TRACE ELEMENT GEOCHEMISTRY OF APOLLO SAMPLE 78236: POTENTIAL CONNECTIONS WITH OTHER MG-SUITE NORITES. Samuel T. Simmons[1], Thomas J. Lapen[1], University of Houston 3800 Calhoun Rd. Houston, TX. 77004,

Introduction: The Mg-suite contains cumulate dunite, troctolite, norite and gabbronorite that are characterized by relatively old crystallization ages which range from the Moon-forming event to as young as ~4.1 Ga [1 and references therein]. This suite is also characterized by primitive (high Mg#) parental melts that are enriched in incompatible elements and have Ni, Co, and Cr contents that are relatively low for the corresponding Mg# of olivine [2,3]. The complex petrogenetic history of the Mg-suite and potential petrogenetic linkages between samples remain unresolved problems.

We present new trace element contents from a representative 1 g sample of the Mg-suite norite 78236,28 that include 38 elements (Table 1). The norites are cumulates which make predictions of the parental melt compositions from bulk rock chemistry difficult. Nonetheless, the bulk rock data can be used to compare and contrast some Mg-suite norites in the lunar collection.

Sample Description: Lunar sample 78236 is a highly shocked and nearly pristine Mg-suite norite [4]. Its major element chemistry compared to other Mg-suite samples places it near the Mg end-member of the suite, potentially representing the end of the LMO stage and the beginning of Mg-suite magmatism [5]. The sample originated from the station 8 boulder that is described as small and glass covered and was collected from atop the lunar regolith. 78236 is mainly composed of ~50% orthopyroxene and about ~50% plagioclase and contains trace amounts of clinopyroxene, Si-rich glass, phosphate, potassium feldspar, baddelyite, zircon, troilite, ilmenorutile, ilmenite, chromite and impact melt [5,6,7]. The orthopyroxene grains are tabular with with shock features including undulatory extinction, mosaicism and planar deformation. The plagioclase is anorthite rich, $An_{93\text{-}95}$ [8,9], with a large percentage of the plagioclase converted to maskelynite. Overall, the sample is relatively friable due to the shock fracturing.

Sample								
78236	Li	Be	B	Sc	Ti	V	Cr	Mn
	6.23	0.88	319	9.99	903	65.6	1949	878.00
	Co	Ni	Cu	Zn	Ga	Rb	Sr	Y
	16.14	24.82	3.38	4.84	3.15	0.89	106	17.3
	Zr	Nb	Cs	Ba	La	Ce	Pr	Nd
	62.2	6.67	0.06	73.4	5.52	14.12	1.95	8.31
	Sm	Eu	Gd	Tb	Dy	Ho	Er	Yb
	2.31	0.89	2.69	0.47	3.11	0.66	1.93	1.88
	Lu	Hf	Ta	Pb	Th	U		
	0.26	1.53	0.28	0.77	0.82	0.30		

Table 1. Trace element data for sample 78236 in ppm

Methods: Apollo 17 sample 78236 was disaggregated using a boron carbide mortar and pestle. The crushed sample was then sieved through a three-stage sieve. The finest cut was collected in the base of the sieve and was used for the whole rock trace element geochemistry. A 16 mg aliquot of the powder was measured out and digested in a Parr bomb using a 4:1 ratio of HF and HNO3 acids. A procedural blank was processed identically and in parallel with the sample. The bombs were heated at 175^{o} C for 48 hours. The sample was then dried down and brought back up in 6M HCL to dissolve the fluoride salts that formed during the sample digestion process. The solution was then spiked using a multi element spike and analyzed on a Varian 810 quadrupole ICP-MS at the University of Houston. The data reduction process corrects for all types of drift using combined internal and external standards. Prior to the run, a 5ppb solution of pure Nd is analyzed in order to correct for oxide interferences with the REE's, Hf and Ta. Typical external uncertainties are less than 5% 2 SD for the elements measured here. The results are listed in Table 2.

Results: One of the inherent challenges is obtaining representative data from small samples of coarse-grained rocks. This, of course, is one of the main reasons for inverting *in situ* trace element data of constituent phases using the appropriate mineral/liquid distribution coefficients to predict parent liquid compositions. In this case, our sample is being processed for Lu-Hf isotope chronology (in progress), precluding in situ measurements. During disaggregation, the friable nature of the sample yielded powder (< 325 mesh) that should represent the 1 g mass of the sample. Another test that we are closely representing the sample composition is to compare our data with INAA data previously determined for 78236 [4]. Overall, there is excellent agreement between the two analyses and both exhibit small to unresolvable Eu anomalies, which seems rare for Mg-suite samples overall. Here, we compare compositions of Mg-suite norites and granulites in order to recognize materials that may be genetically related and guide future isotopic studies to test these connections.

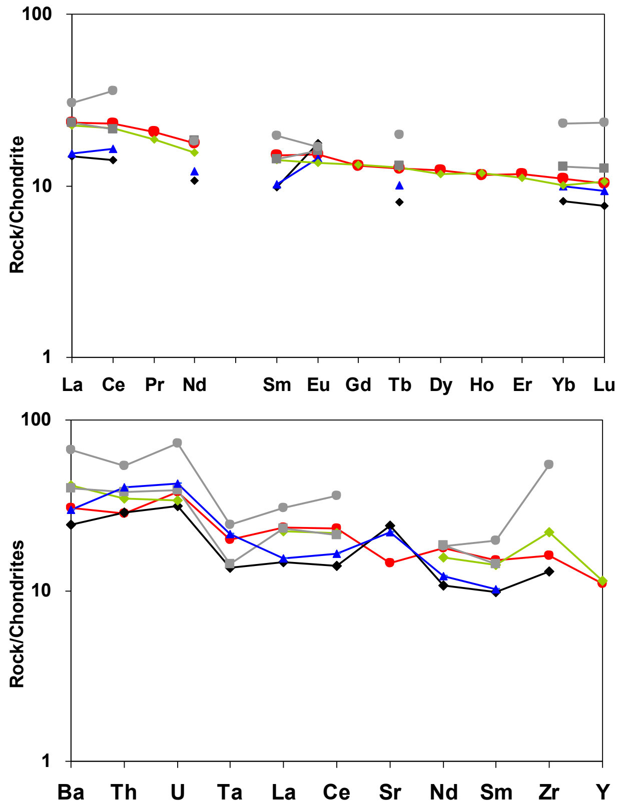

Figure 1. Top: Chondrite-normalized rare earth element (REE) abundances in 78236 (this study), 60035 (black diamond), 72275 (blue triangle), 73235 (green diamond), 77035 (gray square), 77075 (gray circle). See text for details of what portions of each sample are presented. It is notable that 73235 and 77035 have nearly identical REE abundances to 78236.
Bottom: Chondrite-normalized trace element abundances for the samples listed in the top diagram. Coloring scheme is also identical to the above. As shown by the REE data, 73235 and 77035 also have abundances of trace elements that are identical to 78236.

Figure 1 contains chondrite-normalized trace element data for 78236,28 and several Mg-suite norites that have similar trace element compositions. Although the Mg-suite norites likely formed from similar processes and thus have similar major element compositions overall, the cumulate nature gives rise to significant variability in trace element contents. Thus, similar, if not identical, trace element contents could point to a common provenance. The Apollo samples that have the most similar compositions, excluding 78255, 78235 and 78238 which are considered to be identical to 78236 [10], are granulitic breccia 60035 [10], a granulite clast from 72275,397, the troctolite/norite clast ("white clast") from 73235 [11,12], norite clast in melt breccia 77035 [13,14], and the white cataclastic norite in 77075 [15].

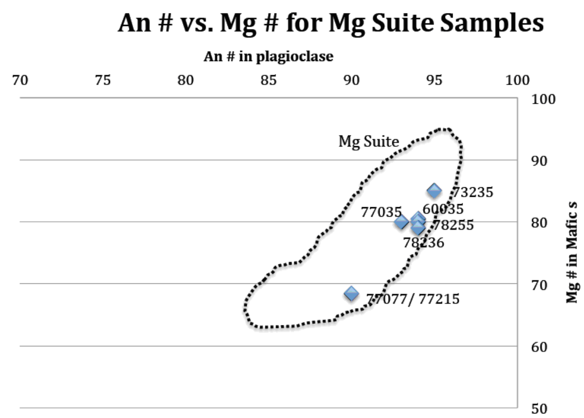

Figure 2. Figure shows an outline of the lunar mg suite with samples 73235, 77035, 60035, 78255, 78236 and 77077/ 77215. With the exception of 77077/77215 the samples are grouped tightly in the Norite/Troctolite field.

Concluding remarks: Overall, the trace element compositions of the above-mentioned samples are similar as are their Mg# of mafic phases and An content of plagioclase (with the exception of 77077/77075; Fig. 2). Of note, the troctolite/norite clast in 73235 and the norite clast in melt breccia of 77035 have nearly identical lithophile trace element compositions as 78236 that perhaps indicates a common provenance prior to impact disruption of the crust. Additionally, two granulite clasts each from 60035 and 72275 have very similar trace element abundances to 78236 and other lunar norites raising the possibility that the protoliths shared a common petrogenesis. The trace element data doesn't prove petrogenetic connections, but provides cause for further isotopic studies of these stones to test these potential connections.

[1] Shearer et al (MSA). [2] Papike et al., 1996 GCA 60. [3] Elardo et al., 2011. [4] Blanchard et al 1982. [5] Edmunson… [6] Jackson et al., 1975. [7] Sclar and Bauer 1975. [8] Dymek et al 1975. [9] McCallum, 1975. [10] Meyer C. (2011) Lunar sample compendium. [10] Salpas P. A. et al (1988) Lunar and Planetary Sci. Conf. 11-19. [11] Hudgins J. A. et al (2008) MAPS MetSoc Japan (abs#5102). [13] Taylor S. R. et al (1975) Lunar Sci. V, 789-791. [14] Bersch M. G. et al (1991) Geophys. Res. Lett. 18, 2085-2088. [15] Warren P. H. (1993) Am. Mineral, 78, 360-376. [16] Warren P. H. and Wasson J. T. (1979) Proc. 10th Lunar Planet Sci. Conf. 583-610. [17] Minkin J. A. et al (1978) Proc. 9th Lunar Planet Sci. Conf. 877-903.