IDENTIFICATION OF AN UNUSUAL IRON RICH LITHOLOGY IN LUNA 24 SOIL. I. J. Ong[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, 1629 E University Blvd., Tucson, AZ 85721. [2]ARES, NASA Johnson Space Center, 2101 NASA Parkway, Houston, TX 77058.

Introduction: Samples of the lunar regolith record the geological diversity of the area on the Moon from which they were collected. In 1976, the Luna 24 mission collected a ~2m drill core from Mare Crisium. The returned sample contained ~60% lithic and mineral fragments, of which common lithologies include very-low-Ti (VLT) ferrobasalts, metabasalts, and olivine vitrophyres [1]. Initial studies of the samples along with remotely sensed chemical data indicate that VLT basalts were an important component of early basin-filling volcanism [2, 3, 4]. Continued study of these samples can reveal important information about the lithologic diversity of the eastern limb of the Moon for comparison to modern remote sensing data and can provide new insights into the evolution of VLT magmas approximately four billion years ago. The textural and chemical analysis of several unusual Luna 24 lithic fragments and preliminary hypotheses about their petrogenesis are presented here.

Sample: A polished thin section of sample 24174,60 was studied. The sample number represents material from the 174 cm interval within the ~2m Luna 24 drill core and is part of the Soviet collection shared with and curated by NASA's Johnson Space Center.

As part of a prior study, Morin et al. [5] identified several fragments in 24174,60 that did not fall into the classifications of basaltic, feldspathic, troctolitic/noritic, breccia (impact melt or regolith), agglutinate, or mineral fragments based on optical light microscopy (Fig. 1). These clasts, as far as the authors are aware, have not been specifically identified in any previous petrological studies of Luna soils [2, 3, 4].

Methods: Thin section 24174,60 was studied using optical light microscopy (plane-polarised light, PPL; cross-polarised light, XPL; and reflected light, RL) with a Keyence VHX-7100 Digital Microscope. A total of nine fragments (four main lithic and five possibly associated fragments) were identified for follow-on chemical analyses.

X-ray maps for 13–14 elements and BSE maps were acquired with a Cameca SX100 electron probe microanalyzer (EPMA) located in the Kuiper Materials Imaging and Characterization Facility (KMICF) at the University of Arizona. Quantitative chemical analyses were also performed on the major phases in the selected fragments.

The composite X-ray maps were used to determine the modal mineralogy of the fragments. *ImageJ* was used in this endeavour through the utilisation of its colour threshold function. This allowed for the areas with a specific colour range representing the same minerals to be highlighted and area calculated.

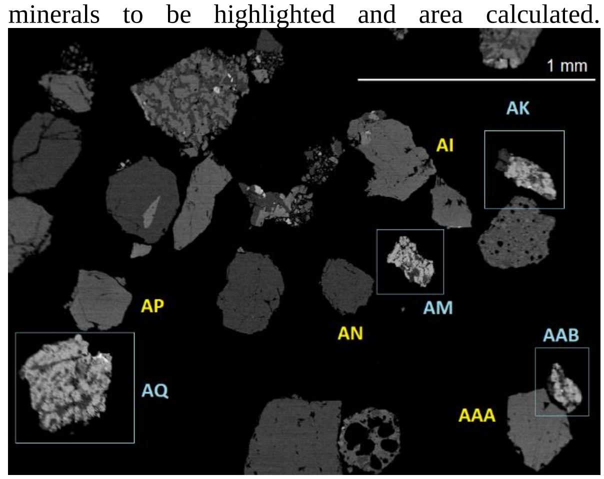

Figure 1. *Backscattered electron (BSE) image of 24174,60 highlighting the four main fragments analysed (AQ, AM, AK, AAB) and the suspected associated clasts (AP, AN, AI, AAA) compared to the other clasts in the soil.*

Results: The lithic fragments have a mottled, fluffy brown appearance under plane-polarised light. These fragments do not have breccia matrix associated with them. In BSE, these fragments stand out by being brighter than the rest of the surrounding lithic and mineral fragments (Fig. 1). Texturally, the lithic fragments contain merrillite and glass that is either poikilitically enclosed by olivine or occurs interstitially to large sub-rounded olivine grains (Fig. 2). The fragments lack vesicles, and the minerals lack exsolution lamellae or zonation.

Modal Mineralogy. X-ray composite images were used to obtain 2D modal abundances of the major phases in the lithic fragments. The range for the modal mineralogy of the four lithic fragments studied is as follows: fayalite (48-62 vol.%), merrillite (10-30 vol.%), glass/feldspar (15-28 vol.%), ilmenite (up to 5 vol.%), and troilite (up to 3 vol.%).

While the above holds true for all the fragments examined, some differences were also observed. For example, the fragment AK is the only one that contains minor amount of baddeleyite (ZrO_2). In addition, only one of the fragments (AAB) contains minor amounts of pyroxene and forsterite. This observation prompted the analysis of the neighbouring mineral fragments (AP, AN, AI, AAA) to the main iron-rich lithic fragments to understand if these fragments were originally associated with one another. This is hypothesised because the mineral fragment AAA is adjacent to AAB and both contain pyroxenes of similar chemical compositions.

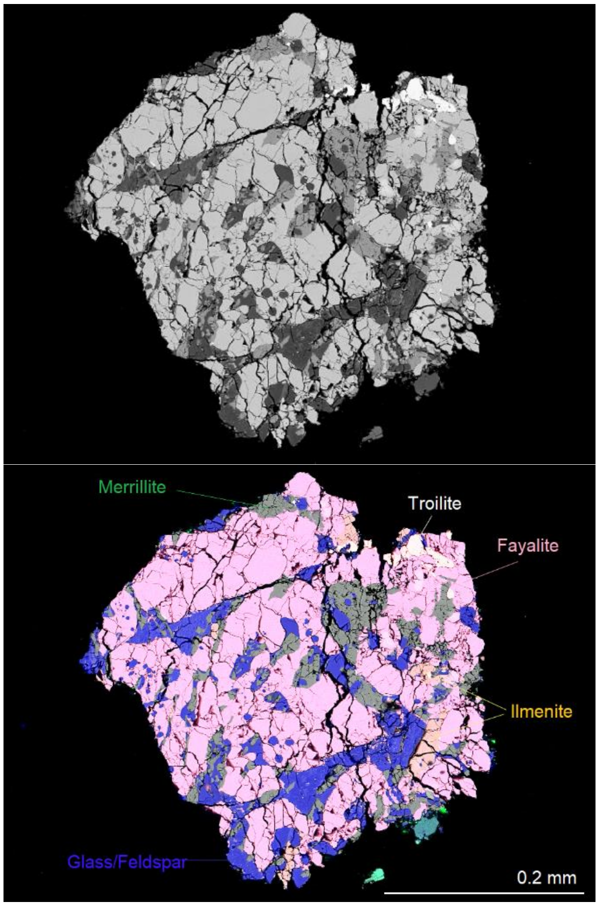

Figure 2. *BSE (top) and composite X-ray map (bottom) of fragment AQ, with Fe in red, Mg in green, Si in blue, and BSE in grey. Major phases are indicated.*

Mineral Chemistry. The olivines in the studied lithic fragments are fayalitic and homogeneous with compositions of greater than Fa_{98} except for a very small portion of fragment AAB with a composition of Fa_{25}. This explains the fact that the clasts appear very bright in the BSE image (Fig. 1, 2).

Lunar merrillite with the ideal formula of $(Mg, Fe^{2+}, Mn^{2+})_2[Ca_{18-x}(Y,REE)_x](Na_{2-x})(P,Si)_{14}O_{56}$ [6] are quite homogeneous and contain 4 to 5.5 wt.% FeO. Yttrium, La, Ce, Pr, and Nd were analysed as proxies for light and heavy rare earth elements (REE). The total REE content in merrillite in these fragments ranged from 3.8 to 4.4 wt.%. Totals ranged from 97.5 to 99.5 wt.% indicating that we captured most of the REE with our analytical routine. The merrillite are relatively rich in Fe (>5 wt.%) compared to most of the other lunar merrillites reported prior [6].

Glass and feldspar are found either interstitial to the fayalite and merrillite, or as blebs in the fayalite or merrillite. The glasses/feldspar contain 48-84 wt.% SiO_2, up to 8.4 wt.% K, up to 1.7% Na, on average ~1.5 wt.% Fe, up to 4 wt.% Ba, and up to 9 wt.% Ca.

Discussion: Coish and Taylor [7] reported finding ‘late-stage rock fragments’ in Luna 24 soil. Although it was reported that the occurrence of full mineral assemblages, like the ones observed here, were rare; they did not observe any phosphates or baddeleyite.

Collectively, the textural and chemical features suggest that this lithology is possibly of cumulate or highland origin as it lacks the usual textures of Mare Crisium basalts and its olivine displays chemical homogeneity [2, 3, 4]. Alternatively, the lithic fragments could represent coarse equivalents of mesostasis that is typically found in mare basalts [6]. If true, then perhaps the formation of this lithology involved silicate liquid immiscibility [8] or this lithology represents a distinct rock type formed by an extreme degree of fractional crystallization so far only witnessed in samples returned from Mare Crisium.

Future work. High-resolution BSE images of the fragments will be obtained using the scanning electron microprobe. The chemistry of oxides and sulphides are currently being determined by EPMA. There are also plans to determine the age of the fragments. With these data, better understanding of the petrogenesis and significance of this unusual lunar lithology can be obtained.

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