**Positive Europium anomalies in Pyroxenes in Ferroan Anorthosite 60025: Implications for FAN Ages.** Torcivia, M.A.[1] and Neal, C.R.[1] [1]University of Notre Dame, Notre Dame IN, 46556; mtorcivi@nd.edu

**Introduction:** The presence of Eu anomalies in chondrite-normalized REE profiles ($REE_N$) of lunar samples is a well-documented phenomenon. In a reducing lunar magma, Eu can exist in a divalent state that allows for it to be preferentially taken up by plagioclase by substituting for the $Ca^{2+}$ cation in the crystal structure [1]. Therefore, lunar plagioclase will display a pronounced positive Eu anomaly in $REE_N$ profiles [2,3]. A consequence of this phenomenon is that the remaining melt will become depleted in Eu, and pyroxenes and other mafic minerals that subsequently crystallize will display a distinct negative Eu anomaly in their respective $REE_N$ profiles [2, 3]. In a study of Ferroan Anorthosite (FAN) sample 60025, however, a very unusual *positive* Eu anomaly in two separate pyroxene grains was discovered.

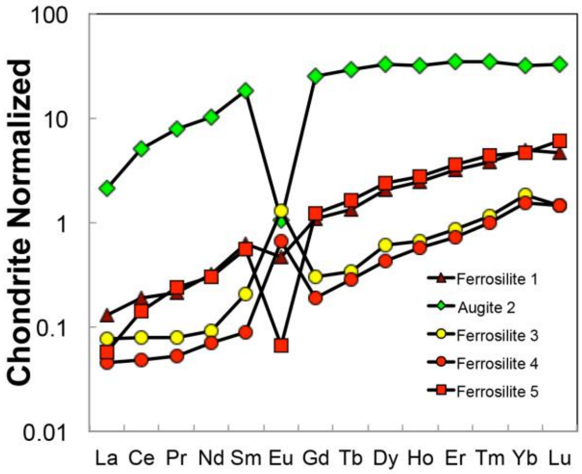


***Figure 1**: $REE_N$ plot of 5 pyroxene grains in 60025,273.*

**Methods:** Sample 60025,273 (thick section) underwent major and minor element analysis via electron microprobe and trace element analysis via laser ablation (LA)-ICP-MS, both at Notre Dame. A total of 5 pyroxene grains (4 Ferrosilite and 1 Augite) were chosen for LA-ICP-MS work using a spot size of 100-µm. Data were reduced using the GLITTER software [4]. Partition coefficients were calculated using the method of [5,6] at 1000˚C.

**Results and Discussion:** The $REE_N$ plot is displayed in Figure 1. Note that analysis 2 is the only Augite with the remaining 4 being Ferrosilite. Ferrosilite analyses 3 and 4 show a distinct positive Eu anomaly as opposed to 1, 2, and 5 that show negative Eu anomalies. Ferrosilites 3 and 4 have REE profiles that are subparallel to Ferrosilites 1 and 5 (that have negative Eu anomalies), but have overall lower REE abundances (except for Eu; Fig. 1). The simplest explanation is that the LA-ICP-MS analyses represent a mixture of pyroxene and plagioclase. To investigate this, mixing between an average of plagioclase analyses from 60025,273 [7] with Augite 2 and Ferrosilite 5 (pyroxenes with distinct negative Eu anomalies) (Fig. 2). The mixing line decreases in discrete 10% steps from a 100% pyroxene end

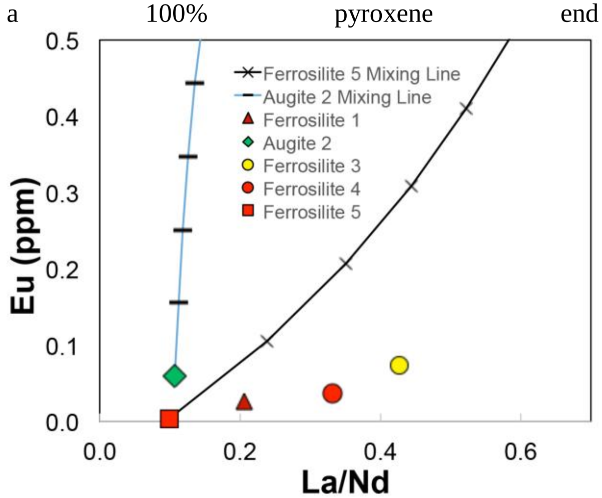


***Figure 2**: La/Nd v. Eu for spots 3 & 4 plotted with possible mixing lines between pyroxene and plagioclase. Analyses with positive Eu anomalies are represented as circles*

member. Since plagioclase is generally enriched in LREE, it usually displays a negative slope between La and Nd while a typical pyroxene grain displays a positive slope between La and Nd as they become more enriched in HREE, therefore La/Nd was used to see if the relatively flat slope between La and Nd observed in analyses 3 and 4 could be a result of mixing between an unseen plagioclase and the target pyroxene grain during ablation. This parameter was plotted against Eu (Figure 2) and shows that neither pyroxene analysis with a positive Eu anomaly from 60025, 273 can be generated through a mixed analysis of pyroxene and plagioclase.

Could element partitioning account for the positive Eu anomalies? Shearer and Papike [8] suggested pyroxene could be responsible for negative Eu anomalies in mare basalts. However, this study showed that pyroxene should develop negative Eu anomalies rather than positive ones.

Previous studies of positive Eu anomalies in terrestrial pyroxenes [9] have concluded that a corresponding positive Eu anomaly in the parent melt is required, but the process for said Eu enrichment has yet to be adequately explained. Figure 3 shows the calculated equilibrium liquids for all analyses at 1000˚C. It is important to note that the equilibrium liquids of Ferrosilite analyses 3 and 4 also show a positive Eu anomaly and that the REE profiles are subparallel to those Ferrosilites that have negative Eu anomalies, but have an overall depletion in REE abundances (except for Eu; Fig. 3). This indicates there needs to be some sort of Eu enrichment in the parent melt to get the positive Eu anomaly in the pyroxene grains.

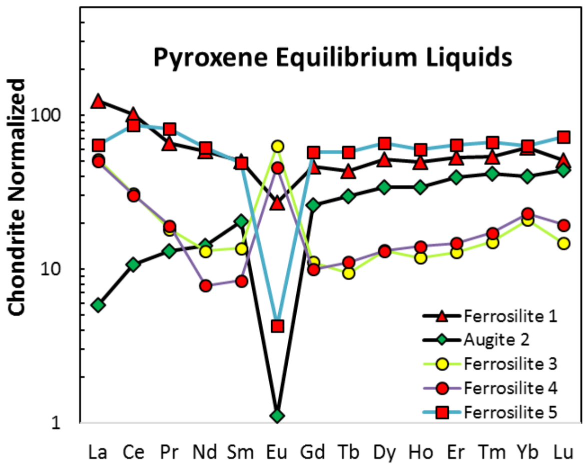


***Figure 3**: $REE_N$ plot of equilibrium liquids for pyroxene analyses 1-5. Equilibrium liquids were calculated using the method of [5,6].*

Ferrosilite analyses 3 and 4 also have the lowest Mg#'s of 0.515 and 0.517, respectively. The equilibrium liquids are inconsistent with being derived from an evolving lunar magma ocean (LMO) liquid [10] given the generally low REE abundances and positive Eu anomalies of equilibrium liquids (Fig. 3). However, the equilibrium liquids for Ferrosilite analyses 1 and 5 are consistent with derivation from an evolving LMO liquid, have negative Eu anomalies (co-crystallizing with plagioclase) and LREE enriched, although concave upward, profiles (Fig. 3). These analyses also have slightly higher (i.e., less evolved) Mg#'s of 0.535 and 0.531, respectively. Augite 2 has a much higher Mg# of 0.616 and a LREE depleted equilibrium liquid REE profile. If this was derived from an evolving LMO liquid, it would need to have crystallized much earlier that the companion Ferrosilites. This would be consistent with the conclusion of [11] that 60025 is *probably a mixture of several FAN lithologies*. However, the equilibrium liquid REE profile is LREE depleted, inconsistent with current LMO evolution models (e.g., [10]), but consistent with initial Nd isotope composition ($\varepsilon_{Nd}$ +0.6) of 60025 reported by [12]. The LREE enriched nature of the Ferrosilite analyses are consistent with the initial Nd isotopic composition ($\varepsilon_{Nd}$ -0.24) for 60025 reported by [13]. The Nd ages are distinct being 4.44±0.02 Ga [12] and 4.367±0.011 Ga [13], again consistent with 60025 being a mixture of distinct FAN lithologies.

Given the work reported here and in [7,14], we can explain the discordant Nd ages of [12,13] for FAN 60025 in the following way. The sample that produced the older age for 60025 [12] contained more of the (older) augitic component noted here. The sample that gave the younger age would have been dominated by the (younger) Ferrosilite component. Both represent FAN samples that crystallized from the LMO at different times and are present in 60025. This explanation **does not** account for the Ferrosilite analyses with positive Eu anomalies. The working hypothesis is that these compositions are a product of crystallization from an impact-generated melt that either partially melted the most evolved plagioclase and pyroxene in 60025 or was introduced externally to the sample. This melt would have the REE composition of the equilibrium liquids for Ferrosilite analyses 3 and 4 (Fig. 3) and would crystallize highly evolved pyroxenes with positive Eu anomalies.

**Conclusions:** Laser ablation ICP-MS analysis of 5 pyroxene grains yielded a very unusual positive Eu anomaly for two Ferrosilite grains in lunar sample 60025,273. The positive anomaly is not due to ablation of plagioclase with these two pyroxene analyses. These were produced from a subsequent impact melt containing the lowest melting point components of a FAN lithology (plagioclase and pyroxene) that was introduced to 60025 after LMO crystallization. The pyroxene components from 60025 highlighted here (and plagioclase analyses in [7]) can be used to explain the two dichotomous Nd crystallization ages reported for this sample [12,13], including the initial Nd isotope compositions. Only by detailed analyses of these complex ferroan anorthosites can their petrology and crystallization age(s) be explained.

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