PETROGRAPHY AND GEOCHEMISTRY OF FELDSPATHIC LUNAR METEORITE LARKMAN NUNATAK 06638. R. A. Zeigler[1] and R. L. Korotev[2]. [1]NASA – JSC, mail code KT, 2101 NASA Pkwy, Houston TX 77058 (ryan.a.zeigler@nasa.gov). [2]Washington University in St. Louis, CB 1169, 1 Brookings Dr., St. Louis, MO 63130.

Introduction: Larkman Nunatak (LAR) 06638 is a lunar meteorite collected during the 2006-2007 ANSMET (Antarctic Search for Meteorites) field season. At just 5.3 g, it is amongst the smallest lunar meteorites ever recovered [1]. The initial classification of the rock revealed it to be a dark-matrix regolith breccia with millimeter-size light-colored clasts and one large (~ 1 cm), light-colored clast [2]. We report here a more detailed description of the petrography and geochemistry of LAR 06638, and discuss potential pairing relationships with other feldspathic lunar meteorites.

Methods Textures in LAR 06638 were characterized by optical microscopy in conjunction with back-scattered electron (BSE) imaging on thin section LAR 06638,13 (25 mm^2). Mineral compositions and variability were assessed by a combination of wavelength dispersive spectroscopy EPMA (electron probe microanalysis) and x-ray mapping on the JEOL 8200 electron probe at Washington University. The bulk composition of LAR 06638 was determined by Instrumental Neutron Activation Analysis (INAA) on 10 subsamples (288 mg total) from both the dark matrix and the light-colored clast, in conjunction with fused bead analyses (by EMPA) of representative INAA subsamples.

Petrography: Thin section LAR 06638,13 has two prominent lithologies present: 60% dark-matrix material and 40% light-colored clast material (Fig. 1). The dark-matrix area consists of lithic, mineral, and glass clasts set in a glassy matrix, whereas the light-colored clast area consists of lithic and mineral clasts set in a fragmental matrix. The lithic clast population of the dark-matrix area is dominated by feldspathic granulite clasts, with a few feldspathic impact-melt breccia clasts also present (Fig. 2a). Both the granulite and impact-melt clasts are dominated by calcic plagioclase (An_{95-99}; almost always >90% by mode). The granulite clasts contain minor amounts of pyroxene and olivine which range widely in size (1-50 μm; typically <10 μm). Pyroxene compositions are typically calcic pigeonite or subcalcic augite with a relatively constant Fe:Mg ratio ($En_{45-67}Wo_{9-35}$); minor amounts of low-Ca pyroxene are also observed ($En_{70-77}Wo_{2-4}$). Olivine grains have a restricted compositional range (Fo_{63-76}, most between Fo_{64-68}). Clasts of feldspathic impact-melt breccia typically have sub-parallel plagioclase laths with very thin "lamellae" (1-2 μm) of mafic glass separating them. The textures and mineral compositions observed in lithic clasts in the light-colored clast area are identical to those described in the dark-matrix area.

The mineral clast population in both lithologies is dominated by plagioclase (An_{95-98}), with lesser amounts of pyroxene ($En_{40-50}Wo_{18-40}$; $En_{60-70}Wo_{2-4}$) and olivine (Fo_{65-76}), with trace amounts of FeTiCr oxides, FeNi metal, and Fe sulfide. Glass clasts are found only in the dark-matrix area and range in shape from irregular fragments to spherules. They are typically feldspathic (<6 wt% FeO) and incompatible element poor (e.g., <0.05 wt% K_2O; <0.3 wt% TiO_2). A few glass clasts are

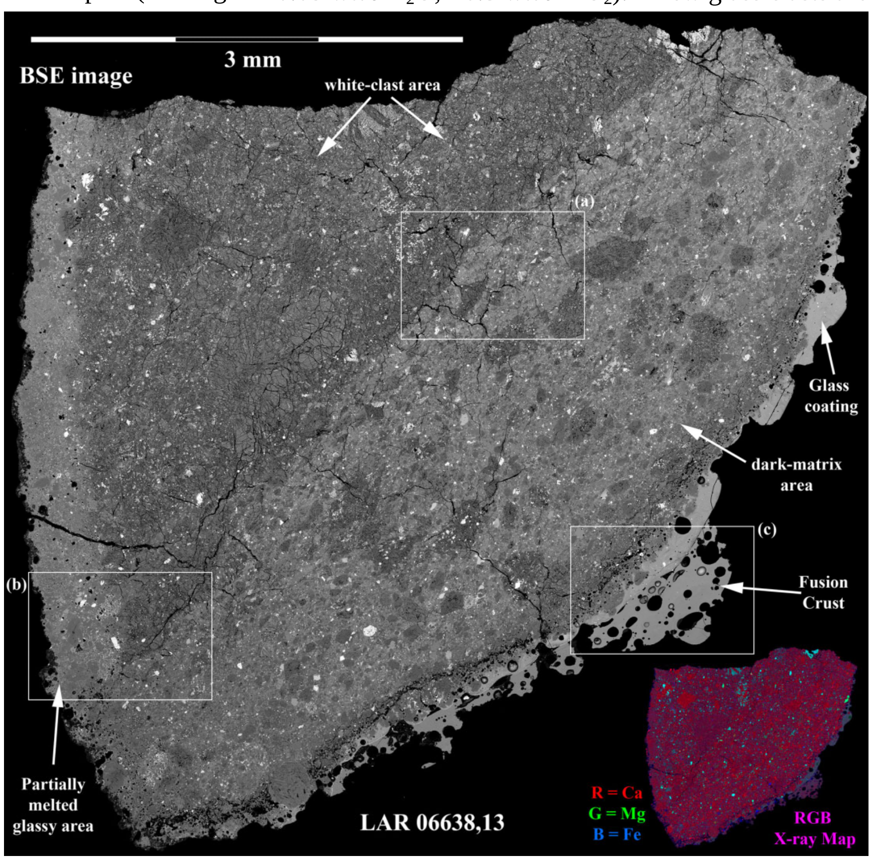

Figure 1: Back-scattered electron image (gray scale) and RGB x-ray image (color) of thin section LAR 06638,13.

moderately mafic (9-12 wt% FeO) and richer in incompatible elements (0.2 wt% K_2O; 2.5 wt% TiO_2). LAR 06638 has three distinct glass coatings (Figs. 2b,c). An inner, more mafic glass coating (16 wt% FeO + MgO) is slightly vesicular and contains schlieren and abundant nanophase Fe globules. This inner glass layer is overlain by a more feldspathic fusion crust (10.4 wt% FeO + MgO) that is highly vesicular and free of schlieren and nanophase Fe. Finally, a partially melted glassy area is also observed, where many of the mafic silicate grains observed in the adjacent textures are missing and presumably incorporated into the moderately mafic glass.

Geochemistry: Overall, LAR 06638 is a highly feldspathic (30 wt% Al_2O_3), incompatible element poor (e.g., 0.4 ppm Th) lunar meteorite, with relatively high concentrations of siderophile elements (280ppm Ni). The compositions of the dark-matrix material and the light-colored clast are similar, but the dark-matrix material is slightly less mafic (0.8× for Sc, 0.95× for FeO) and slightly richer in Na_2O (1.06×), siderophile elements (1.2× for Ni and Ir), and incompatible trace elements (ITE) (1.1-1.2×) than the light-colored clast.

Discussion: LAR 06638 is a glassy-matrix lunar regolith breccia based on the presense of glass spherules, which also contains prominent clasts of a feldspathic fragmental breccia lithology. The similarity in composition of the two lithologies is unsurprising given the observed similarities in the clast populations and mineral compositions in both lithologies. The small differences in composition are likely explained by the incorporation of small amounts of more diverse material into the regolith breccia lithologies, e.g., KREEPy glass clasts to account for the higher siderophile and ITE concentrations and excess plagioclase to account for the lower concentrations of mafic elements and increased Na concentrations. Given the relatively small masses analyzed (~120 mg of each lithology), these small compositional differences could also be sampling effects.

The presense of multiple generations of glass coatings on LAR 06638 is, to our knowledge, unique among lunar meteorites. The more mafic, schlieren and nanophase Fe bearing glass is similar in morphology to the South Ray Crater glass coatings at the Apollo 16 site [3] and likely has a similar origin. The outer, more feldspathic glass has a morphology typical of fusion crust observed on other feldspathic lunar meteorites. It is unclear at this time whether the partially melted glass area represents a partially formed fusion crust or incipient melting due to heating on the lunar surface, likely from an overlying (and possibly ablated) glass splash coating.

LAR 06638 is unlikely to be source-crater paired with any other lunar meteorites. For all elements, it plots right in the range of "typical feldspathic lunar meteorite s" [4]. Among lunar meteorites from Antarctica, LAR 06638 most closely resembles MAC 88104/5 in composition, although it is slightly more feldspathic and 1.8× richer in siderophile elements. Compositionally it is more similar to hot-desert meteorites like Dhofar 490/1084 and NWA 2200 [4].

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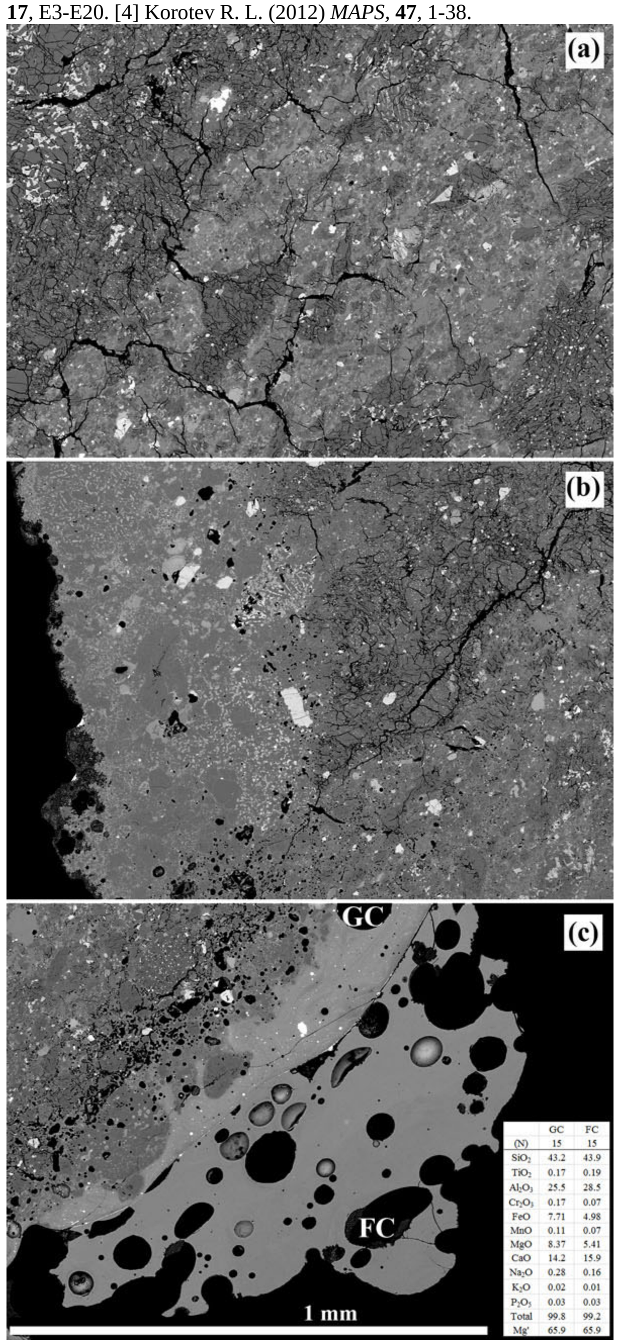
References: [1] http://meteorites.wustl.edu/lunar/ [2] McBride K. et al. (2007) *Ant. Met. News.*, **30**(2). [3] See T. H. et al. (1986) *PLPSC*, **17**, E3-E20. [4] Korotev R. L. (2012) *MAPS*, **47**, 1-38.



	GC	FC
(N)	15	15
SiO_2	43.2	43.9
TiO_2	0.17	0.19
Al_2O_3	25.5	28.5
Cr_2O_3	0.17	0.07
FeO	7.71	4.98
MnO	0.11	0.07
MgO	8.37	5.41
CaO	14.2	15.9
Na_2O	0.28	0.16
K_2O	0.02	0.01
P_2O_5	0.03	0.03
Total	99.8	99.2
Mg'	65.9	65.9

Figure 2: BSE images of the representative lithic clasts and all three glassy coatings. The composition of the glass coating (GC) and fusion crust (FC) are also shown.