LUNAR FERROAN ANORTHOSITES: RARE EARTH ELEMENT MEASUREMENTS OF INDIVIDUAL PLAGIOCLASE AND PYROXENE GRAINS. C. Floss[1], O.B. James[2], J.J. McGee[2] and G. Crozaz[1]. [1]Earth and Planetary Sciences Department & McDonnell Center for the Space Sciences, Washington University, St. Louis, MO 63130; [2]959 National Center, U.S. Geological Survey, Reston, VA 22092.

The petrogenesis of ferroan anorthosites (FANs) from the lunar highlands remains incompletely understood after nearly twenty years of study. These rocks are commonly thought to have formed by plagioclase flotation on top of a moon-wide magma ocean [1]. However, not all features of the anorthosites are readily explained by crystallization from a magma ocean, and their formation as the result of a series of magmatic events has also been suggested [2]. Recently, James *et al.* [3] suggested that the anorthosite suite can be divided into four subgroups, on the basis of modes and mineral compositions.

We have begun an ion microprobe study of plagioclase and pyroxene grains in samples from each of the subgroups, to look for inter- and intra-group variations in REE and other trace element abundances. We report here results for five members (60055,5; 60025,702; 62255,42; 64435,268; and 65315,82) of the largest subgroup, the "typical" FANs. This group is highly anorthositic with relatively ferroan mafic minerals [3]. An important criterion for sample selection is evidence of relict igneous texture, to ensure that only one rock type is being represented. Relict clasts are present in all but one of these samples, 60055,5. However, 60055,5 is compositionally pristine, with low siderophile abundances and narrow compositional ranges of plagioclase and clinopyroxene [4], so we conclude that it is monomict. Our results show that the minerals in 60055,5 are compositionally homogenous for REE and other trace elements as well. In all the samples we studied, analyses of minerals from relict clasts are virtually identical to those from the surrounding matrix, and therefore only averages of the measurements are presented here.

Figure 1 summarizes our results graphically; they are discussed in detail below. 64435,268 contains low-Ca pyroxene with a midrange mg# (100 x molar Mg/[Mg+Fe]) of 56.2, but has relatively primitive anorthite (An98.0). REE abundances in plagioclase are among the lowest we have found, with an average La concentration of 0.38 x C1 for eight analyses. Both high- and low-Ca pyroxene are HREE-enriched, with maximum REE concentrations of 10 x C1 (Yb) and 9 x C1 (Lu), respectively. Mineralogically 60055,5 and 65315,82 are very similar: low-Ca pyroxene has higher mg#'s (64.2 and 63.7, respectively) and plagioclase is somewhat more sodic (An97.7) than in 64435,268. Despite these similarities, plagioclase in 60055,5 has higher REE concentrations (La = 0.45 x C1; average of three analyses) than in 65315,82 (La = 0.33 x C1; average of seven analyses); low-Ca pyroxene, in contrast, has lower REE abundances in 60055,5 [3 x C1 (Yb)] than in 65315,82 [5 x C1 (Yb)]. High-Ca pyroxene from 60055,5 is also relatively REE-poor (only 8 x C1 for the MREE); no high-Ca pyroxene was analysed in 65315,82. Both samples have somewhat lower pyroxene REE concentrations than 64435,268, consistent with their higher mg#'s but not with the more sodic anorthite with which they are associated.

A ferroan lithology that we analysed in 62255,42 is one of the more evolved samples from the main group of FANs. Its anorthite is as sodic as An96.2 and low-Ca pyroxene has mg#'s as low as 49.0. High REE concentrations in both plagioclase and pyroxene reflect this degree of evolution. Plagioclase has an average La concentration of 0.81 x C1 for eight analyses. High- and low-Ca pyroxenes are also REE-enriched, with maximum abundances of 23 x C1 (Er) and 12 x C1 (Lu), respectively. Our fifth sample, 60025,702, contains low-Ca pyroxene with a midrange mg# of 59.5, but has relatively sodic plagioclase (An96.6). REE concentrations in plagioclase are high (La = 0.57 x C1; average of two analyses), as they are in 64435,268. This thin section was made from a split previously analysed by INAA [5]; agreement between the two data sets is excellent. High- and low-Ca pyroxene are very REE-enriched, with maximum abundances of 33 x C1 (Dy) and 13 x C1 (Lu), respectively.

We calculated equilibrium parent liquids for the minerals from each rock (Fig. 2), using distribution coefficients from G.A. McKay [6]. Liquids in equilibrium with plagioclase have REE concentrations ranging from ~8 x C1 to ~20 x C1 (Fig. 2a). The calculations for high-Ca pyroxene yield liquids that are somewhat richer in REE, although the differences are not significant within errors. Abundances range from ~15 x C1 to ~50 x C1 (Fig. 2b). We did not determine equilibrium parent liquids for low-Ca pyroxene because such calculations are subject to large errors, due to large uncertainties in the values for the distribution coefficients and greater errors in the measurements themselves. However, relative REE concentrations among samples are the same as for plagioclase, except that low-Ca pyroxene from 60055,5 appears to be anomalously low in REE.

Our data establish that significant differences exist in the REE abundances of the minerals from these five FANs. However, correlations with variations in major-element parameters, such as mg# in the mafic minerals or anorthite content of the plagioclase, are complex. REE abundances in plagioclase from the five samples define an evolutionary sequence which is fairly well correlated with Na content. The sequences for both high- and low-Ca pyroxene are broadly similar to that of plagioclase. However, these trends are not what would be predicted from the mg#'s of the mafic minerals. REE abundances in pyroxene seem to correlate better with REE contents in associated plagioclase than with the mg#'s of the pyroxenes. Future study of samples from the other three FAN subgroups may help elucidate the nature of REE variations in the anorthosite suite.

[1] J.A. Wood *et al.* (1970) Proc. Apollo 11 Lunar Sci. Conf., 965-988. [2] D. Walker (1983) PLPSC 14, B17-B25. [3] O.B. James *et al.* (1989) PLPSC 19, 219-243. [4] P.A. Warren and J. T. Wasson (1978) PLPSC 9, 185-217. [5] O.B. James *et al.* (1991) PLPSC 21, in press. [6] G.A. McKay (1989) private communication.

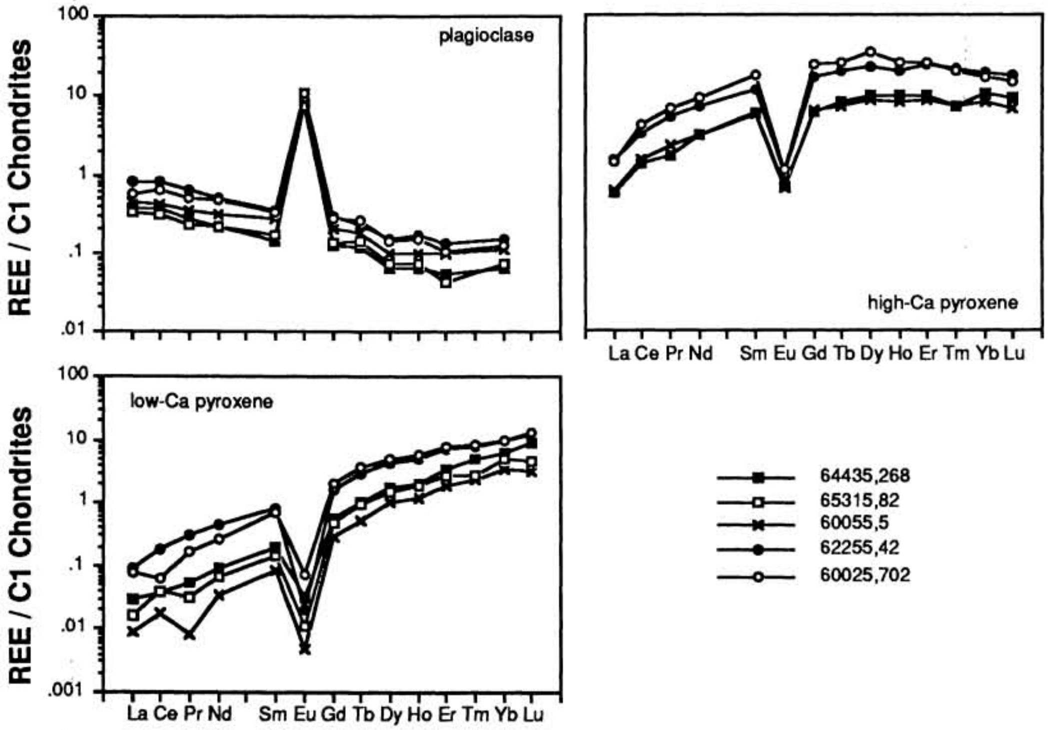

Figure 1. C1 chondrite-normalized REE patterns for minerals from five "typical" ferroan anorthosites. Patterns are averages of several analyses; see text for details.

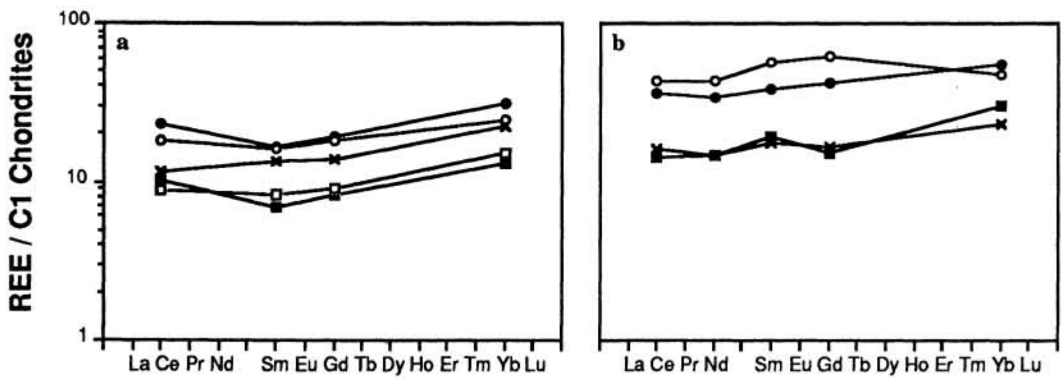

Figure 2. C1 chondrite-normalized REE patterns for five "typical" ferroan anorthosites: a) liquids in equilibrium with average plagioclase REE analyses; b) liquids in equilibrium with average high-Ca pyroxene REE analyses. Symbols as in Fig. 1.