PETROLOGY AND BULK COMPOSITION OF LUNAR MARE BASALT BRECCIA NORTHWEST AFRICA 12384. P. K. Carpenter[1], B. L. Jolliff[1], R.L. Korotev[1], J. H. Tepper[2], A. J. Irving[3] and L. Labenne [1]Dept. of Earth and Planetary Sciences, Washington University, St. Louis, MO, USA (paulc@wustl.edu); [2]Dept. of Geology, University of Puget Sound, Tacoma, WA, USA; [3]Dept. of Earth & Space Sciences, University of Washington, Seattle, WA, USA.

Introduction: Northwest Africa (NWA) 12384 is comprised of two relatively dense stones found in Mali, and represents the 12th confirmed example of a lunar mare basalt meteorite. It is petrologically and compositionally very different from recently found NWA 12008 [1]. Both stones have thin coatings of brown terrestrial weathering products (Mn-rich), but have fresh gray interiors (Fig. 1). Some mare basalt meteorites (representing random ejecta from the lunar near-surface regions) differ from those sampled at mission landing sites. We examine the petrography, bulk composition, and mineral chemistry of a lengthwise cut of the smaller stone (EC-1), and a polished thin section cut parallel to EC-1 was used for initial petrography and comparison with microprobe images.

Figure 1 (top) *The two stones. Photo A. Habibi,* **(bottom)** *Endcut NWA 12384 EC-1.*

Bulk Composition: Clean representative dust produced by cutting the specimen on an Isomet saw were analyzed by ICP-OES at UPS for the following results (in wt.%): SiO_2 45.25, TiO_2 2.00, Al_2O_3 7.51, Cr_2O_3 (0.3), FeO 20.43, MnO 0.28, MgO 13.98, CaO 9.81, Na_2O 0.40, K_2O 0.01, P_2O_5 0.13, SUM 100.09; Mg# = 0.550. The major element bulk composition of NWA 12384 is representative of a low-Ti basalt. In comparison to major element plots Fig. 7 of [1] and Fig. 8 of [2], NWA 12384 is most similar to an average Apollo 15 mare basalt.

EPMA Imaging and Analytical Methods: Backscattered-electron mosaic images, X-ray intensity maps, point analyses, and quantitative compositional maps have been acquired on EC-1 using the JEOL JXA-8200 electron microprobe at Washington University. An AlMgFe RGB X-ray intensity map has been used to identify 24 prominent clasts in EC-1 (Fig. 2). All EPMA data were acquired using Probe for EPMA, measured using wavelength-dispersive spectrometry, background correction made using the mean atomic number (MAN) calibration, and a full $\Phi(\rho z)$ correction was made relative to natural and synthetic mineral standards.

Petrography: NWA 12384 is a breccia consisting of rounded mare basalt clasts with intersertal to plumose textures set in a matrix of related crystalline debris. Major mineral phases are olivine, pigeonite (typically zoned to augite), ferroaugite, and anorthite (converted to maskelynite) with accessory ilmenite, fayalite, silica, hedenbergite, merrillite, fluorapatite, troilite, zirconolite, tranquillityite, and FeNi metal. The basalt clasts also contain K-rich mesostasis. A fine grained vesicular shock vein crosscuts EC-1. Secondary calcite veins and chlorite are present. We report EPMA data on the following prominent clasts and matrix (see Fig 2):

Clast 1 is a basalt containing: olivine (cores $Fa_{24.8-25.0}$, rims $Fa_{55.2-80.7}$, FeO/MnO = 86-119, n=4), pigeonite (cores $Fs_{27.5-28.1}Wo_{6.0-6.5}$, FeO/MnO = 53-65, n=3), augite (rims $Fs_{25.4-84.6}Wo_{29.2-12.4}$, FeO/MnO = 53-91, n=9), and plagioclase ($An_{88.9-93.4}Or_{1.7-0.2}$, n=6).

Clast 2 is a pigeonite basalt, and a representative BSE image is shown in Fig. 3. The pyroxenes are typically zoned with pigeonite cores and augite rims, ferroaugite is intersertal to plagioclase (converted to maskelynite), olivine forms subhedral crystals, and accessory phases include Cr-spinel, ilmenite, troilite, merrillite, fayalite (with immiscible mesostasis), and silica. We analyzed clast 2 by quantitative compositional mapping and cluster analysis as discussed in our companion abstract [3]. The mean cluster values are summarized below both as stoichiometric formula and end members:

Plagioclase $Ca_{0.80}Na_{0.14}K_{0.01}Al_{1.65}Si_{2.25}O_8$, sum 4.99, $An_{83.8}Or_{1.1}$
Pigeonite $Ca_{0.22}Mg_{1.13}Fe_{0.58}Al_{0.09}Si_{1.92}O_6$, sum 4.00, $Fs_{30.0}Wo_{11.2}$
Augite $Ca_{0.59}Mg_{0.79}Fe_{0.49}Al_{0.17}Si_{1.87}O_6$, sum 4.00, $Fs_{26.3}Wo_{31.6}$
Subcalcic augite
$Ca_{0.32}Mg_{0.74}Fe_{0.85}Al_{0.12}Si_{1.90}O_6$, sum 4.00, $Fs_{44.5}Wo_{16.7}$
Ferroaugite $Ca_{0.53}Mg_{0.38}Fe_{0.99}Al_{0.12}Si_{1.89}O_6$, sum 3.99, $Fs_{52.2}Wo_{27.9}$
Olivine $Mg_{1.30}Fe_{0.66}Ca_{0.04}Si_{0.98}O_4$, sum 3.01, $Fa_{33.6}$

Clast 10 is a pigeonite basalt with intersertal ferroaugite, containing: olivine (cores $Fa_{46.7-53.3}$, rims $Fa_{48.5-55.6}$, FeO/MnO = 103-115, n=6), pigeonite (cores $Fs_{28.2-34.6}Wo_{5.9-8.3}$, FeO/MnO = 58-71, n=5), augite (rims $Fs_{36.0-46.2}Wo_{27.2-14.0}$, FeO/MnO = 58-74, n=5), ferroaugite ($Fs_{46.0-49.3}Wo_{14.0-9.7}$, FeO/MnO = 68-73, n=4), and plagioclase ($An_{87.4-90.3}Or_{0.9-0.6}$, n=4).

Clast 16 is an impact melt breccia, with glass matrix: (SiO_2 44.94, TiO_2 2.39, Al_2O_3 8.10, Cr_2O_3 0.57, FeO 20.77, MnO 0.28, MgO 12.91, CaO 8.35, Na_2O 0.37, K_2O 0.08, P_2O_5 0.18, Sum 98.98, n=17).

Clast 19 is an olivine pigeonite vitrophyre containing: olivine ($Fa_{23.7-34.4}$, FeO/MnO = 84-101, n=6), skeletal and euhedral pigeonite (cores $Fs_{26.4-28.1}Wo_{5.8-8.0}$, FeO/MnO = 51-57, n=3; rims $Fs_{28.1-39.6}Wo_{26.5-26.8}$, FeO/MnO = 49-72, n=4), and quench pyroxene matrix (average using defocused beam analysis: $Fs_{39\pm0.03}Wo_{29.0\pm0.04}$, FeO/MnO = 67 ± 6.5, n=5).

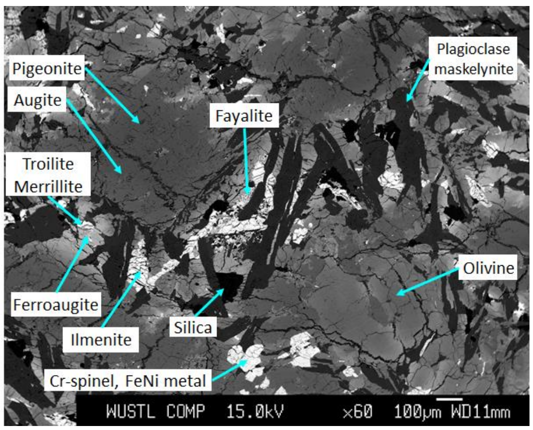

Figure 3 *BSE image, clast 2 QM1 left of center, with representative phases labeled.*

The breccia matrix contains: olivine ($Fa_{33.9-47.2}$, FeO/MnO = 92-106, n = 12), pigeonite ($Fs_{25.4-30.6}Wo_{10.3-9.4}$, FeO/MnO = 52-64, n=4), ferroaugite ($Fs_{35.7-75.5}Wo_{31.6-21.4}$, FeO/MnO = 56-77, n=4), and plagioclase ($An_{87.2-92.8}Or_{2.3-1.1}$, n=3).

Discussion: NWA 12384 is a crystalline polymict breccia dominated by a low-Ti mare basalt lithology with close petrologic and compositional similarities to some Apollo 15 returned samples, as well as to some other mare basalt meteorites [1,2]. We emphasize the need to determine the mineral and bulk composition of individual breccia clasts. This historically relies on modal analysis coupled with *average* mineral compositions to calculate the bulk composition of a clast. However, extensive mineral zoning and variable mineral chemistry require compositional mapping which samples the range of chemistry. We discuss in [3] details of compositional mapping analysis applied to clast 2 as part of our ongoing research on NWA 12384.

References: [1] Cohen M. et al. (2019) *LPS* **L** 2508;[2] Haloda J. et al. (2009) Geochim. Cosmochim Acta 73, 3450-3470; [3] Carpenter P. et al. (2019) LPS **L** 2148.

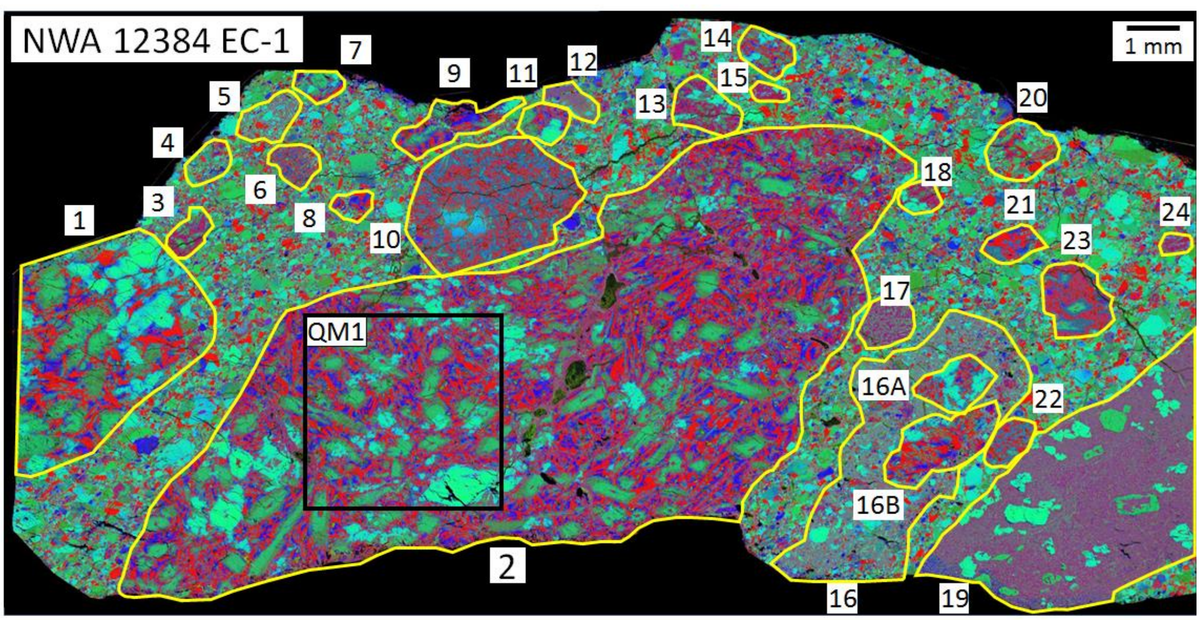

Figure 2. *AlMgFe X-ray intensity map of NWA 12384 EC-1. Numerous clasts are embedded in matrix containing smaller clasts and mineral fragments. Main basalt clast #2 is discussed in detail in companion paper.*