Post-LMO crustal growth. A comparison of Apollo 17 dunites. C.K. Shearer\textsuperscript{1}, P.V. Burger\textsuperscript{1} and Y. Guan\textsuperscript{2}.\textsuperscript{1}Institute of Meteoritics, University of New Mexico, Albuquerque, NM 87131 (cshearer@unm.edu), \textsuperscript{2}Division of Geological and Planetary Science, California Institute of Technology, Pasadena CA 91125.

Introduction: The plutonic rocks of the magnesian suite (Mg-suite) represent the period of lunar basaltic magmatism and crustal growth (~4.46 to 4.1 Ga) that presumably followed the initial differentiation of the Moon by magma ocean (LMO) formation and crystallization and preceded the eruption on the lunar surface and emplacement into the lunar crust of mare basaltic magmas. The volume and distribution of the Mg-suite and its petrogenetic relationship to latter stages of lunar magmatism (mare basalts) remains obscure. These plutonic rocks exhibit a range of compositions and include dunites and other ultramafic lithologies, troctolites, spinel troctolites, norites, and gabbro-norites. Shearer and Papike [1] illustrated the usefulness of using mineral chemistries for unraveling the petrogenetic relationships among Mg-suite lithologies and between Mg-suite and mare magmatism. Here, we compare two types of dunites collected from the Apollo 17 landing site. One suite of dunites (Mg-suite) occurred as clasts in a large boulder, while other dunites occur as xenoliths in high-Ti mare basalts. Do these dunite lithologies represent one or two distinct periods of magmatism (Mg-suite versus mare) or even a lunar mantle lithology? What do the differences between these two dunites reveal about their respective mantle sources?

Analytical Approach: Thin sections of 72415, 72416, 72417, and 72418 were previously examined and analyzed by Shearer and Papike [1]. Thin sections of 74275 (96,97) were initially examined and documented using backscattered electron imaging (BSE) on UNM’s JXA-8200 Superprobe electron microprobe (EPMA). Once suitable areas were located, wavelength dispersive (WDS) X-ray maps were collected for Cr, Ca, Mn, P and Ti, while energy dispersive (EDS) maps were collected for Mg and Fe. Maps were collected using a 15 kV accelerating voltage, a 500 nA beam current and a dwell time of 800 ms/pixel. Additionally, quantitative analyses were conducted as traverses, from core to rim, using both UNM’s EPMA and secondary ion mass spectrometry (SIMS), via the Camaca NanoSIMS-50L, at Caltech. Spot size was ~1 micron using both techniques. The EPMA run conditions included an accelerating voltage of 15 kV and a beam current of 20 nA. Data was collected for Si, Ca, Mg, Fe, Mn, Ti, Cr, P, Ni and V, and standardization was accomplished using Taylor and Co. mineral standards. Quantitative NanoSIMS analyses were collected on $^{27}$Al, $^{28}$Si, $^{47}$Ti, $^{51}$V, $^{59}$Co, $^{62}$Ni and $^{89}$Y, and normalized to the known Si concentration. Unknowns were standardized using in-house UNM pyroxene standards. Future work will confirm the applicability of the standardization and accuracy of results by comparison to quantitative data using UNM’s Camaca 4f SIMS instrument.

Apollo 17 Dunites: Samples 72415, 72416, 72417, and 72418 are cataclastic dunites consisting predominantly of olivine (90-95%, Fo90-86) and minor abundances of plagioclase, pyroxene, Cr-spinel, and metal. Ryder [2,3] suggested that this lithology represents the emplacement of Mg-suite magmas into the shallow lunar crust. The dunite has a Rb-Sr age of 4.55±0.1 Ga [4], though it has a complex shock and thermal history and the Pb in the sample is disturbed [5]. The dunite xenoliths in 74275 were first described in detail by Delano and Lindsley [6]. The xenoliths are mm in diameter, consist of multiple individual olivine grains, and have no accessory phases. BSE images and X-ray maps of divalent cations (i.e., Mg) (Figure 1) indicate substantial reequilibration of the xenoliths with the adjacent high-Ti basaltic melt. However, X-ray maps of Ti, P, and Al (Figure 1) illustrate that these elements preserve the initial magmatic zoning of the xenoliths. The 74275 high-Ti basalt also contains olivine xenocrysts and smaller olivine phenocrysts. Based on their composition and zoning, all three types of olivine in 74275 appear to have crystallized within distinctly different thermal-kinetic regimes. Murthy and Coscio [7] dated 74275 at 3.85 ± 0.08 Ga using Rb-Sr.
Nyquist et al. [8] obtained an age of 3.81 ± 0.32 Ga. The crystallization age of the dunite xenoliths is unknown.

**Comparisons between dunites:** Compared to the dunite clast, the dunite xenolith has remnants of igneous zoning preserved (Figure 1). However, Ryder [2,3] observed some variability in Ca that he attributed to igneous processes. The Mg# of the olivine in the xenolith is too high to be in equilibrium with the 74275 melt, and shows evidence of reaction with the melt. Ryder [2] and Shearer and Papike [1] observed that the olivine from the Mg-suite is lower in CaO and Cr$_2$O$_3$ than the olivine in mare basalts. Figure 2 illustrates that the CaO in the dunite xenolith overlaps with other olivine in 74275 and is substantially higher than in the dunite clasts. Cr$_2$O$_3$ in the xenolith (0.20-0.26 ppm) is lower than in olivine megacrysts (0.25-0.35 wt.%), but is still substantially higher than the olivine in the dunite clasts (0.04-0.06 wt.%). The cores of the individual olivines making up the dunite xenolith have ~0.02 wt.% TiO$_2$, whereas the rims have ~0.10 wt.% TiO$_2$. Xenocrysts have ~0.10-0.20 wt.% TiO$_2$. There appears to be little difference in incompatible trace elements between the two types of dunites. Ni and Co in the olivine in the xenoliths are similar to Mg-suite olivine, and dramatically different from low-Ti mare basalts (Figure 3). Ni and Co concentrations in olivine from the dunite xenolith, however, overlap with measured values for olivine in the high-Ti basalts [1].

**Conclusions:** Although the dunite xenoliths in the high-Ti basalt have reacted with the surrounding melt, most of the data suggests that this dunite was derived from accumulation of olivine during the crystallization of a mare magma. The lack of accessory minerals is consistent with the mare basalt fractional crystallization paths determined by Longhi [9] The three populations of olivine in 74275 crystallized from different basalts; going from phenocrysts to xenocrysts to dunite xenolith, one observes an increase in Mg# along with a decrease in TiO$_2$. This suggests that the different olivine populations crystallized in distinct crustal environments. The dunite xenoliths are not petrologically related to the clasts of dunites that have been associated with Mg-suite magmatism. Comparisons of these two dunites highlight differences between these two episodes of lunar magmatism. Although Ryder [2,3] attributed differences in Ca in the olivine to the depth of emplacement in the lunar crust, it is more likely that these differences reflect diverse melt chemistry. Differences in both Ti and Cr in the dunites are a product of location in the LMO cumulate pile (early versus late). Finally, compatible elements such as Ni and Co are similar in these two dunite lithologies. This may simply be a coincidence tied to the behavior and nature of Ni and Co in early- versus late- LMO cumulates [1,10] or it may be due to the involvement of late-stage cumulates in the petrogenesis of the parental magmas to both types of dunites.