Physical and Chemical Modification of Lunar Crustal Materials as Observed in Feldspathic Lunar Meteorites: Part I- Lithic Clast Chemistry

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Introduction

- Models for the differentiation of the Moon and subsequent evolution of the lunar crust have relied primarily on the analysis of returned rocks and soils from the Apollo and Luna mission [1-2].
- However, lunar meteorites derived from impacts on the lunar surface provide a much better random and representative sampling of the global lunar surface [3-4].
- An important challenge with constraining the evolution of the lunar crust using lunar meteorites involves disentangling secondary shock effects of impact bombardment on the lunar surface from primary features inherited by the lunar magma ocean [5].
- The objective of this project is to assess the degree of shock processing within feldspathic lithic clasts from a variety of lunar meteorites through combined chemical-crystallographic techniques to develop a shock transformation index that can be used to filter out heavily shocked clasts from pristine, unaltered clasts.
- For the first part of this project, here, we investigated the petrology of lithic clasts from three feldspathic lunar meteorites: Northwest Africa (NWA) 13531, Northwest Africa (NWA) 14657, and Northwest Africa (NWA) 14446.

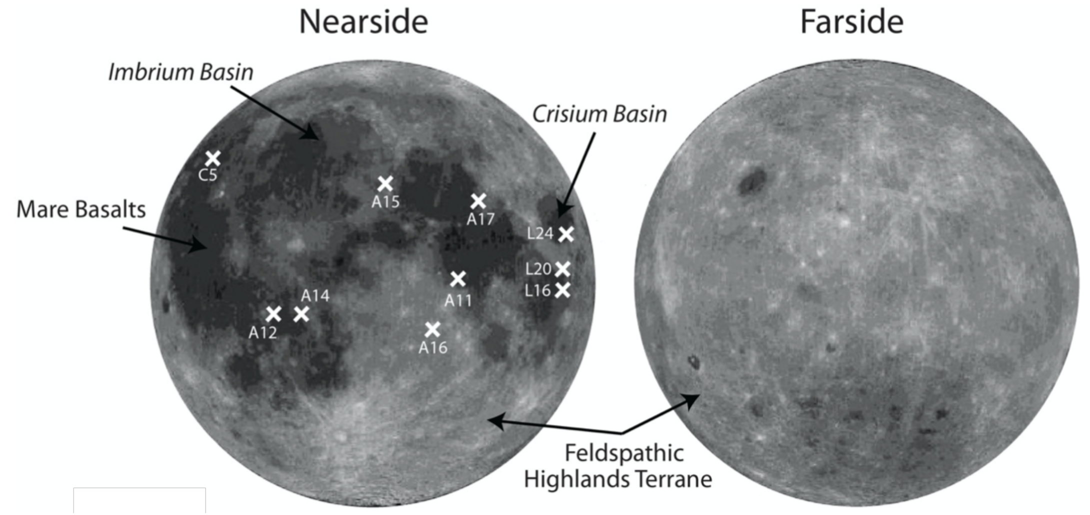


Fig. 1. Image of the nearside and farside of the Moon. Distinct lunar basins and topography, and Apollo (A) and Luna (L) recovery sites identified [6].

Methodology

- Polished thin sections of NWA 13531, 14657, and 14446 were optically studied using a DM2500P polarizing microscope (Fig. 2a) to locate lithic clasts of interest.
- Backscattered Electron (BSE) imaging and Energy Dispersive X-ray Spectroscopy (EDS) analysis of lithic clasts from each polished thin section was conducted at Portland State University using a Zeiss Sigma-VP Scanning Electron Microscope (SEM) (Fig. 2b).
- False color EDS chemical maps were obtained from each lithic clast to identify mineral phases, which were then subsequently analyzed using EDS spots to determine their chemical compositions.

Fig. 2. Polarizing microscope DM2500P used to locate lithic clasts from thin sections (2a); Zeiss Sigma-VP SEM with EDS detector used to analyze lithic clasts (2b).

Petrography

• Northwest Africa (NWA) 13531

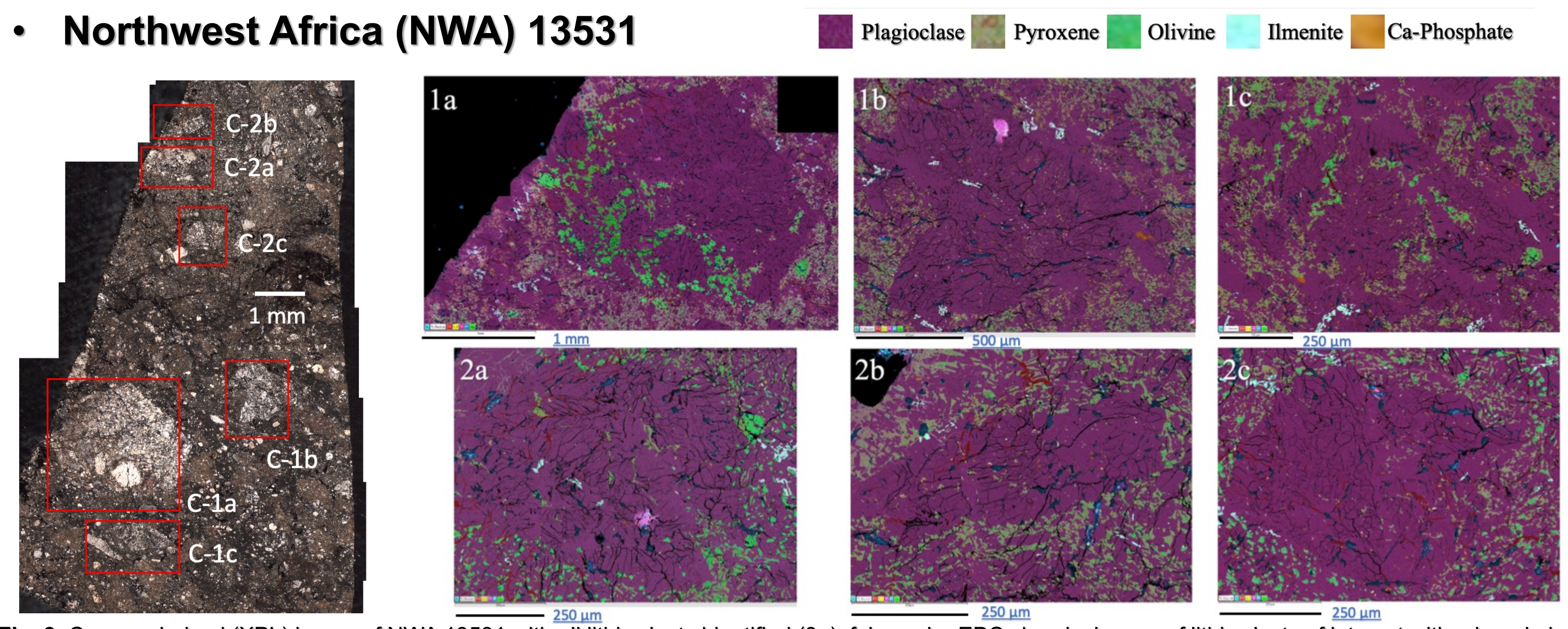


Fig. 3. Cross-polarized (XPL) image of NWA 13531 with all lithic clasts identified (3a); false color EDS chemical maps of lithic clasts of interest with mineral phases identified (3b).

- NWA 13531 represents a feldspathic fragmental breccia composed of lithic clasts sampling primarily ferroan anorthosite (FAN) and magnesian suite (Mg-suite) lithologies.

• Northwest Africa (NWA) 14657

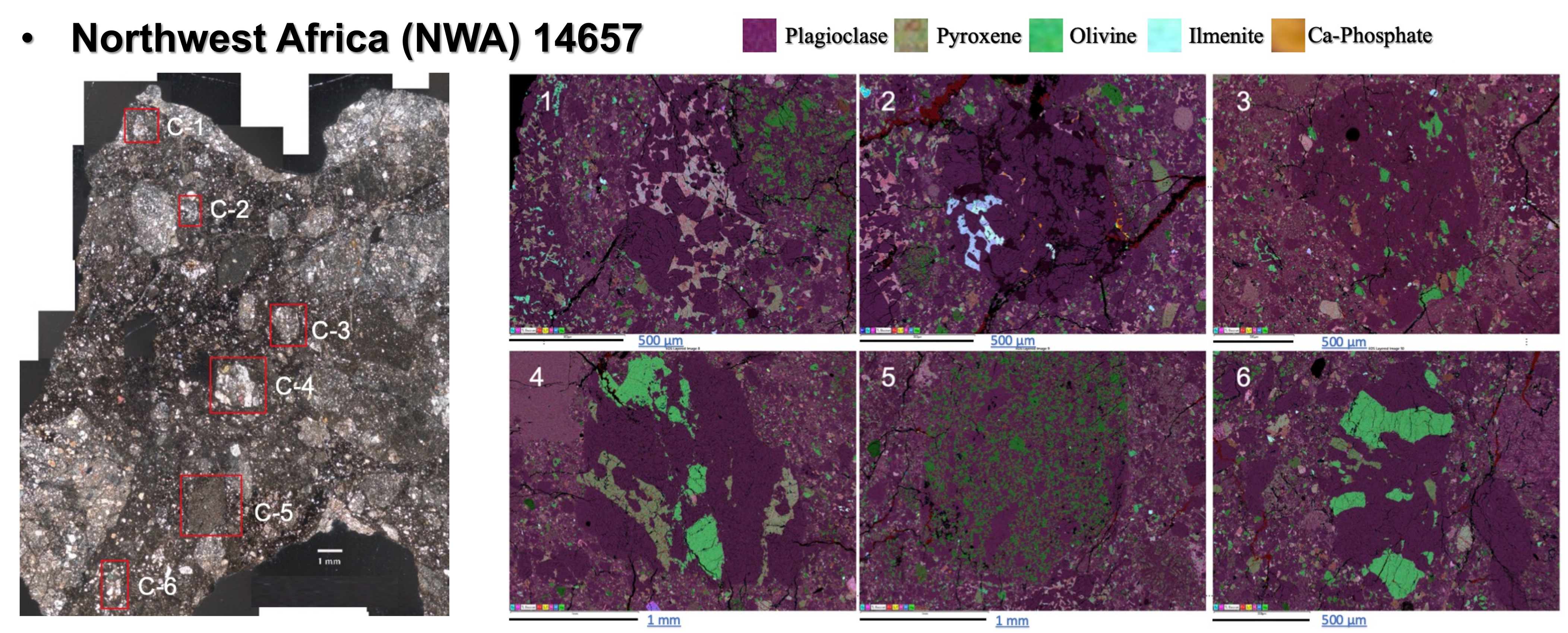


Fig. 4. Cross-polarized (XPL) image of NWA 14657 with all lithic clasts identified (4a); false color EDS chemical maps of lithic clasts of interest with mineral phases identified (4b).

- NWA 14657 represents a feldspathic fragmental breccia composed of lithic clasts sampling a large range lunar highland lithologies, including ferroan anorthosite (FAN), magnesian suite (Mg-suite), magnesian anorthosite (MAN), and hyper-ferroan lithologies.

• Northwest Africa (NWA) 14446

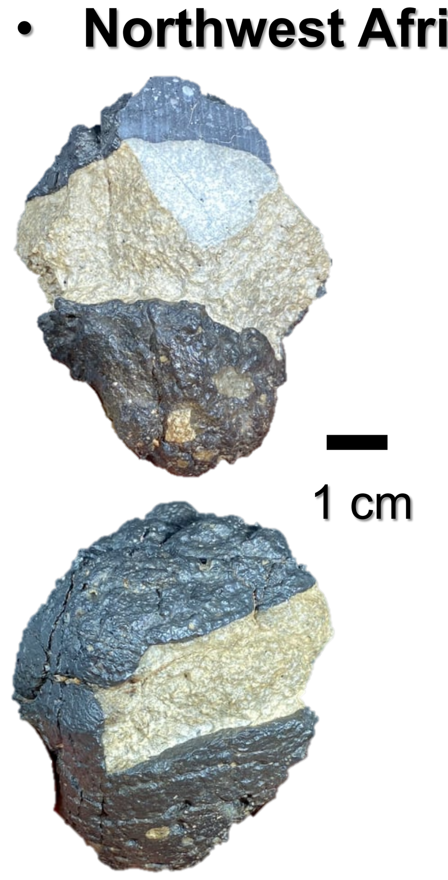
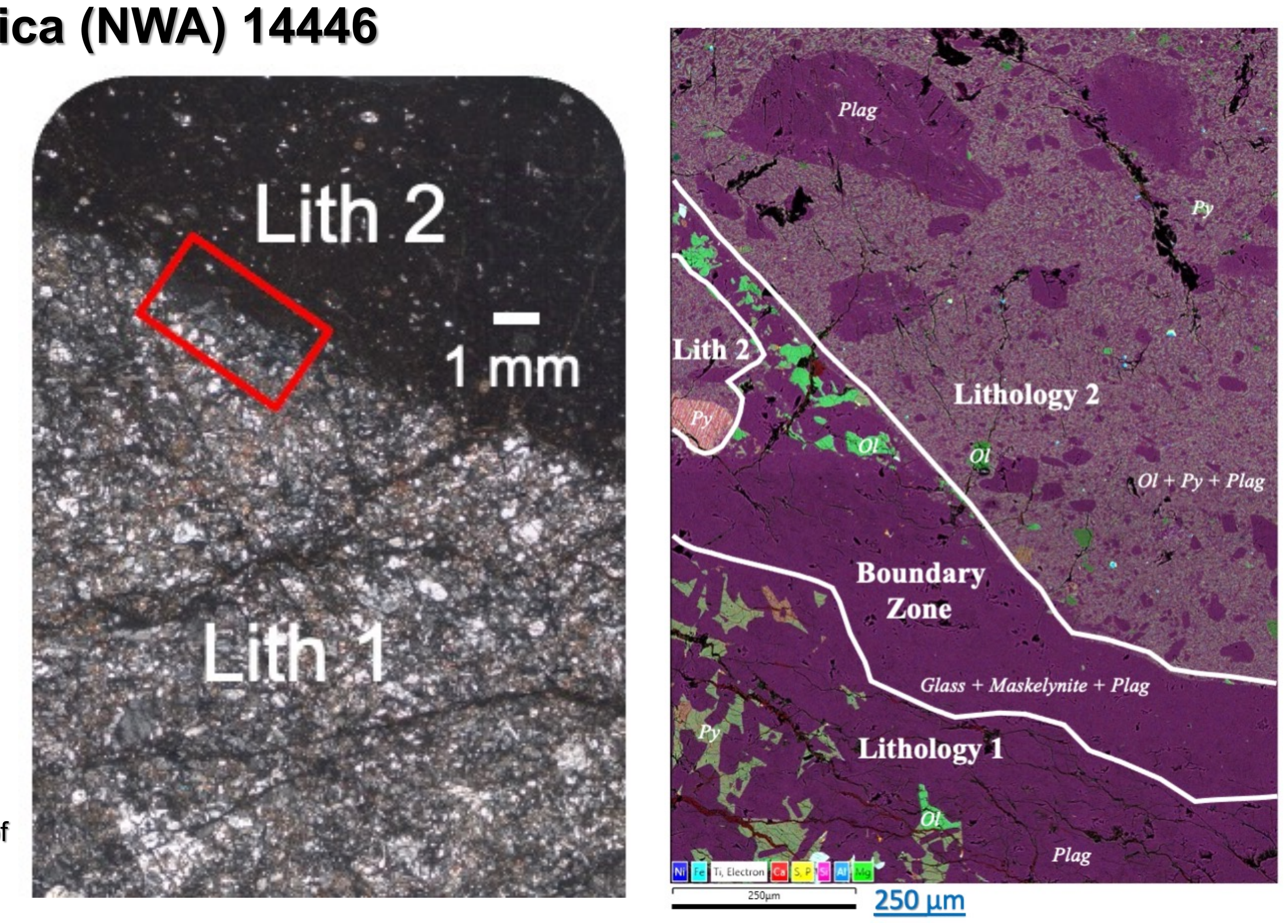


Fig. 5. Hand specimen images of NWA 14446 stone.



- NWA 14446 represents a feldspathic dimict melt breccia [7] composed of two distinct lithologies: Lithology 1 and Lithology 2.
- Lithology 1 represents a crystalline melt breccia derived from a pre-existing ferroan-anorthosite (FAN) precursor.
- Lithology 2 represents a crystalline melt breccia composed of lithic clasts that sample FAN and magnesian anorthosite (MAN) lithologies.
- Boundary zone separating Lithology 1 from Lithology 2 is composed of a mixture of melted glass, maskelynite, and plagioclase from Lith 1.

Fig. 6. Cross-polarized (XPL) image of NWA 14446 with both lithologies identified (6a); false color EDS chemical maps of both Lith 1 and Lith 2 with mineral phases identified (6b).

Geochemistry

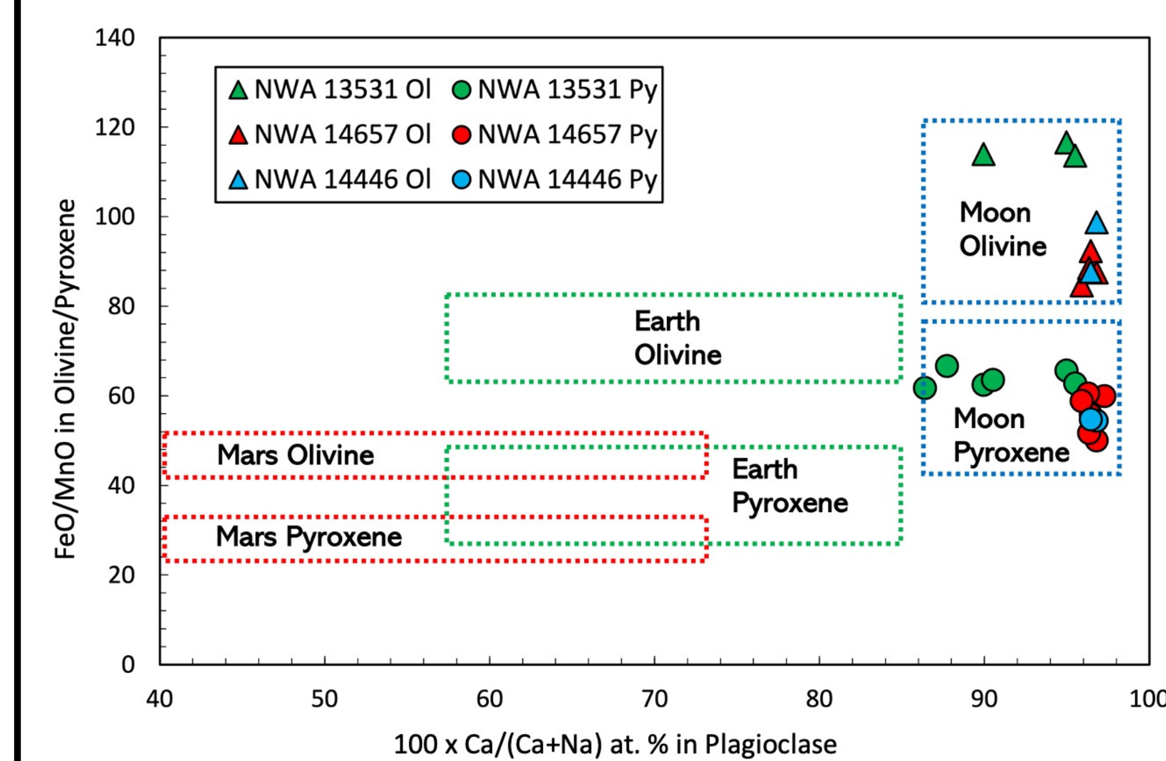


Fig. 7. Plagioclase An. vs. Olivine/Pyroxene FeO/MnO plot for all lithic clasts. Moon, Earth, and Mars fields taken from [8].

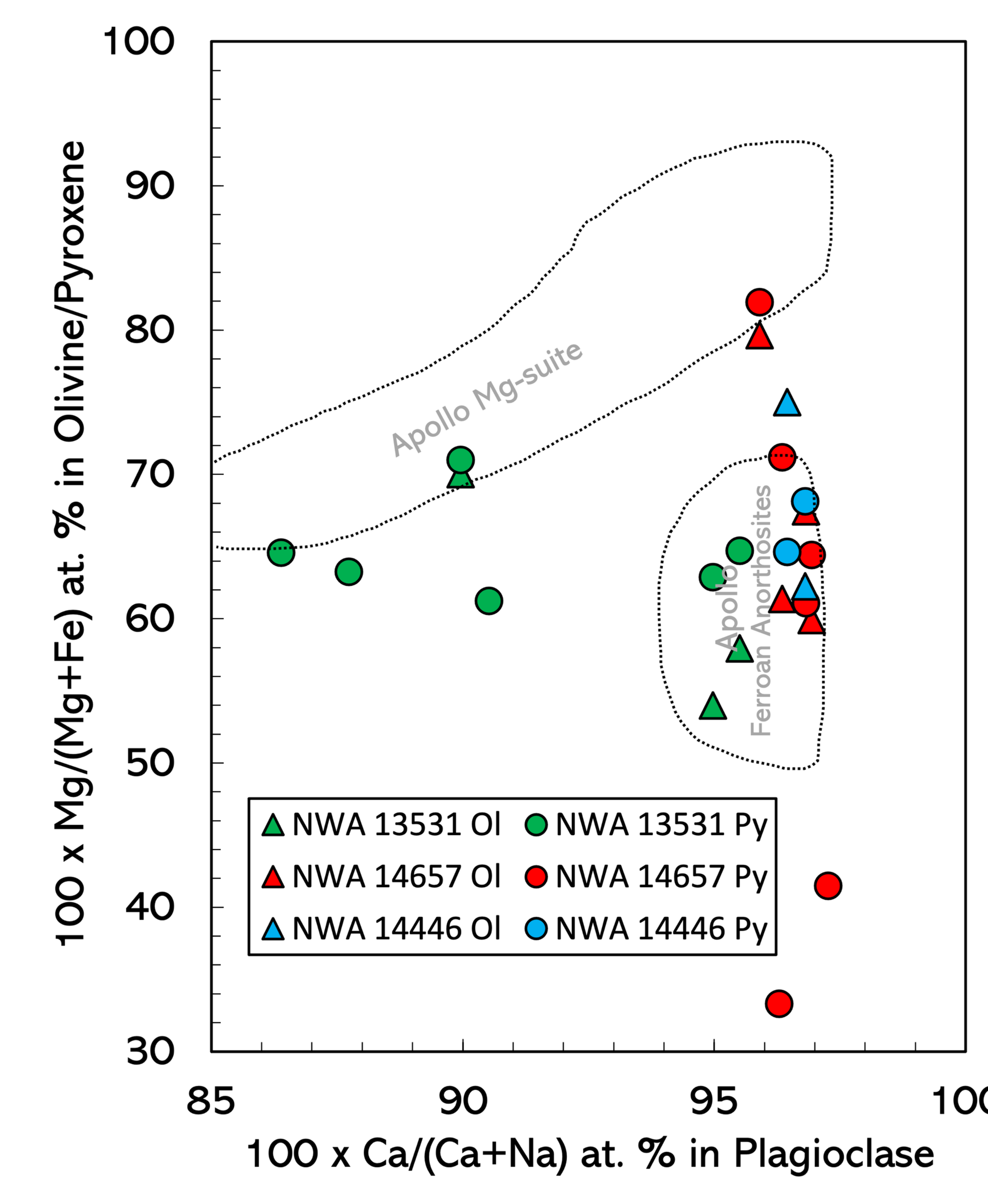


Fig. 8. Plagioclase An. vs. Olivine/Pyroxene Mg# for all lithic clasts. Apollo Mg-suite and ferroan anorthosite fields taken from [9].

Conclusions

- Lithic clasts from NWA 13531, 14657, and 14446 sample a large range in lunar feldspathic lithologies [9-10], indicating **representative sampling of the lunar crust from both nearside and farside crustal sources.**
- Future EBSD analysis of lithic clasts will provide complementary crystallographic information to aid interpretation of shock deformation history and establish a shock transformation index for each lithic clast.

Acknowledgements

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