EXPERIMENTAL PETROLOGY AND ORIGIN OF TITANIFEROUS LUNAR BASALTS. D. Walker, J. Longhi, E. Stolper, T. Grove, and J. F. Hays, Hoffman Lab., Harvard Univ., Cambridge, MA 02138.

Compositional variation of titaniferous basalts from Tranquility Base and Taurus-Littrow can be explained in terms of low-pressure, crystal-liquid fractionation. The compositions do not represent a series of primary melts from the deep lunar interior nor can they be interpreted as the residue of crystallization of any common (low titanium) basaltic magma. They can be interpreted as low-pressure melting products of a plagioclase and ilmenite bearing cumulate, or they can be interpreted as residual liquids from a titaniferous parent magma.

Crystallization behavior of titaniferous basalts can be modeled by phase relations in the system FmO-$FmTiO_3$-$FmSiO_3$-$CaFmSi_2O_6$-$CaAl_2Si_2O_8$ where FmO=FeO+MgO (Fig. 1). For phase relations involving ilmenite or armalcolite, a FmTi-oxide-saturated pseudo-ternary liquidus diagram can be constructed with FmO and Px/Px+Plag as coordinates (Fig. 2c). The multiple saturation curves were located by microprobe analyses of liquids generated in melting experiments in iron capsules in evacuated silica tubes on rock-powder samples of 70215 and 70017. The phases present and the configuration of the saturation volumes are shown in Figure 2c.

The crystallization sequence begins either with olivine (70017∾1225°C) or armalcolite (70215∾1195°C) but both compositions become doubly saturated by 1175°C. Slightly above 1150°C armalcolite reacts with the liquid to form ilmenite. Plagioclase appears (1140-1145°C) before pyroxene, which is present in both by 1135°C. Olivine has reacted away by 1125°C.

The compositions of Apollo 11 ilmenite basalts are also plotted in these projections. The separate symbols follow the classification of James and Jackson (1970). The phase relations determined for the Apollo 17 material are also appropriate to the Apollo 11 basalt crystallization. James and Jackson's petrographic observation that pyroxene appears before plagioclase in the intersertal group and plagioclase appears before pyroxene in the ophitic group is a natural consequence of the positions of the rocks relative to the saturation volumes. The ophitic group variation can be interpreted as being controlled by these saturation curves. The intersertal variation parallels the variation of multiply saturated liquids but appears to be displaced slightly, indicating similar but not identical control. We therefore confirm the experimental work of O'Hara et al. (1970) who claimed a near-cotectic relationship for these compositions. While it may be true that the lunar interior is composed of olivine pyroxenite, this cannot be deduced as done by Ringwood and Essene (1970) on the basis of their Apollo 11 model basalt composition.

Although we confirm the experimental work of O'Hara et al., we doubt that these rocks represent the liquid dregs of a strongly fractionated more primitive magma. Our work on 12002, a primitive picrite, has shown that high-Ti liquid is indeed generated as the residuum. However, this material approaches ilmenite saturation only below 1125°C and would be equivalent only to the more siliceous (low FmO) varieties of the intersertal group. The ophitic group and most of the intersertal group compositions and petrography indicate a higher temperature history in which early saturation with a TiFm oxide phase occurred. The presence of magmatic armalcolite is inconsistent with the proposition that titaniferous basalts are the residual liquids of primitive basalt crystallization.

How then are they formed? It is possible that the titaniferous basalts represent low-pressure partial melts of a feldspathic cumulate (Philpotts and Schnetzler, 1970) produced in the crystallization of a primitive basalt if the source layer in the cumulate had excess ilmenite. It is also possible that these rocks were produced by low-pressure fractional crystallization of a titaniferous primitive magma. Such a magma could be produced by partial melting of an ilmenite bearing source rock at modest depth. For example, the vitrophyre 70215 would be in equilibrium with the assemblage olivine-pigeonite-ilmenite-spinel at a depth of 100 km (5kb). A liquid of this composition would be a suitable parent for both the Apollo 17 suite and Apollo 11 ophitic suite. A different parent liquid is required for the Apollo 11 intersertal suite, but the required differences may be small.

References: James and Jackson (1970), JGR 75, 5793; O'Hara et al. (1970), G&CA Suppl. 1, V. 1, 695; Philpotts and Schnetzler (1970), G&CA Suppl. 1, V. 2, 1471; Ringwood and Essene (1970), G&CA Suppl. 1, V. 1, 769.

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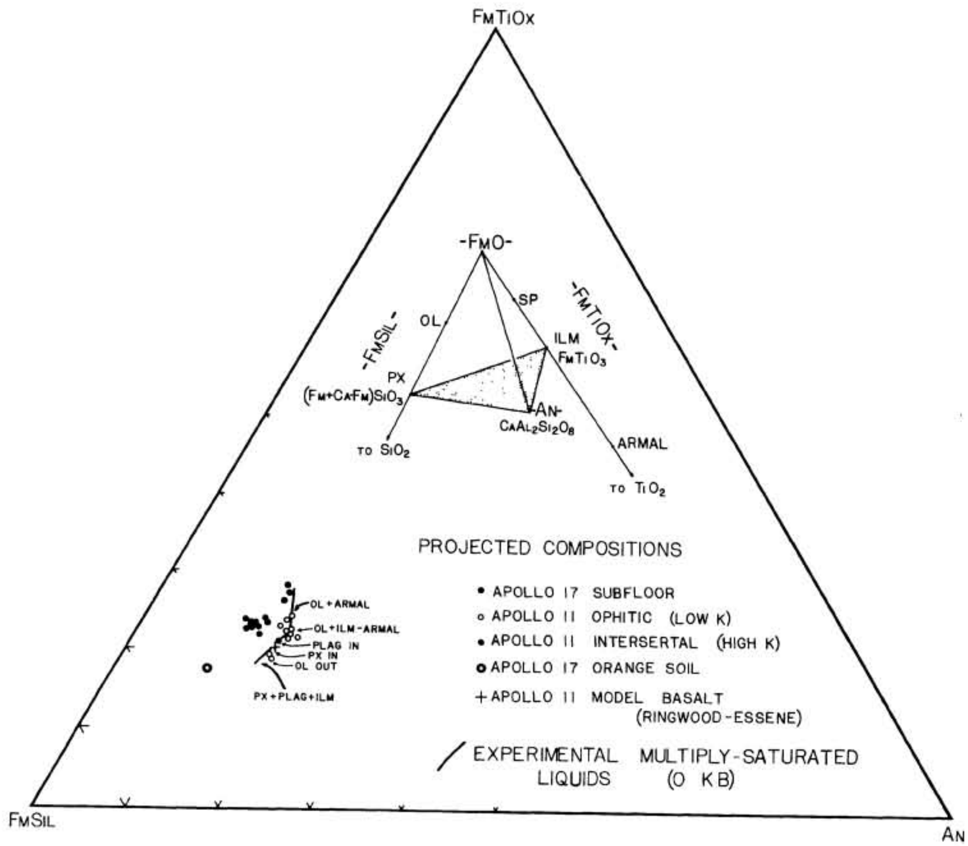

SUBPROJECTIONS IN RECTANGULAR COORDINATES