PARENT MAGMA COMPOSITIONS OF LUNAR HIGHLANDS MG-SUITE ROCKS: A MELT INCLUSION PERSPECTIVE. Y. Sonzogni (sonzogni@lpi.usra.edu) and A. H. Treiman, Lunar and Planetary Institute, 3600 Bay Area Boulevard, Houston TX 77058.

Introduction: The lunar highland Mg-suite is a series of plutonic igneous rocks including dunites, troctolites, norites, and gabbronorites that represent early crustal modification after crystallization of the lunar magma ocean [1]. Many studies have explored the trace element characteristics of the Mg-suite rocks and their parent melts [e.g., 2-8]; however, very little is known of the major element compositions of those melts [9-12].

Igneous melt can be trapped in growing minerals, and remnants of that melt can be preserved as melt inclusions (MIs). For the first time here, we explore whether MIs can be useful in retrieving parent melt compositions of Mg-suite rocks. Our approach is to obtain chemical analyses by EMP on MIs in plagioclase (Pl) and orthopyroxene (Opx) crystals in Mg-norite 78235.

Samples and Methods: 78235 is a 200 g, coarse-grained, shocked norite [13-16]. We studied thin section 78235.47, which consists of 55% Pl (An$_{93.94}$Ab$_{8.6}$Or$_{1.5}$), 42% Opx (En$_{78.84}$Fs$_{19.26}$Wo$_{2.4}$, Mg# = 80-81), 2% glass veins, and 1% pockets of accessory silica, apatite, whitlockite, and chromite.

We obtained petrographic data, phase compositions, and bulk compositions from 11 MIs in 7 Pl and 7 MIs in 5 Opx from 78235.47. Phase compositions were obtained with the Cameca SX-100 EPMA at Johnson Space Center; analytical conditions were 15 kV, 10 nA, 30-60 s count times, and 1-10 µm spot size.

Bulk compositions of pure glass inclusions were obtained by averaging 2-3 spot analyses. The bulk compositions of partially crystallized inclusions were calculated as the normalized sum of the weight proportions of each phase in a melt inclusion (calculated from areal proportions) multiplied by the average composition of the phase.

Inclusion petrography: MIs in Pl occur in two textures: small oblong, hexagonal, or irregular inclusions (<20 µm, mostly ~10 µm) composed mostly of glass (Fig. 1a; GMIs in Fig. 2a); and larger irregular or octagonal inclusions (~30 µm) that are ~60% crystallized (Fig. 1b; CMIs in Fig. 2a). Small MIs contain silicic glass (86-92 wt% SiO$_2$) and small grains of oxide phases and/or Fe-Ni metal (<5 µm, mostly ~1 µm). In all but one MI, the glass appears on BSE images as a fine intergrowth of two glasses of different compositions, possibly resulting from silicate liquid immiscibility. The MIs may also show a few µm-sized, needle-shape crystals of possibly phosphates and oxide phases; tiny Pl crystals (~2 µm) were found in one MI. The larger MIs contain silicic glass (86.92 wt% SiO$_2$), stocky crystals of Opx (En$_{82.84}$Fs$_{14.1}$Wo$_{2.4}$, Mg# = 84-86) and/or Al-rich Cpx (En$_{47.80}$Fs$_{5.12}$Wo$_{4.48}$, Al$_2$O$_3$ = 3.8-6.7 wt%, Mg# = 87-91), and small oxide blebs (~5 µm in diameter). In all of the MIs, the glass appears as a mixture of glass blebs of two compositions on BSE images. MIs in Opx are small irregular bodies (<10 µm) composed of silicic glass (75-79 wt% SiO$_2$) and µm-sized blebs of oxide minerals (including chromite) (Fig. 1c; GMIs in Fig. 2b). The glass is chemically heterogeneous in all but one MI, appearing on BSE images as a mixture of glass blebs of two compositions. In one MI (Fig. 1d; CMI in Fig. 2b), the two glasses (75 and 99 wt% SiO$_2$) are fairly well separated from each other; this MI also contains one diopside crystal (En$_{39}$Fs$_{3.2}$Wo$_{55}$; Mg# = 87) and oxide phases. Two inclusions are composed of nearly pure silica, and presumably are exsolutions from the Pl rather than MIs [17]. These inclusions are not considered further.

Original trapped melt: Phase and bulk compositions for MIs in 78235.47 Pl and Opx are plotted in a model phase diagram for Olivine–Plagioclase–Quartz in Fig. 2. In this diagram, the bulk compositions of crystallized melt inclusions in Pl (CMIs in Fig. 2a) fall in a mixing space between the compositions of glass, Cpx, and Opx in these MIs (grey quadrilateral in Fig. 2a), in agreement with these MIs consisting of both glass and pyroxene. The bulk compositions being consistent with each other, we consider their average as a reasonable estimate of the bulk composition of crystallized MIs in Pl.

As shown in Fig. 2a, the average bulk composition for crystallized MIs in Pl plots in the liquidus field of low-Ca pyroxene, and thus represents a melt that would not be saturated in Pl. This is because the inclusion melt
crystallized host Pl onto the walls of the inclusions after entrapment, with metastable suppression of opx crystallization. The average bulk composition thus cannot represent the melt at the time of entrapment, i.e., the original trapped melt (OTM), because the OTM composition must be saturated with the host mineral, i.e. Pl. An approximation of the OTM composition was reconstructed from the average bulk composition by adding host Pl to yield a melt that is co-saturated with Pl and low-Ca pyroxene, that is, minimally saturated with Pl (red dashed line and red star in Fig. 2a; Table 1).

The bulk compositions of glassy melt inclusions in Pl (GMIs in Fig. 2a) are similar to those of glasses in crystallized MIs. We interpret the glassy MIs in Pl to be (in fact) crystallized MIs from which daughter pyroxenes crystals were not exposed at the thin section surface.

The bulk compositions of glassy MIs in Opx (GMIs in Fig. 2b) are problematic. They could represent a metastable extension of the eutectic melt composition (blue star in Fig. 2b), before silica starts to crystallize. If true, this suggests that MIs in Opx were trapped after MIs in Pl. It is unclear whether the crystallized MI in Opx (CMI in Fig. 2b) contains Cpx or not. If not, its bulk composition would plot with the glassy MIs in Fig. 2b.

**Discussion and conclusion:** The OTM reconstructed for crystallized MIs in Pl of 78234.47 contains very little K2O and no measurable P2O5, in agreement with the very low K2O and P2O5 contents of the bulk norite (0.06-0.08 wt% and 0.04-0.05 wt%, respectively; [13,14,16]). Assuming that all the K2O in the reconstructed OTM results from the contribution of a lunar KREEP component (as estimated by [20]), we calculated that the OTM contained ~2.5% of that KREEP component. This contribution would result in ~0.05 wt% P2O5 in the OTM, a value that is below the detection limit of P2O5 in this study. Thus, our data is consistent with minimal contribution of a lunar KREEP component in the source area for the parent melt of norite 78325. This result is in contradiction with the very KREEPpy nature of Mg-norites which are inferred from trace-element data [1,6].

We have presented here the case for retrieving parent melt compositions from Mg-norites using MIs. We caution against any over-interpretation of the limited dataset at this stage, and further data are needed to better constrain the parent melt compositions determined in this study. However, we have demonstrated the potential of MIs for retrieving Mg-suite parent melt compositions, and strongly invite future workers to consider MIs in the study of Mg-suite rocks petrogenesis.


<table>
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<th>SiO₂</th>
<th>TiO₂</th>
<th>Al₂O₃</th>
<th>Cr₂O₃</th>
<th>FeO</th>
<th>MnO</th>
<th>MgO</th>
<th>CaO</th>
<th>Na₂O</th>
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Ni, P, F, and Cl were below detection limits in all phases.

![Fig. 2. Phase and bulk compositions (BCs) for melt inclusions (MIs) in plagioclase (a) and orthopyroxene (b) from lunar highland Mg-norites 78235.47 projected in oxygen units from Wollastonite (Wo) onto the Olave-Plagioclase-Quartz (Ol-Pl-Qz) phase diagram relevant to the Mg-suite parent melt composition from [12], after [18]. CMI = Crystallized melt inclusion; GMI = Glassy melt inclusion; GI = Glass; Px = Pyroxene; OTM = Original trapped melt. See text for explanations.](image-url)