ASSESSING THE RELATIONSHIPS BETWEEN MAJOR LUNAR CRUSTAL LITHOLOGIES AND METEORITIC CLASTS USING MAJOR AND TRACE ELEMENT MODELLING. S. M. Elardo and D. F. Astudillo Manosalva. The Florida Planets Lab, Department of Geological Sciences, University of Florida, Gainesville, FL 32611, USA. selardo@ufl.edu.

Introduction: The compositional distinctions between the major lunar igneous crustal lithologies (i.e., ferroan anorthosites, Mg-suite, alkali-suite) were well established based on analyses of Apollo samples [1, 2]. However, the continual discovery and analysis of lithic clasts found in lunar meteorites have introduced complexity into the models for the origins of these lithologies and the relationships between them. The lunar meteorite collection as a whole is expected to provide an essentially random sampling of the lunar surface, thereby offering a more global view of lithologic diversity in the lunar crust than the Apollo and Luna collections, which were collected from within and around the chemically-distinct Procellarum KREEP Terrain (PKT). Lithic clasts such as magnesian anorthosites, anorthositic troctolites, and granulites in feldspathic meteorites have mineral compositions that define a range in major element compositions which overlaps with the high Mg#s of the Mg-suite while also showing little variation in An# with decreasing Mg#, thus overlapping the compositions of FANs (Fig. 1) [e.g., 3]. Many meteoritic magnesian anorthosites, anorthositic troctolites, and granulites also have low bulk REE abundances, and chondrite-normalized REE patterns, Th/Sm, and Ti/Sc that are distinct from ferroan anorthosites, Mg-suite lithologies, and the KREEP reservoir. Although it is likely that many such samples have been altered by impact processes, or in some cases may be the products of impacts or impact melt crystallization, many clasts are likely to be derived from igneous lithologies [e.g., 4-6].

Here we examine the complex origins of lithic clasts in lunar meteorites and relationships between those clasts and other crustal lithologies using major element modelling and inferred parental magma trace element compositions. Our major element modelling explores the conditions under which cumulates with the compositions of lithic clasts in feldspathic lunar meteorites can be produced. We use published REE abundances in plagioclase from clasts in feldspathic lunar meteorites to calculate possible ranges in parental magma compositions for comparison to crustal lithologies defined by Apollo samples and for comparison to bulk clast abundances.

Major Element Modeling: The process of partial melting of dunite + anorthosite ± KREEP that was experimentally simulated by Elardo et al. [7] was recreated numerically here using the pMELTS algorithm [8, 9]. This was done to produce melt compositions that contained alkalis, since controlled-atmosphere furnace experiments such as those in Elardo et al. [7] commonly lose Na_2O and K_2O. Partial melts of the same degrees produced by Elardo et al. [7] were then used for fractional crystallization calculations using both pMELTS and the MAGFOX program [10-12]. The fO_2 of each starting composition was set at the iron-wüstite buffer at the beginning of the pMELTS calculations. Solid phases were fractionated until the calculations terminated.

Trace Element Modelling: Analyses of REE abundances in plagioclase in lithic clasts from various feld-

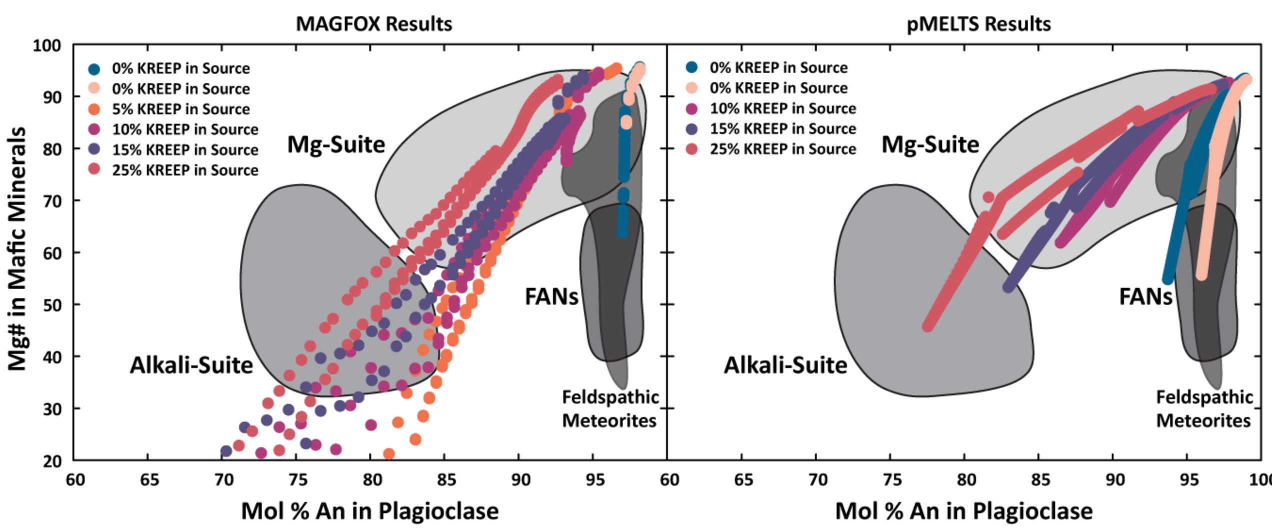

Figure 1: Plot of Mg# of mafic minerals vs. An# in plagioclase for lunar crustal rock suites (gray fields) and for the results of fractional crystallization modelling of possible Mg-suite parental magmas produced from KREEP-free and KREE-bearing sources.

spathic lunar meteorites [4-6, 13-15] were used in combination with existing parameterizations for plagioclase-melt REE partitioning [16, 17] to estimate possible parental melt compositions for the magmas that formed these lithologies from 1100-1300 °C at IW -1. We recognize that it is likely that at least some lithic clasts in feldspathic lunar meteorites do not represent igneous lithologies and/or that plagioclase may not retain primary REE abundances. However, the studies from which we take data have taken steps to assess these possibilities and largely conclude that, at minimum, REE's have not been widely redistributed during alteration or metamorphism.

Results and Interpretations: The fractional crystallization trends of selected melts from KREEP-bearing sources calculated using both MAGFOX and pMELTS are shown in Fig. 1. Results from both software demonstrate that the Mg-suite to alkali-suite fractionation trend and the production of troctolite-norite-gabbronorite cumulates is consistent with partial melting of hybridized sources containing early LMO dunites, crustal anorthosite, and variable amounts of KREEP, followed by intrusion and fractional crystallization of those melts. Results from melts from KREEP-free sources show that at least some magnesian anorthosites, and possibly even some FANs, may be the product of secondary (i.e., post-LMO) crustal magmatism produced from KREEP-free Mg-suite source rocks. These results demonstrate that the near-vertical differentiation trend in Mg# vs. An# is not necessarily attributable solely to lithologies produced in the LMO and could, at least in part be the product of secondary magmatism. We emphasize, however, that magma formation form hybridized sources, as invoked for the Mg-suite, requires a pre-existing anorthositic crust. The global extent of Mg-suite magmatism is uncertain and KREEP-rich Mg-suite magmatism is likely far more common than KREEP-free Mg-suite magmas [7], so it remains unclear how prevalent lithologies formed via this mechanism should be Moon-wide.

The inferred abundances of REEs for the parental melts to feldspathic meteoritic lithologies vary widely at 1200 °C, as does the shape of the parental melt REE pattern (Fig. 2). The majority of plagioclase parental melts have REE abundances intermediate to FAN and Mg-suite troctolite parental melts calculated at 1200 °C, though some others overlap with those melts. The shapes of parental melt REE patterns are broadly more similar to FAN parental magmas than those for the Mg- and alkali-suites, but there is some overlap (Fig. 2).

Furthermore, inferences based on the REE abundances of plagioclase parental melts do not always agree with interpretations based on bulk compositions of the same clasts. We find one such example of this to be

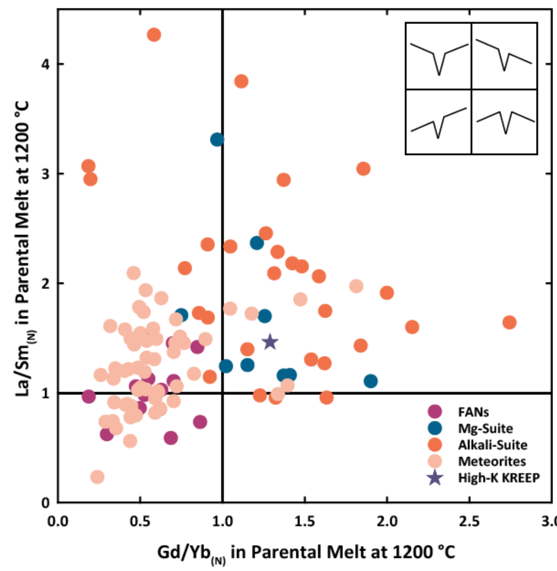

Figure 2: Plot of the LREE and HREE slopes for plagioclase parental melts for lithic clasts in feldspathic lunar meteorites compared to FANs, the Mg-suite, and the alkali-suite. Data sources for meteoritic plagioclase are in the text.

clasts from lunar meteorite NWA 10401 [5]. Gross et al. [5] showed that the major element compositions of these clasts and their constituent mafic silicates have Mg#s of ~82, making them similar to Mg-suite rocks. The clasts and bulk meteorite, however, have very low REE and Th abundances, and thus seemingly lack a KREEP component. Gross et al. [5] suggested that this could represent a KREEP-free occurrence of Mg-suite magmatism. Despite this, the plagioclase parental melt that we calculate at 1200 °C for NWA 10401 is nearly identical to high-K KREEP [18] in terms of REE abundances and REE pattern shape. This example highlights the complexity and, in some cases, ambiguity in interpreting the origins of lithic clasts in feldspathic lunar meteorites.

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