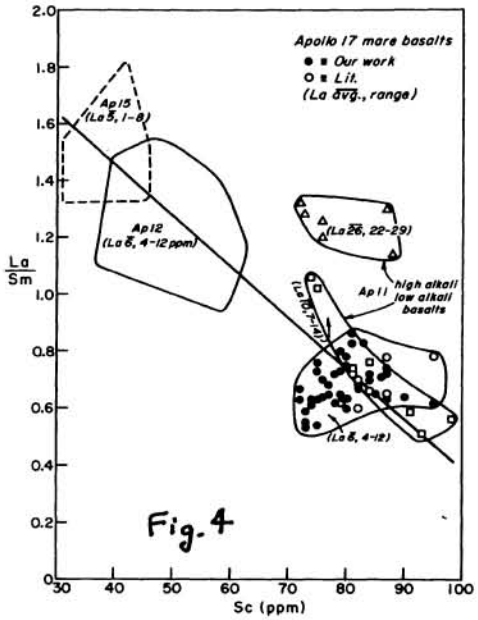

Fig. 4

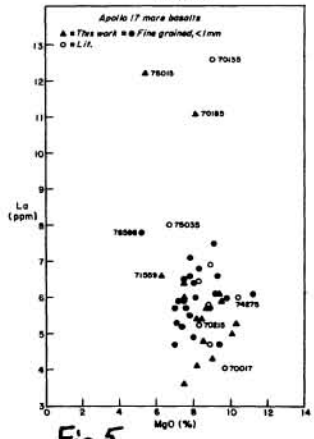

Fig.5

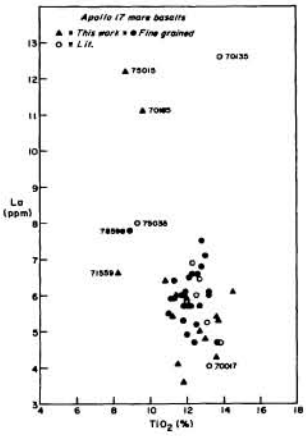

Fig. 6