ASSESSING THE VOLATILE INVENTORY OF BASALTIC FRAGMENTS IN LUNA SOILS

COLLEGE OF SCIENCE
LUNAR & PLANETARY LABORATORY

S. M. Morin[1], J. J. Barnes[1], Z. E. Wilbur[1], A. C. Stadermann[1], K. Domanik[1], and F. M. McCubbin[2]
[1]Lunar and Planetary Laboratory, University of Arizona (jjbarnes@arizona.edu), [2]ARES, NASA Johnson Space Center

KUIPER MATERIALS IMAGING & CHARACTERIZATION FACILITY

Background & Goals

- Potassium, rare earth elements and phosphorous comprise a lunar geochemical component called 'KREEP'. This signature manifests itself on the lunar nearside as the Procellarum KREEP Terrane (PKT).
- Prior work suggests that Apollo samples contain volatile signatures that are reflective of variable contamination by KREEP [1-3].
  - By investigating materials from outside the PKT we can test this model (Fig. 1).
- We present modal mineralogy and mineral chemistry for a selection of basalt fragments found in soils from Mare Fecunditatis (Luna 16) and Mare Crisium (Luna 24)
- Our work will provide the petrologic context for future volatile element analyses

Here, we present the initial characterization of Luna 16 and 24 basalt fragments to eventually better understand the volatile budget of the Moon.

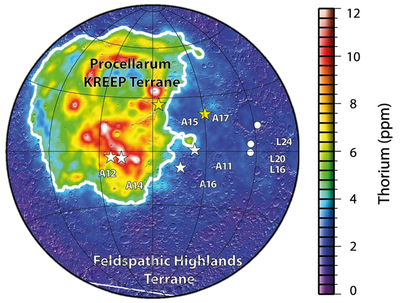


Figure 1. Location of Procellarum KREEP Terrane on the lunar nearside relative to the Apollo and Luna landing sites. Modified from [4]

Methods & Statistics

- Categorized **235 soil particles** from the <1 mm size fraction across seven Luna 16 and 24 thin sections with a Keyence VHX-7000 Digital Microscope in plane polarized, cross polarized and reflected light.
- Of **42 basaltic fragments** identified, **13 were studied** using a Cameca SX-100 Electron Microprobe, with elemental X-ray mapping, backscattered electron (BSE) images, and quantitative geochemical spot analyses.
- Using ImageJ, we created color composites (Figures 2-4) from the elemental X-ray maps in order to determine modal mineralogy for each basalt fragment.

Results

- Six Luna 16 basalt fragments were studied:
  - All low-Ti, with <10% modal ilmenite
  - 30–50% feldspar, 27–52% pyroxene
  - Most have low olivine, less than ~5%
- Seven Luna 24 basalt fragments were studied:
  - Very-low-Ti, all but one have <1% ilmenite
  - 24174,60aaj has 3.5% modal ilmenite
  - Variable plagioclase and pyroxene contents, 29–62% and 33–64%, respectively
  - Highly variable olivine abundance of between 0 and 16% by mode
  - Minor phases in both Luna 16 and 24 basalts include silica, Ca-phosphate, troilite, Fe-metal, K-feldspar, K-rich glass, ulvöspinel, and a Zr-phase.

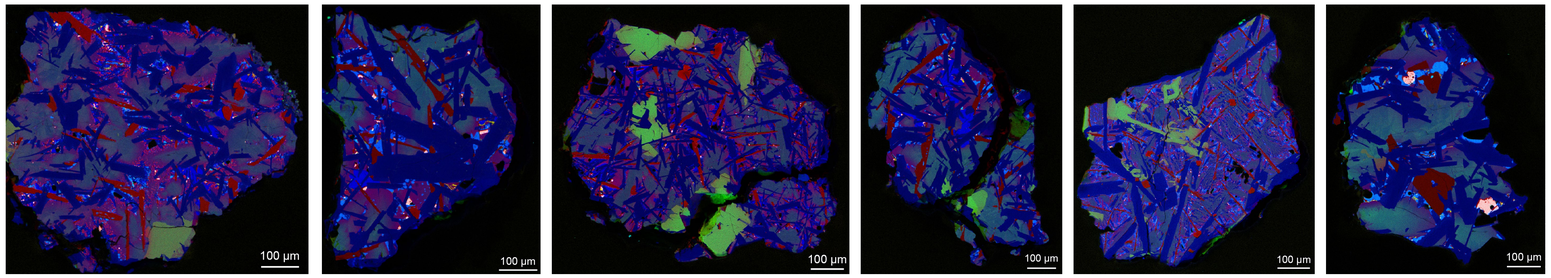


Figure 2. Elemental X-ray composites of basaltic fragments from 21013,3. From left to right: fragment a, b, c, f, i, and j. Iron = red, Mg = green, Si = blue, K = cyan, P = yellow, and S = white.

X-Ray Composites

- Figures 2-4 are X-ray composites of the studied basalt fragments that highlight the igneous textures and abundances of minerals present.
- The composites highlight the compositional zoning of olivine and pyroxene crystals.
- Late-stage mesostasis (rich in P, K, Si, S) is more prevalent in basalts from Luna 16 than Luna 24.

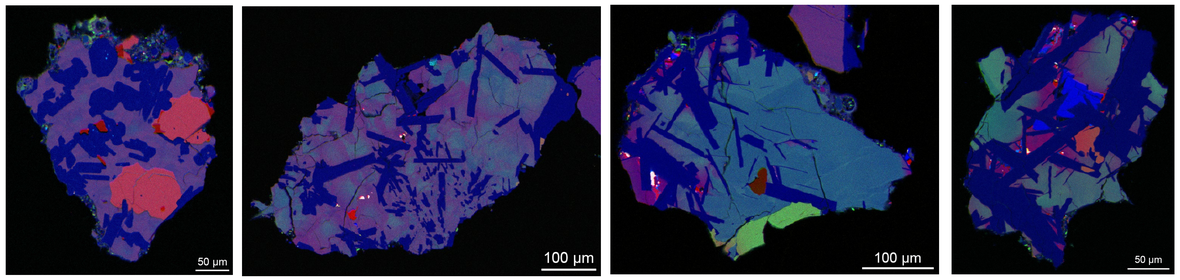
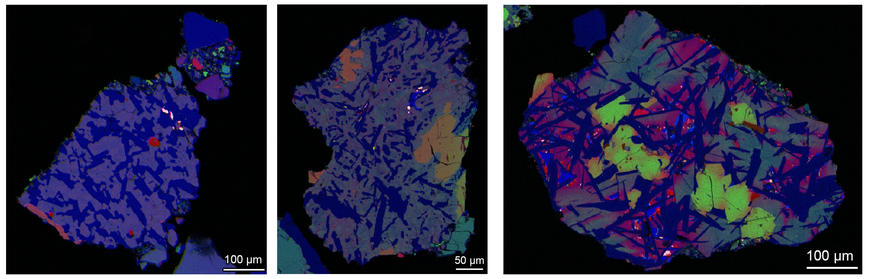


Figure 3. Elemental X-ray composites of basaltic fragments from 24109,55. From left to right: ai, al, ao, and az. Color scheme is identical to that of Figure 2.

Figure 4. Elemental X-ray composites of basaltic fragments from 24174,60. From left to right: ab, aad, and aaj. Color scheme is identical to that of Figure 2.



Modal Mineralogy

- Modal abundance of major and some minor phases have been obtained using ImageJ (Fig. 5)
- Phases include pyroxene, olivine, feldspar, ilmenite, troilite, silica, and phosphate

Mg-rich Px
Fe-rich Px
Olivine
Ilmenite
Fe/FeS/Sp
Silica
Feldspar
Phosphate

Pyroxene & Olivine Compositions

- Pyroxene compositions are plotted on a truncated ternary diagram (Fig. 6).
- Pyroxenes are mostly intermediate and follow similar geochemical trends.
- Olivine compositions are generally intermediate, ranging from Fa_{30-75} for all but one data point.

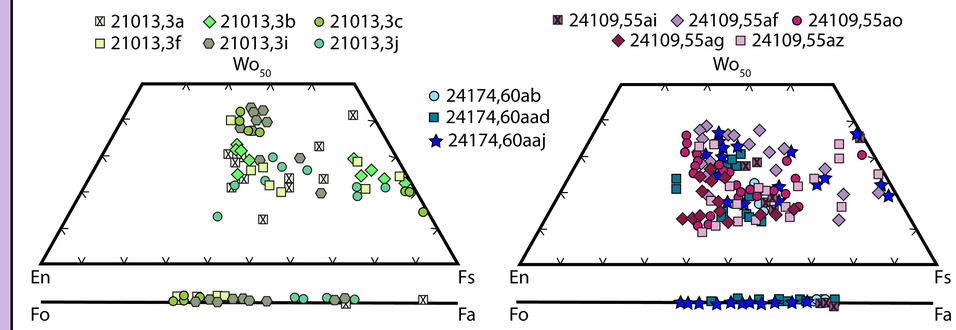


Figure 6. Pyroxene and olivine compositions for Luna 16 (left) and Luna 24 (right) basalt fragments from thin sections 21013,3, 24174,60, and 24109,55.

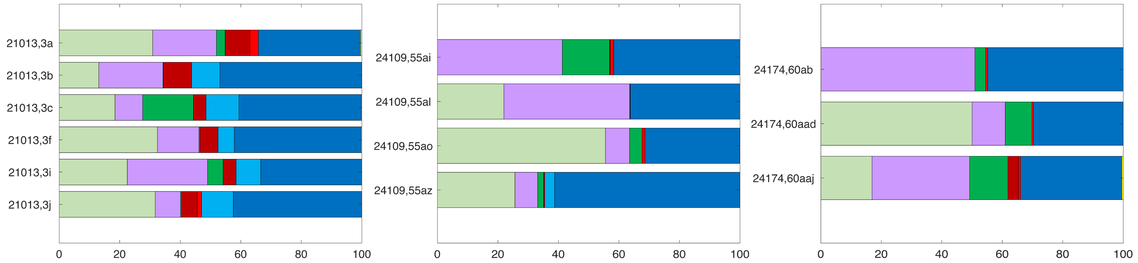


Figure 5. Modal abundances of major and some minor phases in the Luna 16 and 24 basalt fragments.

Future Work

- We identify both low and very-low-Ti basalt fragments in Luna 16 and 24 soils.
- Next, we will determine the composition of plagioclase, and minor and trace phases in these fragments, including ilmenite, mesostasis glass, ulvöspinel, and phosphates.
- We will then study the volatile inventories of the basalt fragments. The results will expand our understanding of magmatic volatiles and Cl isotope fractionation on the Moon.

References: [1] Barnes J. J. et al. 2016. Earth and Planetary Science Letters 447:84-94. [2] Boyce J. W. et al. 2015. Science Advances 1:e1500380. [3] Stephant A. et al. 2019. Earth and Planetary Science Letters 523:115715. [4] Laneuville et al. 2018. Journal of Geophysical Research: Planets 123:12.

Acknowledgements: *We thank the Apollo sample curator and NASA's CAPTEM for the allocation of Luna samples to this study. This work is supported by start-up funds to JJB.* Instrumentation supported by NASA (grants #NNX12AL47G and #NNX15AJ22G) and NSF (grant #1531243).