

IMMISCIBLE SILICATE MELTS IN 12013?

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It is generally recognized (1,2,3) that the origin of highly evolved lunar compositions, i.e. those enriched in such elements as K, U, REE, P, Zr, etc. is a fundamental problem in lunar petrogenesis. Earlier (4), and in a companion paper in this volume we have argued that highly evolved liquids residual to the primitive fractionation of the outer moon were enriched in FeO and TiO₂ and became unstable exsolving SiO₂-enriched immiscible melts remarkably similar to lunar granites. In such an event, trivalent REE, U, P, Zr and other highly charged cations would be partitioned into the ferrobasaltic melt, K, Rb, Cs and Na into the granitic immiscible melt, and Ba, Sr and Eu⁺⁺ would not be strongly fractionated between the two melts according to experimental evidence (5,6). Some components of lunar rock 12013 have some of these chemical attributes which has led Quick et al. (1) to suggest that the felsite and basaltic aphanitic matrix (BAM) compositions may be lithologies that are related by a process of silicate liquid immiscibility (SLI). If this is indeed true, then these compositions may provide invaluable data pertaining to the origin and nature of highly evolved liquids in the lunar crust (1).

A simple experimental test of the SLI hypothesis is to determine whether mixtures of the felsite and BAM compositions produce coexisting immiscible melts near the liquidus. Experiments on synthetic compositions containing from 0 to 100% felsite (reduced to fo₂ conditions corresponding to those of the iron-wustite buffer and run in Mo foil containers) all proved negative; liquid immiscibility was not encountered in any composition near the liquidus temperature. Moreover, the liquidus of the BAM composition is slightly above 1140°C and is marked by the appearance of olivine (Fo₇₇) and plagioclase (An₆₁). The liquidus of the felsite is about 1080°C and was marked by the appearance of clinopyroxene (Wo₃₈En₅₄Fs₈). If the felsite and BAM composition were indeed pristine magmas related by SLI, they should both have the same liquidus temperatures and the nature and compositions of the liquidus phases should be identical. This clearly is not the case!

The experimental data clearly prove that the BAM and felsite

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compositions do not represent equilibrated liquids which originated by SLI. The chemistry of the two compositions provides additional support for this conclusion. A particularly troubling observation is that the Al_2O_3 content of BAM (13.2 wt%) is greater than that in the felsite ($\sim 12.0\%$) (1). This is contrary to the results obtained in experimentally derived lunar immiscible melts (4) and from the analysis of immiscible glasses located in the mesostasis of lunar basalts (7). In fact, a liquid line of descent for a melt corresponding to a composition of 90% BAM and 10% felsite did indeed become immiscible at about 1020°C after about 75% crystallization. However, the immiscible liquids were similar (but less fractionated) to those normally encountered, i.e. Al_2O_3 was enriched in the granite (12.6% Al_2O_3) and not in the ferrobasalt composition (8.0% Al_2O_3). A second inconsistency is the strong enrichment of Ba in the 12013 felsite such that $\text{Ba (felsite)}/\text{Ba (BAM)} \approx 200$. Trace element partitioning studies (5,6) indicate that this ratio, like those of Sr and Eu^{+2} , should be slightly less than unity. In agreement with this, Eu is only slightly enriched in BAM (1). Finally, the fact that there is more Na in the BAM than in the felsite is inconsistent with Na partitioning data (6,7) and the hypothesis that these lithologies are two crystallized immiscible melts.

Although the above data do not support the hypothesis that the 12013 BAM and felsite are pristine immiscible liquids, they do not reject the SLI hypothesis altogether. It is quite possible that these compositions do not represent true liquids because of contamination by assimilated clastic material or because of complexities arising from the crystallization and fractional crystallization of each immiscible liquid. For example, the low Ba contents of BAM might be explained by fractionation of cel-sian-bearing alkali feldspar. The fact that the BAM composition is high in both Na and Al relative to the felsite suggests that a Na-plagioclase may have been preferentially added to the BAM analyzed (1). If 10-15% plagioclase similar in composition to the Na-plagioclase reported in BAM (1) somehow has been added to BAM, the liquid prior to this addition would be much closer to the immiscible complement of the felsite. Obviously there could have been other additions as well. The theory that SLI has played some role in the origin of the 12013 BAM remains attractive because of the dramatic contrast between the extremely enriched REEPTiU elements ($\text{La} \approx 700 \times$ chondrite) and the modestly evolved FeO/MgO (0.6 by wt) ratio (see (1)).

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