MELT-WALLROCK REACTIONS ON THE MOON: EXPERIMENTAL CONSTRAINTS ON THE FORMATION OF NEWLY DISCOVERED MG-SPINEL ANORTHOSITES. T.C. Prissel[1], S.W. Parman[1], C.R.M. Jackson[1], D. Dhingra[1], G. Ganskow[1], L. Cheek[1], M.J. Rutherford[1], P. Hess[1], C.M. Pieters[1]. [1]Deptartment of Geological Sciences, Brown University. 324 Brook St., Box 1846, Providence, RI 02912. Tabb_Prissel@Brown.edu

Introduction: Recent remote mineralogical data acquired by the Moon Mineralogy Mapper (M^3) aboard Chandrayaan-1 has identified Mg-spinel-rich lithologies, likely associated with anorthosites [1,2]. While the petrogenesis of this newly discovered lunar rock type remains problematic, three key petrologic characteristics have been drawn from the spectra: **1)** a high fraction of spinel (~ 30%), **2)** a low fraction of mafic minerals (< 5% olivine or pyroxene), and **3)** an unusual spinel composition (high Mg-Al, <5% Fe) [1,2,communication with authors of 1,2]. Additionally, both localities (Theophilus Crater on the lunar nearside and Muscoviense Basin on the farside) appear to be sampling lower crustal depths.

Spinel-bearing lithologies, such as pink spinel troctolites (PST), are found in the lunar collection, but always contain olivine +/- pyroxene [e.g. 3-8]. Moreover, the Fe contents of spinels in PST are higher than the spectrally inferred Fe contents for the Mg-spinel anorthosite (Sp-An) (Fig.1). While the formation of PST is consistent with the low-pressure crystallization of forsterite-normative lunar magmas, this process is difficult to explain the markedly low mafic abundance of the new Sp-An. Thus, the M^3 finding has renewed an interest in the processes surrounding the origins of PST and connections, if any, to the new Mg-spinel anorthosite [9,10].

Alternatively, Mg-spinel has been produced in experiments examining the dissolution of anorthite into lunar basalts [11]. This suggests a mechanism for the formation of spinel-bearing anorthosites through the reactive porous flow (RPF) of a lunar basaltic magma through an anorthositic crust [9,10]. Similar processes are well documented in terrestrial magmatic systems [12] and have been linked to regional characteristics of the spinel-rich areas detected by M^3 [9]. In this study we aim to experimentally constrain the physical and chemical conditions necessary to reproduce an Mg-spinel lithology consistent with the key spectral observations from M^3.

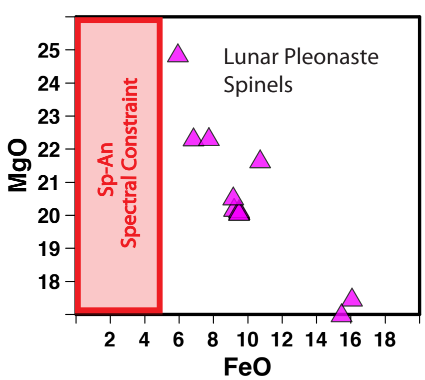

Fig.1. Lunar pleonaste spinel data (triangles) from the literature in wt% as compared to the spectroscopic constraint field from M^3 [3-8].

We have conducted a series of experiments simulating melt-wallrock interactions on the Moon. The Apollo 15C (A15C) green glass composition [13] and pressure effects (ambient – 8kbar) were investigated. Herein, we provide experimental evidence suggesting the formation of an Mg-rich spinel anorthosite via RPF of known lunar basalts into an anorthositic crust.

Experimental Summary: The starting composition was modeled and synthesized after the A15C green glass [13] by mixing reagent grade oxides to yield (by weight) 48.04% SiO_2, 0.24% TiO_2, 7.69% Al_2O_3, 0.43% Cr_2O_3, 16.23% FeO, 0.17% MnO, 18.51% MgO, 8.66% CaO, 0.01% Na_2O, 0.03% P_2O_5. This experimental mix was then conditioned at the IW buffer inside a horizontal gas-mixing furnace.

The basalt mix was put in contact with sintered pure anorthite pellets. This experimental charge was then housed inside a graphite capsule. For experiments at less than 8kbar pressure, this "package" was sealed inside a Pt capsule and run within an internally heated pressure vessel (Ar gas P-medium) at or near the liquidus temperature of the basalt (~1400-1450^{o}C). The 8kbar experiments were run inside a piston cylinder apparatus at the same temperatures. All experimental glass and spinel analyses were performed on a CAMECA SX 100 Electron Microprobe (Brown University).

Results: Experiments produced an assemblage of spinel (~15 vol.%) and less than 5 vol.% mafics within the anorthite layer (mafic abundance was estimated from the interstitial melt remaining within the assemblage). Although the spinel mode from the experiments is lower than the spectroscopic observations, our experimental runs were equivalent to melt/wallrock ratios of ~ 0.1. Indeed, continued injections of magma intruding the anorthositic crust would drive the melt/wallrock ratios to higher values increasing the fra-

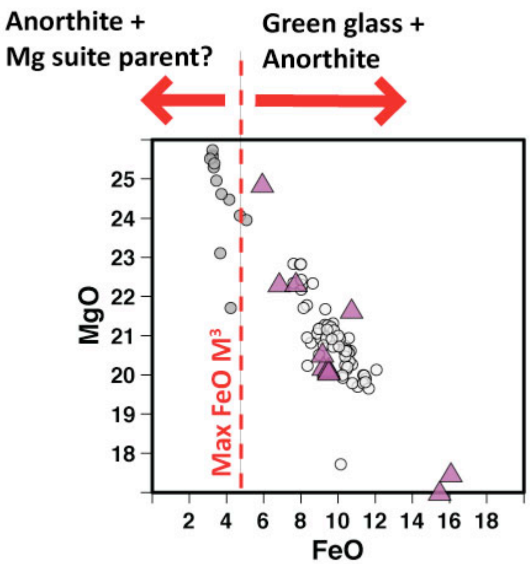

Fig. 2. Same plot as Fig. 1 now showing experimental spinels. Open circles are experiments ≥1kbar. Grey filled circles are from a 1kbar run at fO_2 ~ IW–2. The A15C green glass reacting with anorthite produces spinels with greater than 5 wt% FeO, whereas an Mg-suite parent magma during the same process is predicted to form spinels compositionally consistent with M^3 observations.

ction of spinel in the assemblage.

The experimental spinels are high-Mg, low-Fe (~10wt%) and low-Cr. While they are too high in FeO to match the spinels in the anorthosite, they closely resemble those found in PST (Fig. 2). However, a single experiment at 1kbar was run at low fO_2 (~IW–2), such that Fe-metal was smelted from the melt driving the composition of the liquid to higher Mg/Fe. Spinels produced during this experiment plot within the spectral constraint (Fig. 2). Therefore, we suggest a more Mg-rich melt (i.e. Mg-suite parental magma [14]) should produce not only a similar assemblage, but with spinel compositions consistent with the spectral observations. Experiments testing this hypothesis are currently underway.

No spinel was produced at 0.5kbar pressure constraining the depth of formation for Sp-An, with respect to the A15C green glass composition, to depths greater than ~10km on the Moon (Fig. 3). This occurs because the spinel stability field in the Fo-An-Si system decreases with pressure. Compared to the A15C green glass, an Mg-suite parent magma would be more Fo-normative and will interact with anorthite to form spinel at lower pressures.

Conclusions: Experimental results from melt-wallrock reactions between an A15C green glass and anorthite match many features of the newly identified Mg-spinel anorthosite. Therefore, Mg-spinel will be a reaction product wherever mafic melts come into contact with the lunar anorthositic crust.

The presence of spinel constrains the depth of formation (for the green glass > 10km). A more forsterite-normative melt would produce spinel at shallower depths (Fig. 3). Extrapolation from the experimental data suggests a reaction between Mg-suite parental magmas [14] and an anothrositic crust would lead to assemblages and spinel compositions consistent with the spectroscopic observations.

Thus, Mg-spinel lithologies should be a widespread, though perhaps low-volume, part of the lunar rock record. Mapping the spatial distribution and composition of such spinel-bearing lithologies will shed light on the long history of melt production and melt transport on the Moon.

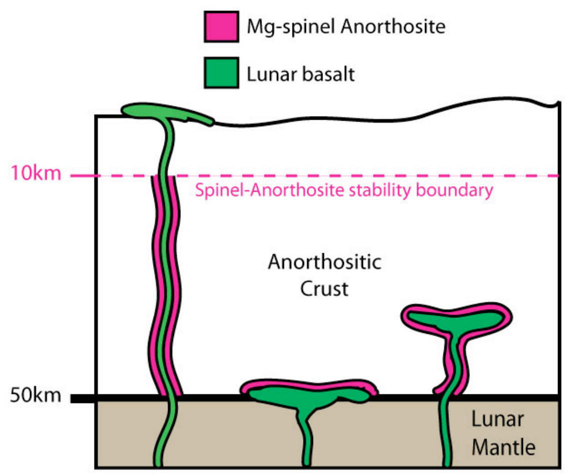

Fig. 3. Potential locations of Sp-An due to melt-wallrock reactions. For the A15C green glass, Sp-An forms only at depths >10km. An Mg-suite parental magma undergoing the same process should stabalize the Sp-An to shallower depths.

Acknowledgements: The authors gratefully acknowledge the support of the NASA Lunar Science Institute contract number NNA09DB34A.

References: [1] Pieters C.M. et al. (2011) *JGR, 116.* doi:10.1029/2010JE003727 [2] Dhingra D. et al. (2011) *GRL, 38.* doi:10.1029/2011GL047314 [3] Haggerty S.E. (1973) *Geochim. Cosmo. Acta, 37.* 857-867 [4] Prinz M. et al. (1974) *Science, 179.* 74-76 [5] Anderson A.T. (1973) *J. Geology, 81.* 219-226 [6] Ridley W.I. et al. (1973) *J. Geology, 81.* 621-631 [7] Baker M.B. and Herzberg C.T. (1980) *11th PLPSC.* 535-553 [8] Snyder G.A. et al (1998) *LPSC XXIX.* 1144 [9] Gross J. and Treiman A.H. (2011) *JGR, 116.* doi:10.1029/2011JE003858 [10] Parman S.W. et al. (2011) *Lunar Sci. Forum.* 389 [11] Morgan Z. et al. (2006) *GeoChim. Cosmo. Acta 70.* 3477-3491 [12] Kelemen P.B. et al. (1995) *Nature, 375.* 747-753 [13] Delano J.W. (1986) *JGR, 91.* D201-D213 [14] Longhi J. et al. (2009) *Geochim. Cosmo. Acta, 74.* 784-798