A Compositional Dichotomy Between Spinels Detected from Orbit and Found in Samples: Can ANGSA Help? L. E. Galien[1] and C. R. Neal[1], [1]Department of Civil and Environmental Engineering and Earth Sciences, University of Notre Dame, Notre Dame, IN 46556, USA (lgalien@nd.edu)

Introduction: The presence of Mg-spinel on the lunar surface detected by the Moon Mineralogy Mapper (M^3) has elevated the interest in spinel minerals during the evolution of the Moon [1,2]. Few analyzed spinel compositions in lunar meteorites and returned samples represent the composition of Mg-spinel seen by M^3 **Mg# > 0.9 and Cr# <0.05** [1,3-7] (**Fig. 1**).

There are indications that some of the lithic clasts in 73001 and 73002 may also contain spinel. Here we present spinel data from other Station 3 samples along with collected data on 73215,275 to examine any connections between the M^3 observations and spinel compositions in returned lunar samples.

73215 is an aphanitic impact melt breccia collected from a small crater rim between Stations 2 and 3 near the Taurus-Littrow Valley [8]. Clast compositions vary, and include pyroxene, olivine, plagioclase, and spinel minerals. A range of spinel compositions, including magnesium-rich spinels have been recognized previously in basaltic domains within 73215,170 [9]. 73215,534 and 73215,539 spinels have been characterized as Mg# = 0.76-0.85, and Cr# - 0.09-0.11, and Mg# = 0.74-0.77, Cr# = 0.1-0.11, respectively [10]. 73263 contains pleonaste spinel with Mg# = 0.8, and Cr# = 0.08 [12]. The chemical composition of 73215,275 provides further insight into Stations 2 and 3.

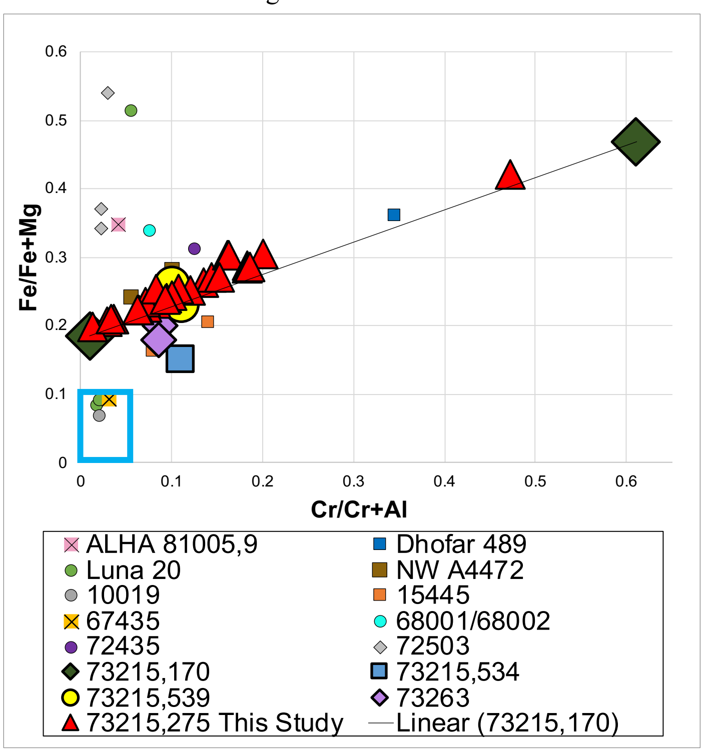

Figure 1. 73215,275 spinel Fe# vs Cr# plotted with other lunar spinel compositions, including four other bolded Station 3 samples: 73215,170, 73215,539, 73215,534, and 73263 [3,5,7,10-13,17-24]. The line is connected the end members for the compositional range of spinel in 73215,170 (green diamonds). Data collected in this work is represented by red triangles. The blue box represents the Mg-spinel compositions detected by M^3 [1,2,25].

Lunar Spinel Formation: Lunar spinel is usually associated with areas of thinner crust and feldspathic materials, and forms in the upper mantle or lower crust [1,2]. Spinel-rich lunar lithologies, like the remotely detected spinel anorthosite outcrops, cannot represent primary melts because of the thermal divide between basaltic and spinel forming melts [13-16]. However, crystal fractionation of the magma can overcome the thermal divide and form spinel-bearing lithologies [11,13,17]. Main methods of formation of spinel-bearing rocks include cumulate accumulation, nearly complete impact melting or metamorphism of a mafic parent, crystallization from troctolitic melts, and assimilation of anorthositic material into basaltic magma [13].

Methods: Thin section 73215,275 (**Fig. 2**) was photographed using a petrographic microscope. The sample was mapped for elements Mg, Fe, Ca, Ti, Al, K, Si, Mn, Na, and Cr using a CAMECA SX100 electron microprobe and Energy Dispersive Spectroscopy to identify potential spinel crystals. Point data were taken for Na_2O, MgO, Al_2O_3, SiO2, CaO, TiO_2, Cr_2O_3, MnO, FeO, and V_2O_3 via electron microprobe. Fe/(Fe+Mg), Cr/(Cr+Al), and Ti/(Ti+Al) ratios (Fe#, Cr#, and Ti#, respectively) were calculated for each point.

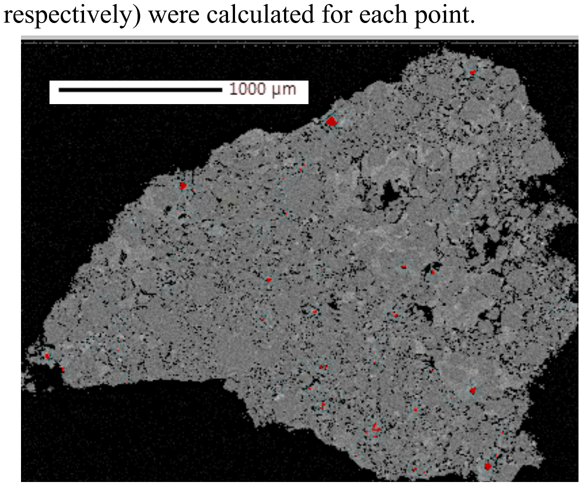

Figure 2. A false color image of 73215,275 where red points are spinel crystals.

Results & Discussion: Spinel is found across 73215,275, often in small groupings, with the largest crystals towards the edge. 73215 contains both chromium-rich and aluminum-rich spinel compositions. 73215,275 spinels plot in a trend from lower Cr# and Fe#, to higher, with one spinel plotting to the far right, with both a high Cr# and Fe# (**Fig. 1**). This trend lies along the compositional trend for spinel in 73215,170 [12].

Fe# ranges from 0.197 to 0.419 in 73215,275, which is similar to Fe# determined by [12,19] for Apollo 17 samples, with the majority of 73215,275 spinel being lower in iron than in samples from Station 2, and higher or the same as those from Station 3 (**Fig. 1**). The 73215,275 (and potentially 73215,170) spinel data define a fractionation trend, suggesting crystallization from an evolving magma. In fact, all spinel from aphanitic impact melt breccia 73215 fall on this trend, suggesting that either the target lithology(ies) were rich in spinel or the impact melt reacted with Al-rich lithologies to generate spinel and the impact was of sufficient magnitude to induce a melt that underwent crystal fractionation. Other Station 3 spinel-bearing samples fall off the trend defined by 73215,275 and ,170.

The maximum Fe# value for 73215,275 is 0.419 (**Fig. 1)**, is higher than spinel Fe# values reported in [10] for 73215 clasts but is still within the range of compositions for 73215,170 from [12]. The Ti# for spinel in 73215,275 ranges from 0.004 to 0.076, and Cr# ranges from 0.013 to 0.473.

73215,275 spinels are compositionally similar to those in lunar meteorite NWA-4472 and highlands soil sample 73263 (**Fig. 1**). Several data points show high Mg# and low Cr# in 73215,275, indicating a pleonaste composition similar to spinel from the highlands massifs [4,12].

While the most primitive spinel compositions in this sample are similar in Cr# to those detected by M^3, they are more iron rich (**Fig. 1**). Only spinel compositions from Apollo 11 regolith breccia 10019, Apollo 16 impact melt breccia 67475, and Luna 20 regolith fall within the M^3 compositional box (**Fig. 1**)

Conclusions: 73215,275 and ,170 show a nearly identical evolutionary trend. Both contain spinel minerals that define a crystal fractionation trend. Such a fractionation trend may be able to overcome the thermal divide to generate spinel from primitive primary melts of the lunar interior [11,12,16]. Other 73215 clasts contain spinel minerals that also fall on this trend. This suggests that:

1) target lithology(ies) were rich in spinel, or
2) the impact melt reacted with Al-rich lithologies to generate spinel, and
3) the impact was of sufficient magnitude to induce a melt that underwent crystal fractionation.

Spinel compositions that fall within the compositional range detected by M^3 have not yet been found in Station 3 samples from Apollo 17. Three examples do exist: Apollo 11 regolith breccia 10019, Apollo 16 impact melt breccia 67475, and Luna 20 regolith (**Fig. 1**). Interestingly, no spinel-bearing outcrops were recognized close to the Apollo 17 site [2].

Future Work: Apollo Next Generation Sample Analysis (ANGSA) regolith samples 73001 and 73002 (including lithic clasts) will be investigated for spinel occurrences to expand this sample investigation to try to explain the large spinel outcrops observed from orbital data [1,2].

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