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

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Abstract

- The origin of the Moon is a topic that is enthusiastically debated due to the limited amount of samples returned from the surface.
- Just after the Moon formed, it is thought that the Moon had a lunar magma ocean, a vast world of flowing magma that reached unknown depths.
- The precise chemical nature of the magma ocean is unknown, but can be elucidated with chemical analysis of rocks from a wide variety of locales.
- In particular, olivine, plagioclase, and pyroxene crystals, termed "mafic crystals", record chemical changes in the lunar magma ocean.
- 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 (Fig. 1).
- NWA 11788 contains rock pieces rich in olivine, plagioclase, and pyroxene crystals.
- In this study we analyzed the chemistry of olivine, plagioclase, and pyroxene crystals to determine if any new rock types exist in NWA11788.
- We also determined which thin sections contained abundant mafic crystals, and therefore should be targeted for future chemical analysis.

FIG 1. Lunar meteorite NWA 11788)

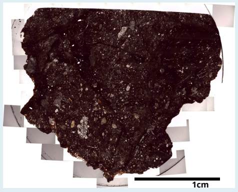


FIG 2. Plane polarized photomosaic of slide A5

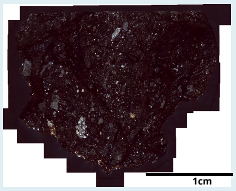


FIG 3. Cross polarized photomosaic of slide A5

Methodology

- NWA 11788 was sliced into 18 sections that were mounted to glass slides so that they can be viewed with a petrographic microscope.
- 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.

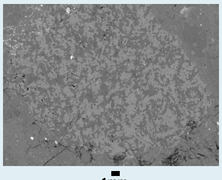
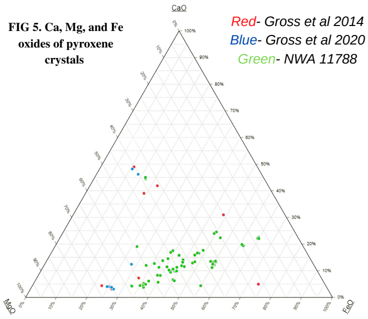


FIG 4. Backscatter Electron image of a rock in section #3. Dark grey is plagioclase, light grey is pyroxene and olivine, bright white is metal.

Results

- Pyroxene exhibits a much wider range of compositions than previous studies (Fig. 5).
- Olivine in NWA 11788 has a lower Mg# and plagioclase has a wider range of An% compared to published data (Fig. 7).
- A few rock fragments fall outside of the range of previous studies (Fig. 7).
- Olivine in this study has a lower Mg# and a higher amount of Cr compared to previous studies (Fig. 6).
- Mg# and Cr# of spinel has lower Cr# and Mg# than published data (Fig. 8).

FIG 5. Ca, Mg, and Fe oxides of pyroxene crystals



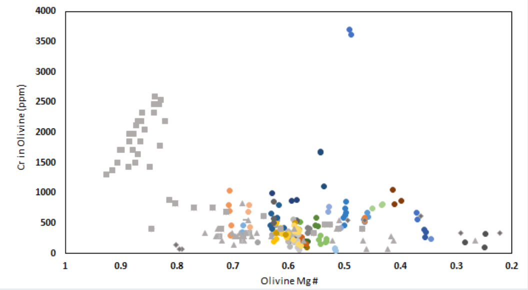


FIG 6. Mg# vs Cr2O3 in Olivine

Color Circles- NWA 11788
Gray points- Published data

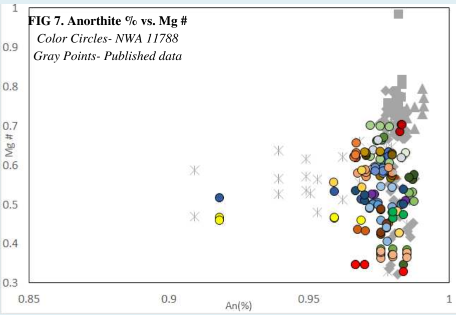


FIG 7. Anorthite % vs. Mg #

Color Circles- NWA 11788
Gray Points- Published data

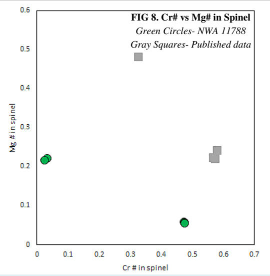


FIG 8. Cr# vs Mg# in Spinel

Green Circles- NWA 11788
Gray Squares- Published data

Conclusion

- Mafic crystals in the NWA 11788 have a wider range of compositions compared to previous studies (Figs. 5,6,7,8), 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. 6 and low Mg# in Fig. 8). 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. 9) 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 (Figs. 10 & 11) are prioritized for future major element chemical analysis.

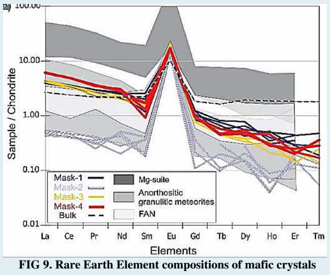
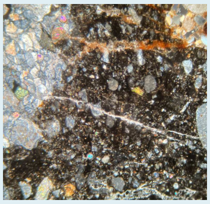


FIG 9. Rare Earth Element compositions of mafic crystals from various lunar rocks types (Gross et al., 2020).



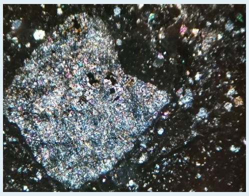
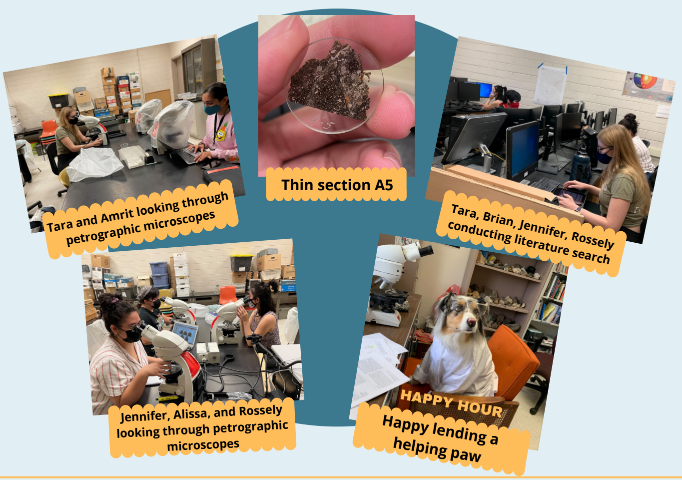


Figure 10 & 11. Cross polarized light thin sections of NWA11788.The bright colors (pink, green, blue, yellow/orange) represent the olivine fragments, along with a vein cutting across (top image) consists of an olivine deposit surrounded by a brecciated matrix.



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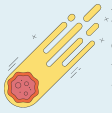

References

Gross, J., Hilton, A., Prissel, T. C., Setera, J. B., Korotev, R. L., & Calzada-Diaz, A. (2020). Geochemistry and Petrogenesis of Northwest AFRICA 10401: A new 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 LUNAR MAGNESIAN 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