Determining the Abundance and Chemical Composition of Mafic Crystals in a Lunar Meteorite

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Background

- The origin of the Moon is a topic that is fervently debated due to the limited number of samples returned from the surface.
- Just after the Moon formed, it was thought that the Moon had a lunar magma ocean (LMO), a vast world of flowing magma that reached unknown depths.
- The precise chemical nature of the LMO is unknown
- Olivine, plagioclase, and pyroxene crystals, termed "mafic crystals", record chemical changes that occurred in in the LMO.
- The LMO model can be improved with chemical analysis of rocks from a wide variety of locales.
- Lunar meteorites can contain "new" types of rocks because they can come from anywhere on the Moon.
- The focus of this study is a new meteorite, NWA 11788, that has not been analyzed before.
- This study was part of a 4-week summer undergraduate research program

Methodology

- NWA 11788 was sliced into 19 thin sections for petrographic analyses.
- Using a petrographic microscope, mafic crystals were identified in each section.
- Photomosaics were assembled for 7 thin sections (e.g. Figs. 2-3).
- Chemical analysis of mafic crystals was obtained for 5 sections using a JEOL JXA 8230 electron microprobe at the Colorado State University (Fig. 4).
- Chemical analyses of mafic crystals was compared to published data to determine if any new rock types are present in NWA 11788.

FIG 1. Lunar meteorite NWA 11788.

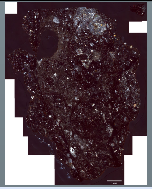


FIG 3. Cross-polarized photomosaic of slide A5.

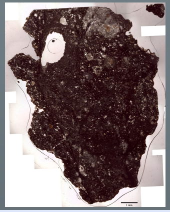


FIG 2. Plane-polarized photomosaic of slide A5.

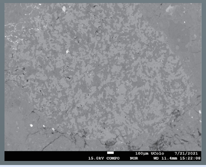


FIG 4. Backscatter Electron image of a rock in FIG 3. Dark grey is plagioclase, light grey is pyroxene and olivine, bright white is metal.

Nearside Procellarum KREEP Terrane

- The LMO model indicates that the nearside lunar crust contains KREEP, a material rich in incompatible elements.
- The model is limited because it is based only on samples from the Apollo missions, which all came from the KREEP area.
- Lunar meteorites can expand the model because they come from all areas of the moon, and thus are more representative of the Moon's crust.

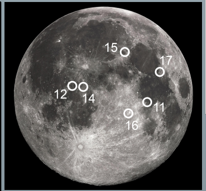


FIG 5. Apollo Landing Sites

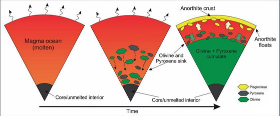
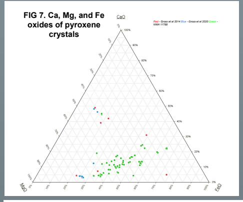
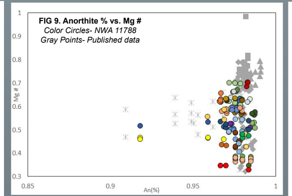


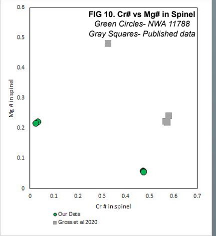
FIG 6. Diagram of proposed differentiation and crystallization history of LMO model. Mafic cumulates sank down into the core, subsequently forming the lunar mantle. Plagioclase then crystallized and floated upward producing the global anorthositic crust. (Rapp et al, 2013).

Abundance and Chemical Compositions

- Pyroxene exhibits a much wider range of compositions than previous studies (Fig. 7).
- Olivine in NWA 11788 has a lower Mg# and plagioclase has a wider range of An% compared to published data (Fig. 9).
- A few rock fragments fall outside of the range of previous studies (Fig. 8).Olivine in this study has a lower Mg# and a higher amount of Cr compared to previous studies (Fig. 8). Mg# and Cr# of spinel has lower Cr# and Mg# than published data (Fig. 10).







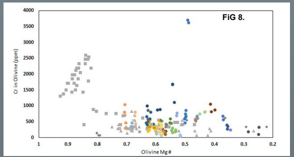


FIG 8. Mg# vs Cr2O3 in Olivine Color Circles- NWA 11788 Gray points - published data.

Conclusions

- Mafic crystals in the NWA 11788 have a wider range of compositions compared to previous studies (Figs.7,8,9,10), indicating that new rock types may be present in this sample.
- Some data points have low or high abundances of elements (e.g. points with high Cr in Fig. 7 and low Mg# in Fig. 10). Further investigation is needed to determine if these are true outliers.
- New rock types can help constrain the chemical nature of the lunar magma ocean.

Future Work

- Trace element chemical analysis (Fig. 11) will be performed using a laser ablation inductively coupled plasma mass spectrometer.
- Trace element results will be compared to previously published data and put into context with lunar magma ocean models.
- Additional sections containing abundant mafic crystals (Fig. 12 & 13) are prioritized for future major element chemical analysis.

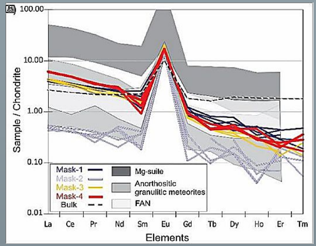


FIG 11. Rare Earth Element compositions of mafic crystals from various lunar rocks types (Gross et al., 2020).

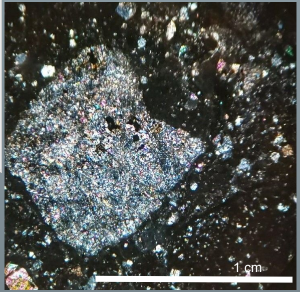


FIG 12 & 13. Cross polarized light thin sections of NWA 11788.The bright colors (pink, green, blue,yellow/orange) represent the olivine fragments, alongwith a vein cutting across (top image) consists of an olivine deposit surrounded by a brecciated matrix.

References

Gross, J., Hilton, A., Prissel, T. C., Setera, J. B., Korotev, R. L., & Calzada-Diaz, A. (2020). Geochemistry and Petrogenesis of Northwest AFRICA 10401: Anew type of The Mg-Suite Rocks. Journal of Geophysical Research: Planets, 125(5). https://doi.org/10.1029/2019je006225

Gross, J., Treiman, A. H., & Mercer, C. N. (2014). Lunar feldspathic METEORITES: Constraints on the geology of the lunar Highlands, and the origin of the lunar crust. Earth and Planetary Science Letters, 388, 318–328. https://doi.org/10.1016/j.epsl.2013.12.006

Kent, J. J., Brandon, A. D., Joy, K. H., Peslier, A. H., Lapen, T. J., Irving, A. J., & Coleff, D. M. (2017). Mineralogy and Petrogenesis of LUNARMAGNESIAN granulitic meteorite Northwest AFRICA 5744. Meteoritics & Planetary Science, 52(9), 1916–1940. https://doi.org/10.1111/maps.12898

Mercer, C. N., Treiman, A. H., & Joy, K. H. (2013). New lunar meteorite Northwest Africa 2996: A window into FARSIDE LITHOLOGIES and petrogenesis. Meteoritics & Planetary Science, 48(2), 289–315. https://doi.org/10.1111/maps.12056

Treiman, A. H., Maloy, A. K., Shearer, C. K., & Gross, J. (2010). Magnesian anorthositic granulites in LUNAR meteorites Allan HILLS a81005 AND dhofar 309: Geochemistry and global significance. Meteoritics & Planetary Science, 45(2), 163–180. https://doi.org/10.1111/j.1945-5100.2010.01014.x

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