THE LUNAR MANTLE: AN OLIVINE PERIDOTITE, NOT A PYROXENE PERIDOTITE; A.B. Binder, Institut für Geophysik, Neue Universität, D-2300 Kiel, Germany

The results presented in this paper are largely based on an analysis of published major oxide compositions and the U, Th,K and REE contents of the various mare basalt samples studied by a number of investigators. These data were used to identify 12 well defined (based on 3 to 12 samples), chemically distinct basalt units and 4 poorly defined (based on 1 sample) units. The composition of the parent magma of each of these 16 units is defined as 1) the mean composition of all the samples of the unit for those flows which show little or no evidence of differentiation during crystallization (e.g. the Apollo 11 and 17 units), 2) the mean composition of rocks near the middle of well defined differentiation trends (e.g. Apollo 12 and 15 units), 3) the composition of a nearly holochyaline sample (e.g. 12009, (1)) of a well defined differentiation series and 4) the composition of a single sample in those cases where only 1 sample is available (e.g. 12038 high aluminous basalt (2)) or in the cases of the orange and green glasses.

Based on the assumption that the mare basalt magmas were derived from a relatively homogeneous mantle by varying degrees of partial melting (e.g. 1,3), then the compositions of these 16 magmas can be used to determine the composition of the upper part of the lunar mantle. To this end the compositional data for these 16 magmas are plotted on a pseudo-termary phase diagram in Figure 1. Included in Figure 1 is the position of the olivine-pyroxene cotectic at a variety of depth intervals as derived from experimental crystallization data obtained on various mare basalts (e.g. 1,3,4). From Figure 1, it is apparent that the Apollo 11, 17 and the high aluminous magmas all lie near the cotectic at 100 km. Also the Apollo 12, 15, orange glass and green glass magmas all lie along a tight set of olivine control lines which intersect the 100 km cotectic near the positions of the Apollo 11 and 17 magma points. In particular, 5 of the magmas lie on a single, central olivine line. This pattern of points strongly suggests that the magmas were produced by varying degrees of partial melting of an olivine dominated source region whose compositional point plots on the central olivine control line near the olivine corner of the diagram, e.g. point O which has a normative composition of 85% olivine, 10% pyroxene and 5% anorthite. Small degrees of partial melting of such a material would produce quartz normative magmas which would lie along a cotectic (Apollo 11 and 17 basalts). Of these magmas, those produced by the smallest degree of melting would be relatively plagioclase rich, i.e. high aluminous basalts. With increasing degrees of partial melting, the composition of the resulting melts would leave the

OLIVINE PERIDOTITE LUNAR MANTLE

A.B. Binder

cotectic and move along an olivine control line. Such magmas would become increasing rich in olivine as melting proceeded (Apollo 12 and 15 basalts→green and orange glass sequence).

While the most obvious interpretation of the data plotted in Figure 1 is that given above, i.e. that the upper mantle is olivine rich and not pyroxene rich as previously assumed (e.g. 1,3, 4) the latter possibility can not be completely excluded. This is the case since it is possible that all the melts lie on cotectics and the composition of the upper mantle is somewhere near the pyroxene point on the diagram, e.g. point P. If this were the case, then the depth of origin of the magmas is given by the depth of the cotectic line on which they lie. These depths, 60 km for an Apollo 11 magma to 290 km for the orange and green glass magmas, are considerably shallower than previously estimated (e.g.1, 3, 4) depths of ~200 to 500 km for all magmas (it is noted that if the mantle is olivine rich, the depths derived from the cotectic lines for those magma points lying on olivine control lines are the maximum possible depths of origin for the magmas, hence the conclusion that the magmas came from shallow depths is independent of the composition of the mantle). The identification of such shallow depths of magma origin contradicts the suggested constraint, based on the stability of the mascons, which lead to the choice of a deep, pyroxene rich source over a shallow olivine rich source (3). In addition, if the mantle were pyroxene rich, then the apparent alignment of the Apollo 12, 15, orange, and green glass magmas on olivine control lines would have to be accidental and this is statistically unlikely. Also, the absence of data points along the deeper cotectic lines (>200 km) to the right of the Apollo 12 and 15 data is difficult to explain if the mantle is pyroxene rich. This observation would require that small degrees of partial melting occure only infrequently at depth-again this seems statistically unlikely. However, if the mantle is olivine rich, then the apparent absence of small degrees of partial melting from depth is explained because all the magmas can originate at ~60 - 150 km as is consistant with the data in Figure 1. Thus, the pattern of points in Figure 1 is readly explained if the mantle is an olivine preidotite and is statistically unlikely if the mantle is a pyroxene peridotite.

In conclusion, the available evidence strongly indicates that the upper 200 - 300 km of the lunar mantle is olivine rich (70%-85% olivine). If this is the case, then, based on the normal differentiation sequence for ultra mafic materials (5), it is most likely that the entire lunar mantle is olivine rich, e.g. point O in Figure 1. It is noted that these conclusions are consistant with the seismic results (6). Further the composition of the earth's mantle (point E in Figure 1) lies on or near the olivine control lines through the mare magma points. This strongly suggests that there is a genetic relationship between the composition of the lunar and terrestrial mantles. If this is the case,

OLIVINE PERIDOTITE LUNAR MANTLE

A.B. Binder

then the current data strongly favor the fission origin of the moon (6).

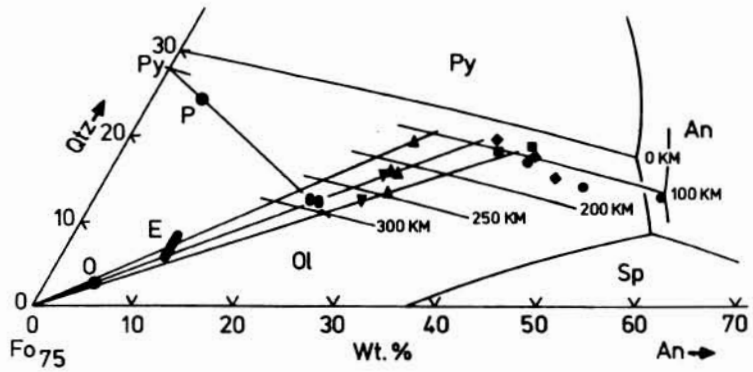

Figure 1. Plot of the mare basalt magma composition points on a pseudo-ternary phase diagram for quartz, anorthite and olivine (Fo_{75}). The data points are as follows: circles-high aluminous magmas, squares-Apollo 17 magmas, diamonds-Apollo 11 magmas, top up triangles-Apollo 15 magmas, top down triangles-Apollo 12 magmas, ovals-orange and green glass magmas.

REFERENCES:

1) Green, D.H., Ringwood, A.E., Ware, N.G., Hibberson, W.O., Major, A. and Kiss, E., 1971, Proc. Second. Lunar Sci Conf., p. 601 - 615.
2) Reid, A.M., and Jakes,P., (1974), Luna 16 revisited: the case for aluminous mare basalts. In "Lunar Science V" pp. 627 - 629, The Lunar Science Institute, Houston.
3) Ringwood, A.E., and Essene, E., 1970 Proc. Apollo 11 Lunar Sci-Conf., p. 769 - 799.
4) Grove, T.L., Walker, D., Longhi, J., Stolper, E., and Hays, J. F., 1973, Proc. Third Lunar Sci. Conf., p. 995 - 1011.
5) Binder, A.B.,(1975), On the petrology and structure of a gravi-ationally differentiated moon of fission origin, The Moon 13, pp. 431 - 473.
6) Dainty, A.M., Toksöz, M.N., Solomon, S.C., Anderson, K.P., and Goins, N.R., 1974, Proc. Fifth Lunar Sci. Conf., p. 3091 - 3114.

Publication No. 123, Institute of Geophysics,University, D-2300 Kiel, Germany