ION MICROPROBE ANALYSES OF REE IN MINERALS FROM APOLLO 15 QUARTZ MONZODIORITES. Marilyn M. Lindstrom, NASA Johnson Space Center, Houston, TX, Ursula B. Marvin, Harvard-Smithsonian Center for Astrophysics, Cambridge MA, and Ghislaine Crozaz, Washington University, St Louis, MO.

Quartz monzodiorites (QMD) are highly evolved lunar plutonic rocks first identified by Ryder (1) in 15405, a KREEP basalt impact melt rock. He proposed that the associated KREEP basalt, QMD, and granite clasts in the breccia were remnants of a KREEP basalt differentiated pluton. Last year Marvin et al (2) found several additional QMD and granite fragments in the soil adjacent to 15405. We also identified an alkali norite clast from 15405 as a possible representative of the parent magma. However, all of the fragments are very small and coarse-grained and may not be representative of liquid compositions. This is clearly the case for 15405 alkali norite, which is too rich in Al and REE for any reasonable liquid. This heterogeneity made it impossible to do detailed modeling of the fractionation sequence.

Trace element analyses of individual mineral grains are required for modeling to avoid the problems of heterogeneity in bulk samples. We measured REE and other trace elements in phosphates, pyroxenes and plagioclases from the alkali norite, several QMD, and a granite. Measurements were made on a Cameca IMS-3f ion microprobe using the procedures of Zinner and Crozaz (3).

Results are shown in Figures 1-3 which are chondrite-normalized REE plots for phosphates, pyroxenes, and plagioclases. These REE patterns are qualitatively consistent with previous analyses of these minerals in lunar samples and with the proposed differentiation process. The REE concentrations in each phase increase from alkali norite to QMD to granite as would be expected for differentiation. Whitlockites are extremely rich in REE, with a LREE-enriched pattern and a large negative Eu anomaly. Concentrations and patterns are very similar to those Lindstrom et al (4) measured previously in three other types of REE-rich lunar plutonic rocks. Apatite is much less enriched in REE, but has a parallel REE pattern. This partitioning between whitlockite and apatite is more extreme than observed for alkali gabbronorite (4) where the whitlockite/apatite distribution coefficients are around 20 compared with 100 in QMD. Pyroxenes exhibit LREE-depleted patterns and negative Eu anomalies, while plagioclases have LREE-enriched patterns and positive Eu anomalies. Both are typical of their respective minerals, and very similar to our earlier ion probe analyses of silicates in alkali gabbronorites (5).

Quantitative modeling of liquid compositions using individual mineral analyses shows that the situation is complex. REE concentrations in equilibrium liquids were calculated using McKay's experimentally determined distribution coefficients for whitlockite (6), pyroxene (7), and plagioclase (8). Appropriate distribution coefficients were unknown for two pyroxenes because analyses were of exsolved pigeonite-augite grains and the proportions of the two phases were not determined. Alkali norite 15405,170 is the only sample for which coexisting pyroxene and plagioclase analyses are available. Liquids calculated from these phases are very similar in REE concentration, except for the heaviest REE where plagioclase data are highly uncertain. This liquid has LREE concentrations comparable to those of Apollo 15 KREEP basalts, but middle REE concentrations are somewhat lower. Liquids calculated from QMD plagioclases have higher REE concentrations. These liquids are consistent with the proposed fractionation process. However, liquids calculated from the whitlockites have REE concentrations factors of three to five times higher than those of liquids calculated from coexisting plagioclases. Either the distribution coefficients used are inappropriate or coexisting plagioclase and whitlockite are not in equilibrium. Plagioclase distribution coefficients are fairly well known, but those of whitlockite are less certain. Dickinson and Hess (9) measured whitlockite distribution coefficients a factor of 2.5 lower than those of McKay (6), but use of these distribution coefficients increases calcualted liquid concentrations, making the disagreement with plagioclase worse. Another possibility is that liquids calculated from plagioclase and pyroxene are initial or bulk liquids, while that calculated from whitlockite is a late stage liquid at the time of whitlockite crystallization. The minerals may not have equilibrated with each other, but may be represent stages in crystallization. Another possibility is that lunar whitlockites are essentially saturated with REE such that Henry's law is not obeyed (7) and appropriate distribution coefficients are not known. The present data are not sufficient to evaluate this problem.

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