LIMITS FROM Eu MASS BALANCE ON THE PROPORTIONS OF KREEP AND FERROAN ANORTHOSITE IN THE LUNAR SURFACE CRUST Larry A. Haskin and Randy L. Korotev, Dept. of Earth and Planetary Sciences and McDonnell Center for the Space Sciences, Washington University, St. Louis, MO 63130.

Previously (1), we showed by using the mean Th concentration of the lunar surface crust (from orbital gamma-ray data) and relationships among concentrations of Th, Sm, and Eu in highlands polymict samples that the average lunar surface crust has no substantial Eu anomaly. The surface crust contains some 65-70% plagioclase; that plagioclase appears, on the average, not to have separated from the residual liquid of its crystallization. Here, using the same data, we show limits on the proportion of KREEP and an upper limit on the proportion of plagioclase of ferroan anorthosite (FAN) composition in the average surface crust. Whether these limits are valid for the whole crust (a poorly defined entity) is uncertain.

We begin with a variant of a common model for polymict crustal materials, that these are a mechanical mixture of KREEP, anorthosite, a mafic component, and a small proportion of meteorite component. Here, we choose the composition of KREEP from (2), use the composition of FAN (3) to represent all of the plagioclase in the average crust, and relegate all material not in these two components to a third component (everything else-ELSE). We set the mean value for Al_2O_3 at 25 ± 1% (4) and use the correlation between FeO and Al_2O_3 to obtain the average concentration of FeO (5.7 ± .6%). Six mass balance equations in eight variables describe the concentrations of Th, Sm, Eu, FeO, and Al_2O_3 in the mean crust. Unknowns are the proportions of each component and concentrations of each element in ELSE. As all plagioclase that might actually have been part of the rocks whose non-plagioclase portions make up ELSE is included in the plagioclase component (FAN), we set the concentration of Al_2O_3 in ELSE at 1%. Then, we vary the mean proportion of KREEP within the limits we estimate for the non-KREEP portion of the mean crust (0.06-0.3 μg/g) based on systematics of the concentration ratio Sm/Eu versus the concentration of Th and on white clasts of ALHA81005. The upper limit to the proportion of KREEP is 4.7% and the lower limit is 3.4%, proportions independent of flaws in the model, described below.

Proportions of the other components are 69-70% for FAN and 26-27% for ELSE. This mass balance, which relegates to ELSE whatever is not contributed by KREEP and FAN, requires that the mafic component ELSE contain 20-40% of the Eu in the mean surface crust and a Eu anomaly ranging in size from none to significantly positive (despite loss of the entire plagioclase component). Since ELSE has no plagioclase (beyond what 1% of Al_2O_3 would allow) and is unlikely to contain any other Eu-selective mineral, we regard this model to be a faulty description of the surface crust. Varying the mean Eu and Sm concentrations of the surface crust to the maximum extent allowed by the data can yield a mass balance with no ELSE Eu anomaly, but the crust then has a substantial negative Eu anomaly, not a positive one as expected for a crust containing substantial cumulus plagioclase. The only solution to the dilemma is to require that the concentration of Eu in the mean plagioclase component be significantly higher than the rather narrow range found in FAN (ave. 0.8 μg/g).

This might occur if the crust had two major plagioclase components--FAN plus another with higher Eu concentration. This second plagioclase component seems implied by the many highlands samples with low Sm concentrations but Eu concentrations above 1 μg/g (Fig. 1). We rule out alkali anorthosite for this component because its abundance in the Apollo and Luna collections is so low; its presence does not increase the Eu concentrations in Apollo 14 soils above the trend for polymict materials from all missions. We rule out the plagioclase in mare basalts because required proportions of mare basalt are higher than seem allowed by observation (6-13% A-11, 17 basalt or 17-33% A-12, 14, 15 basalt, although only 3-6% L-16 basalt) and because polymict samples with low Sm concentrations (Fig. 1) cannot contain enough mare basalt to supply the Eu. A highlands plagioclase component is required. A logical choice might be the plagioclase associated with mg-suite pristine plutonic rocks, some of which have Eu concentrations twice as high as that of FAN. As KREEP and the combined plagioclase components can furnish only a small fraction of the Fe and Mg required for the surface crust, the bulk of those elements must be in ELSE. Thus, the mg' value of ELSE must match the surface crustal mean (Fig. 2), in the range 0.65-0.71. Mg-suite pristine rocks in that range of mg' contain too much Eu; the mass balance cannot accomodate the proportion of ELSE needed to provide the FeO and MgO without providing far too much Eu.

The next choice is to use mg-suite rocks with lower Eu concentrations and correct mg' values, or to use those that have high mg' values and offset them with ferroan highlands rocks with reasonable Eu concentrations. Both of these options require use of rock types not prominent in the pristine collection, or even among the abundant granulites, to represent a major component of the lunar highlands. Either the pristine sample collection is unrepresentative of the principal types of highlands rocks or the lunar polymict samples do not represent the lunar surface.

If the polymict samples represent the surface crust, their excess Eu, beyond what KREEP and FAN-like plagioclase can provide, indicates that another plagioclase component must be present. If that component contains a generously high Eu concentration (Fig. 1) of twice that of FAN (2 x 0.8 μg/g), no more than 60% of the plagioclase in the lunar crust, or about 40% of the lunar crust, can consist of FAN. The proportion of FAN decreases as the Eu concentration of the second plagioclase component decreases. Such a crust cannot have ferroan anorthosite as its dominant component.

REFERENCES: [1] Korotev and Haskin (1987) *Lunar and Planetary Science XVIII*, 505-506. [2] Warren and Wasson (1979, *Revs. Geophys. Space Phys.* 17, 73-88. [3] Korotev et al. (1980) *Proc. Lunar Planet. Sci. Conf. 11th*, 395-429.

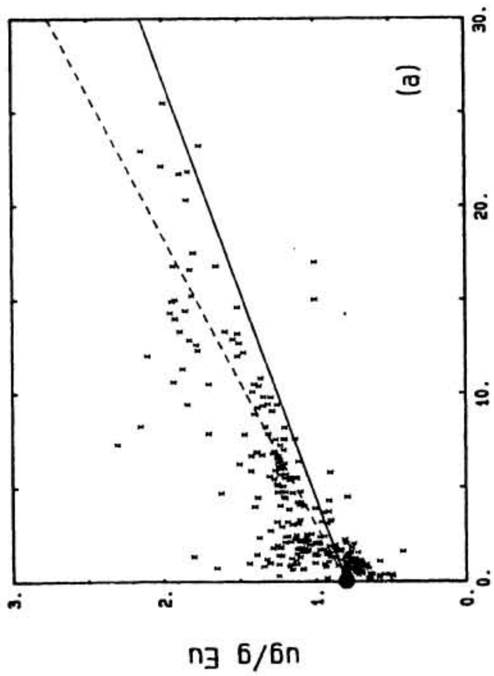

Fig. 1. Eu vs. Sm concentrations in highlands polymict samples. Solid line is KREEP-FAN mixing line; dotted line is for sample of KREEP with highest Eu.

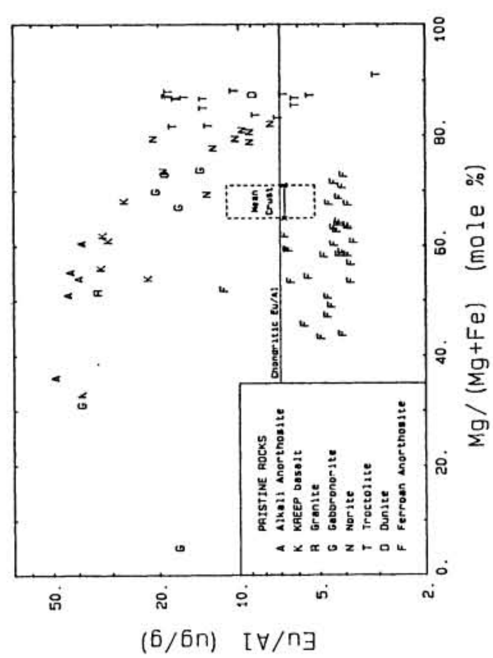

Fig. 2. Concentration ratio Eu/Al vs. mg'. FAN has low mg' but contributes negligible Fe and Mg to mixes.