PARTITIONING OF REE BETWEEN OLIVINE, PLAGIOCLASE, AND SYNTHETIC BASALTIC MELTS: IMPLICATIONS FOR THE ORIGIN OF LUNAR AMORPHITES. G.A. McKay, GSFC, NASA/Johnson Space Center, Houston, TX 77058.

Consideration of crystal/liquid partitioning behavior constitutes one of the primary methods of interpreting trace element abundances in igneous rocks. In order to use this approach to better constrain the processes which formed the lunar crust and mantle, we are experimentally investigating partitioning behavior for several important elements and minerals. This abstract reports recent results for partitioning of REE between olivine and synthetic Apollo 12 basaltic melts, and between olivine and plagioclase and synthetic LKFH basaltic melts, and discusses implications of these results for the inferred compositions of anorthosite parent liquids.

Experimental starting materials were synthetic glasses doped with 0.2-4 wt. % REE. The LKFH glass was the one used in the partitioning studies of McKay and Weill (1). Charges were suspended from Pt wire loops in 1 atm gas mixing furnaces (log 10T=11), cooled from above their liquidus to temperatures resulting in ~10% crystallization (1250-1200°C) at rates of 0.5-1000°C/hr, held at these constant temperatures for 1-4 days, and quenched. Resulting crystals and glass were analysed for REE with a special electron microprobe technique having a sensitivity of ~10 ppm. Results of 40-day reversal experiments indicate that equilibrium is closely approached in 1-4 day experiments.

The most likely reason for the discrepancy is that earlier results are incorrect because traverses in specially prepared synthetic BEE-free olivines surrounded by REE-bearing glass show an apparent Ce content in olivine along a traverse perpendicular to a partitioning interface. It is not yet known whether this excitation is due to secondary analytical errors, it is necessary to analyze points which are more than 100 μm from the nearest glass. This analytical difficulty probably represents an important source of error in earlier partitioning studies which used the microprobe to measure distribution coefficient values, including (1,2,3). All new values reported in this abstract were measured at locations > 100 μm from the nearest glass.

REE D-values for olivine/liquid are shown in Fig. 2. Error bars represent twice the standard deviation of the mean of replicate determinations, or twice the standard deviation predicted from counting statistics, whichever is larger. Values from McKay and Weill (1) for the same LKFH starting material as that used in this study, and phenocryst/matrix values from Schnetzler and Philpotts (4) are also shown. The slopes of the new distribution coefficient patterns are nearly identical for both LKFH and mare basaltic melts, and are much steeper than those of earlier patterns. Values for new patterns, however, are much lower than earlier ones, by factors of 100-1000 in the case of the extrapolated Ce values. It is unlikely that this major discrepancy between earlier values and the new ones results from unrecognized experimental or analytical errors in the present study. Reproducibility of results in replicate experiments, verification of equilibrium through reversal experiments, and agreement of pattern slopes for the two different compositions give credibility to the new results.

The most likely reason for the discrepancy is that earlier results are incorrect because of analytical or experimental errors. This is almost certainly the case for the results of McKay and Weill (1,2,3). The synthetic olivine crystals for which they measured D-values were only ~20 μm in width. For crystals of this size, characteristic X-rays excited from adjacent glass would contribute significantly to the measured intensity, resulting in erroneously high apparent distribution coefficients (Fig. 1). This effect would be greater for elements having lower D-values, thus flattening the slope of the distribution coefficient pattern. New D-values measured from much larger crystals grown from the same starting material show the much steeper pattern.

Schnetzler and Philpotts themselves suggested that their olivine/liquid distribution coefficients might be affected by ~1%/matrix contamination of their olivine separates. They noted that K, Rb, Sr, Ba, and the REE all show similar D-values, an unexpected result for elements of divergent charge and ionic radii, but a result which is consistent with contamination. Fig. 2 shows the apparent distribution coefficient pattern which would result if olivines having an actual distribution coefficients the mare basalt values determined in the present study were contaminated with 1%/matrix and analysed in bulk. There is close agreement between this "synthesized" contaminated pattern and the phenocryst/matrix pattern of Schnetzler and Philpotts. Hence, these data are consistent with their olivine, having a true distribution coefficient pattern similar to those of the present study, with their much flatter apparent pattern resulting from the presence of ~1%/matrix contamination in their olivine separates.

New plagioclase/liquid values for Sm, Gd, and Yb are shown in Fig. 3, along with values from Weill and McKay (3) for phases of similar composition. Error bars are as described above. Results for Sm from the two studies are in precise agreement within analytical uncertainties. However, the new value for Yb is lower than the earlier value by a factor of 3. The earlier results are probably in error due to the analytical problem discussed above. This problem was avoided in the present...
study by growing crystals of sufficient size that analyses could be performed at locations > 100 μm from glass.

Implications of the revised distribution coefficient values for parent liquids of lunar anorthosites were investigated. Parent liquid REE patterns were calculated for 17 anorthosite analyses from the literature, using the method of Paster et al. (5). In this method, a bulk rock sample is considered to initially have consisted of cumulus crystals of plagioclase, mafics, and trapped intercumulus liquid. Calculations were performed for assumed trapped liquid contents ranging from 0 to the maximum value consistent with the Fe or Mg content in the sample, assuming FeO and MgO contents of 10% for the trapped liquid. Fe or Mg mass balance considerations require a specific proportion of cumulus olivine or pyroxene for each assumed trapped liquid content. These calculations were performed using earlier plagioclase and olivine D-values from (1.31, as well as the new values from this study. A typical example of the resulting parent liquids is shown in Fig. 4. The old distribution coefficients yielded strongly fractionated parent liquids for all permissible trapped liquid contents. In contrast, for low trapped liquid contents, the new coefficients permit parent liquids with trivalent REE which are within 25% of chondritic relative values. Eu still shows a small positive anomaly for the 60015 parent liquid, but this would disappear with a 20% increase in the value of D(Eu,Pl), which is probably within uncertainties.

For many of the 17 anorthosites studied, parent liquid compositions calculated using the earlier D-values were strongly fractionated for all permissible trapped liquid contents. In part, this observation led Longhi (6) to propose very complex petrogenetic processes for anorthosite genesis, and Haskin et al. (7) to propose that anorthosites have suffered secondary melt extraction. However, if the new D-values are used, then for each of the 17 anorthosites studied there is a combination of mafic assemblage and trapped liquid content for which the resulting parent liquid trivalent REE abundances are within 25% of chondritic relative values. Hence, the revised distribution coefficients permit but do not require anorthosites to have crystallised from nearly unfractinated parent liquids. Effects of the revised D-values on calculated parent liquids for lunar dunite 72415 are currently under investigation.


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