PETROLOGIC, CHEMICAL AND PHYSICAL CHARACTERIZATION OF UNIQUE LUNAR VITRIC REGOLITH BRECCIA NORTHWEST AFRICA 10404. S. M. Kuehner[1], A. Wittmann[2], R. L. Korotev[3], P. Carpenter[3], R. J. Macke[4], D. T. Britt[5], A. J. Irving[1] and D. Pitt [1]Dept. of Earth & Space Sciences, University of Washington, Seattle, WA 98195 (irvingaj@uw.edu), [2]LeRoy Eyring Center for Solid State Science, Arizona State University, Tempe, AZ, [3]Dept. of Earth & Planetary Sciences, Washington University, St. Louis, MO, [4]Vatican Observatory, V-00120 Vatican City State, [5]Dept. of Physics, University of Central Florida, Orlando, FL.

Introduction: Northwest Africa 10404 is a 229 gram lunar feldspathic breccia stone recovered in 2015. Among lunar breccias (both returned samples and meteorites) this specimen is remarkable for its content of partly devitrified glass clasts and its porosity.

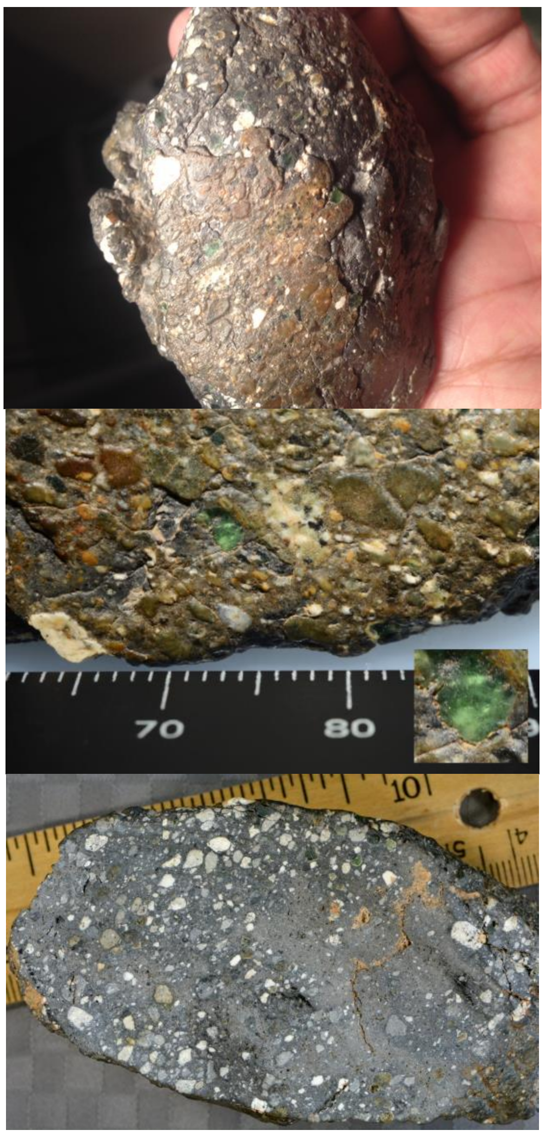

Figure 1. Top. *Whole NWA 10404 stone © M. Aid.* **Center.** *~3 mm green glass clast.* **Bottom.** *Interior slice showing white to light brownish gray glassy and crystalline lithic clasts in a gray, vesicular matrix.*

Petrography: Angular to rounded lithic clasts show extensive brittle deformation, and comprise reworked polymict breccias, clast-bearing microcrystalline to vitric melt rocks, and fine to medium grained poikilitic rocks with variable feldspar content. Mineral clasts are mainly anorthite ($An_{96.1-97.0}Or_{0.0}$), pigeonite ($Fs_{21.1-25.9}Wo_{11.0-11.5}$; FeO/MnO = 59-60) , orthopyroxene ($Fs_{37.6}Wo_{3.2}$; FeO/MnO = 64), subcalcic augite ($Fs_{21.9}Wo_{11.0-11.5}$; FeO/MnO = 51), augite ($Fs_{20.0}Wo_{37.9}$; FeO/MnO = 46), olivine ($Fa_{26.4-47.2}$; FeO/MnO = 77-84), plus rare Ti-chromite, troilite and taenite.

Glass clasts range from translucent to brown to green, with shapes from angular to round (implying that some may be fragments of larger spherules). All glass clasts are holohyaline with isotropic cores and 0.1-0.3 mm thick concentric rims of spherulitic crystallites (Figure 2), implying reactions with the matrix. Semi-quantitative analyses of glasses by EDS and *in situ* X-ray fluorescence show highly variable contents of Si, Al, Ca, Fe and Cr, which presumably signify impact-triggered melting of various mixtures of the major minerals present during breccia formation.

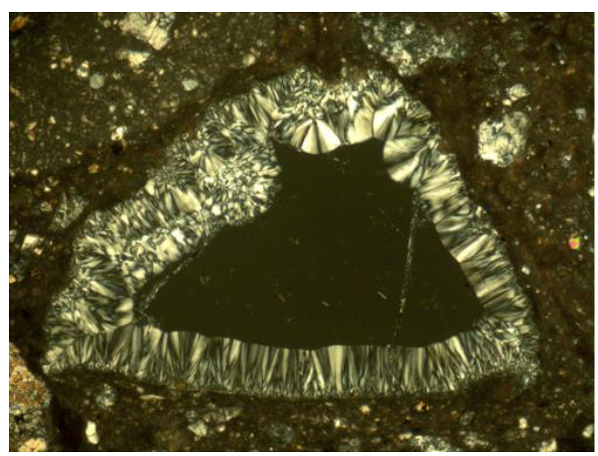

Figure 2. *Cross polarized light optical image of partly devitrified glass clast (width of field = 2.37 mm).*

Together these clasts are set in a fine grained matrix that is in part clastic and otherwise vitric and frothy-vesicular (see Figure 3).

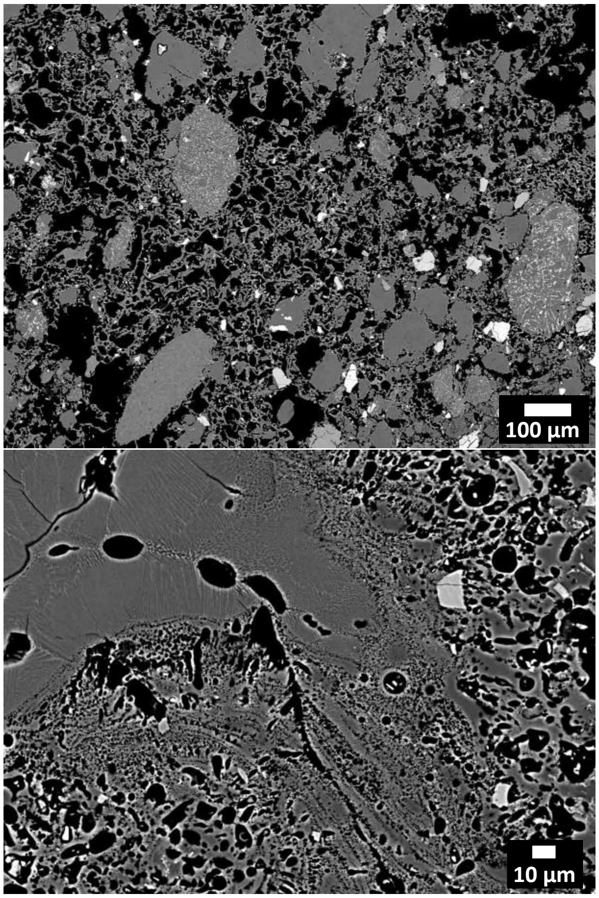

Figure 3. *BSE images of vitric vesicular matrix.*

Bulk Elemental Composition: Six ~35 mg subsamples measured by INAA gave mean values of:

FeO 3.78 wt.%, Na_2O 0.357 wt.%; (in ppm) Cr 540, Sc 6.8, Co 14.7, Ni 140, Ba 65, La 4.2, Sm 1.98, Eu 0.837, Yb 1.45, Lu 0.205, Hf 1.5, Th 0.74; Ir 6 ppb

Relative to other lunar feldspathic rocks ([1], see Figure 4), NWA 10404 is also highly feldspathic but contains variable proportions of a KREEP-rich lithology.

Bulk Physical Properties: Measurements of density and porosity were made on a 147 gram specimen, as part of an ongoing survey project [2, 3]. The bulk density of 2.51 g cm^{-3} in combination with the 9.3% porosity yields a grain density of 2.76 g cm^{-3}. NWA 10404 is relatively porous for a feldspathic lunar breccia, but its density is within the typical range. Magnetic susceptibility: log chi = 2.16.

Discussion: In terms of bulk rock and mineral component compositions NWA 10404 is fairly typical for lunar feldspathic rocks. If the glass fragments represent

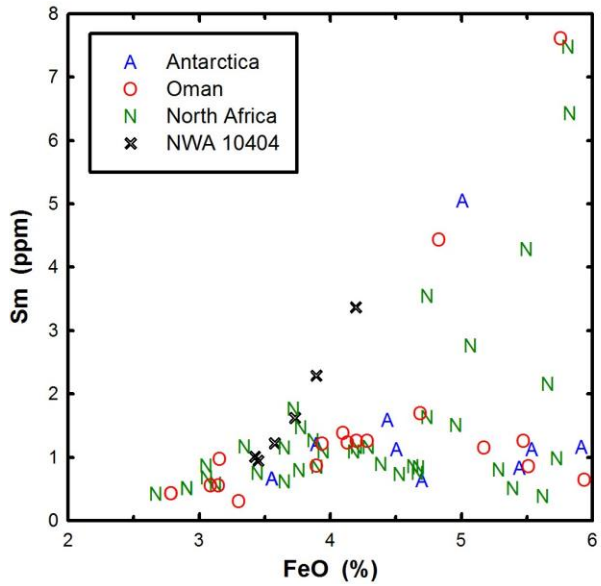

Figure 4. *Correlation of FeO and Sm for subsamples on NWA 10404 compared to means for all lunar meteorites with <6% FeO.*

broken spherules, we can infer this to be a regolith breccia. Because no fusion crust is preserved and vesicular groundmass also occurs in the central portion of the specimen, it seems implausible that the groundmass was heated during atmospheric passage. However, the delicate melt structures (Figure 3) may suggest that the groundmass was melted during the impact launch event from the Moon. Similar vesicularities characterize agglutinates, which are products of micro-scale impacts on the surface of planetary bodies that cause shock melting and degassing of implanted volatiles [4]. If NWA 10404 formed from flash-heated lunar regolith, it must have had an unusually high content of volatiles. Such regolith could be present in permanently shadowed regions near the lunar poles, where water ice deposits are thought to have accumulated [5, 6]. The presence of water ice could have facilitated glass formation by lowering silicate and oxide melting points.

The devitrified glass clasts in NWA 10404 appear to be unique among lunar highlands rocks, and must signify a very unusual thermal environment, perhaps operative during the event that launched this meteoroid from the Moon.

References: [1] Korotev R. and Irving A. 2016. *Lunar Planet. Sci.* **XLVII**, this conference [2] Kiefer W. et al. 2012. *Geophys. Res. Lett.* **39**, L07201 [3] Macke R. et al. 2016. *Lunar Planet. Sci.* **XLVII**, this conference [4] Liu Y. et al. 2012 *Nature Geosci.* **5**, 779-782 [5] Clark R. 2009 *Science* **326**, 562-564 [6] Pieters C. et al. 2009 *Science* **326**, 568-572.