A PETROGRAPHIC STUDY OF LUNAR METEORITE NORTHEAST AFRICA 001.
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Introduction: Lunar meteorite Northeast Africa 001 (NEA 001) was collected in northern Sudan in 2002. The original stone has a brownish, grey color, lacks a fusion crust and weighed 262 g [1]. NEA 001 is a polymict feldspathic regolith breccia [2, 3].

For this investigation, a thick section sub-split of NEA 001 has been studied. It exhibits prominent fracturing, probably resulting from multiple shock events. These fractures have been infilled with terrestrial minerals during its residence time on Earth (mapped out by extensive yellow fractures in Fig. 1a). The sample is clast rich, with lithic and mineral grain fragments consolidated in an Al-rich glass and melt-rich matrix. Large clasts of melt material, rare agglutinates and small impact spherules provide evidence of the sample's impact history.

Methods: The section was analyzed with a JEOL JXA-8100 SEM at UCL. Individual mineral grain analyses were acquired with an integrated WDS system. BSE images and clast bulk composition analyses were obtained with an accompanying Oxford Instruments EDS probe, coupled with the INCA software package. Clast bulk compositions were acquired using a digitally controlled broad area beam-sweep analysis and results normalized to reduce errors. Elemental mapping (Fig. 1a) was conducted using a LEO-1455VP EDS probe with INCA software, at the NHM.

Petrography and Mineral Chemistry: NEA 001 is a polymict clastic breccia. The sample exhibits several large, well defined clasts from a range of lunar lithological provenances:

Feldspathic Clast Component: These clasts form the dominant lithological component of the sample (~40 - 50%). They have typical FAN bulk compositions [4], and are comprised of anorthositic gabbros, anorthositic norites and large (<3 mm) feldspathic impact melt breccias that exhibit a range of textures from microporphyritic crystalline clastic varieties, to non-clastic quenched intersertal fragments.

Mare Basalt Component: Previous studies of NEA 001 have noted a minor mare basalt component [2, 3]. This sub-split, however, exhibits a higher proportion (~20 - 25% of the sample) of basaltic material than previously reported, suggesting that the local regolith that formed NEA 001 is more complex and heterogeneous than first thought.

The largest observed lithic fragment is a basaltic breccia clast (~6 x 4 mm in size: top left clast feature in Fig.1a). The clast is divided into two components: a holocrystalline component (BC1) exhibiting a variety

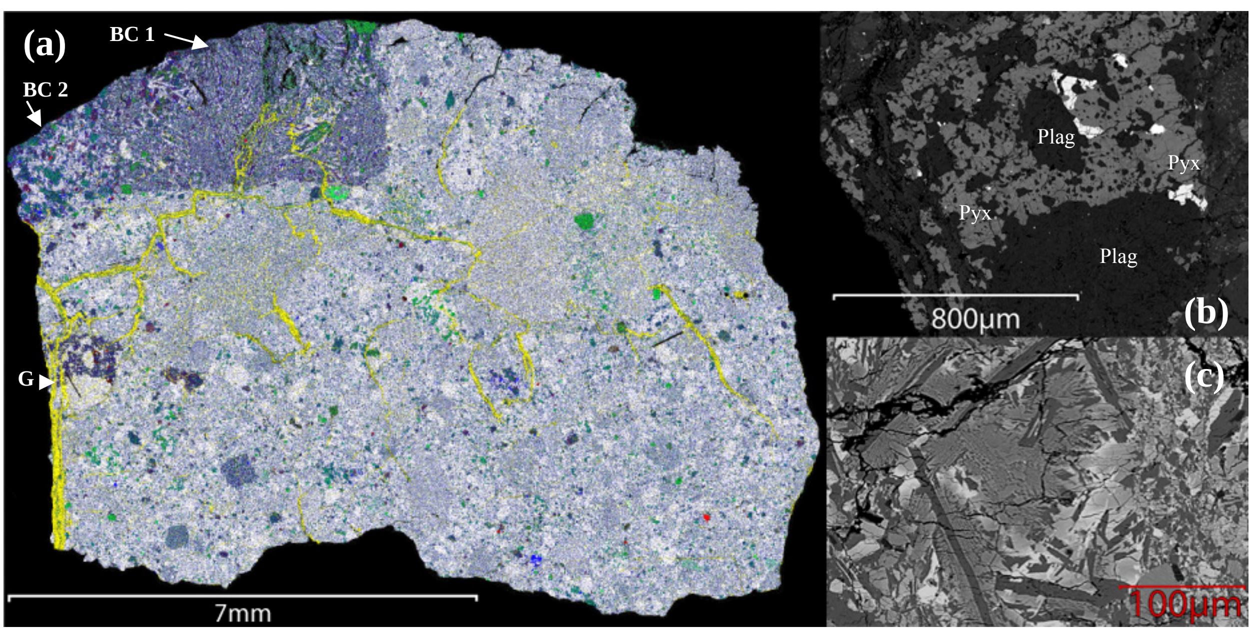

Figure 1: (a) Montaged elemental map of NEA 001: Si = blue, Al = white, Mg = green, Fe = red, Ca = yellow and Ti = pink (same color scheme as depicted in Fig.1 of [6]). (b) BSE image of large gabbroic clast with minor ilmenite phases (clast labeled as 'G' in 1a). (c) Devitrified plumose textures in large shocked basaltic clast (clast labeled as 'BC' in 1a). Labeled phases: 'Plag' = plagioclase; 'Pyx' = pyroxene.

of textures from sub-ophitic (<400 µm grain size) with plagioclases (An_{96-97}) and zoned pyroxenes (En_{17-54} Fs_{30-67} Wo_{14-35}), to microcrystalline plumose recrystallized areas (Fig. 1c). This range of textures indicates that the clast has been heavily shock metamorphosed. A smaller section, to the left of the clast (BC2: Fig. 1a), is comprised of coarse-grained fragmental breccia. The plagioclase in this section has a similar compositional range (An_{94-98}), whilst the pyroxenes are more varied (En_{5-72} Fs_{23-78} Wo_{5-37}). The boundary between these sections is gradual and indistinct indicating that the two portions represent an earlier complete fragment of a pre-existing fragmental or regolith breccia. Both components have a VLT mare basalt bulk composition (TiO_2 = 0.45 ± 0.06 and 0.36 ± 0.11).

Smaller granulated gabbroic lithic fragments (i.e. Fig. 1b) are distributed throughout the NEA 001 matrix. Many of them are feldspathic but have a minor ilmenite mineral phase component, indicating that they originate from a thermally annealed Al-rich basalt bedrock source.

A small (~0.4 x 0.2 mm) siliceous clast with a high bulk SiO_2 component (bright blue area at bottom right of sample in Fig. 1a) indicates the mixing and inclusion of more evolved material that has possibly originated from a residual melt component of a proximal mare basalt bedrock source.

Discussion: NEA 001 is a polymict regolith breccia that is dominated by feldspathic (FAN) lithic clasts and mineral fragments. We measure a bulk sample composition (in wt. %) of: SiO_2 = 43.2 ± 1.8, TiO_2 = 0.19 ± 0.35, Al_2O_3 = 26.2 ± 3.6, FeO = 6.8 ± 3.3, MgO = 5.5 ± 1.7 and CaO = 18 ± 2.9. These values were calculated using averaged elemental data from the INCA montaged element map: (Fig.1, Fig.3), and are in agreement with values previously obtained for NEA 001 [4]. The sample is marginally enriched in bulk FeO composition (Fig. 3a) compared with other FAN feldspathic lunar meteorites [4]; evidence of the mafic contribution to the sub-split from non-FAN basaltic lithologies.

Our study shows NEA 001 to be compositionally and petrographically similar to several other lunar meteorites including ALHA 81005 [6], Yamato-791197 [7] and PCA 02007 [5, 8]. These stones also have minor VLT and Low-Ti mare basalt components, similar to that found in NEA 001.

We hypothesize that NEA 001 was consolidated in a highland FAN regolith that was located in proximity to a VLT mare basalt component [3].

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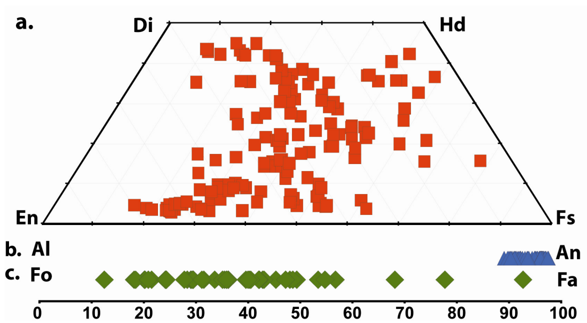

Figure 2: Mineral grain compositions analyzed in NEA 001 sub-split: (a) Pyroxene grains (Wo_{3-45} En_{5-80} Fs_{10-78}). (b) Range of plagioclase An content (An_{89-98}) and (c) olivine Fa content (Fo_{12-93}).

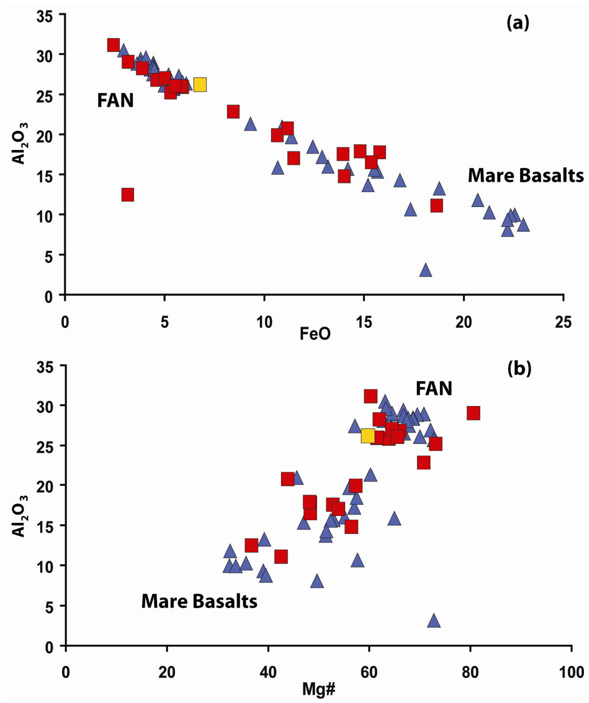

Figure 3: NEA 001 bulk clast compositions (red squares) and estimated bulk NEA 001 sample composition (yellow) (a) Al_2O_3 vs. FeO wt.% and (b) Al_2O_3 wt.% vs. Mg# [atomic Mg/Mg+Fe^{2+}]. NEA 001 compositional data are compared with bulk compositions of other lunar meteorites (blue triangles) taken from [4, 5, 9].

References: [1] Russell et al. (2005) *MAPS,* Vol. 89, A201-A263. [2] Korotev and Irving. (2005) *LPSC XXXVI,* Abstract #1220. [3] Haloda et al. (2005) *LPSC XXXVI,* Abstract #1487. [4] Korotev (2005) *Chemie der Erde – Geochemistry.* Vol. 65, p. 297-346. [5] Joy et al. (2006) *LPSC XXXVII,* Abstract #1274. [6] Maloy et al. (2004) *LPSC XXXV,* Abstract #1159. [7] Zeigler et al. (2004) *LPSC XXXV,* Abstract #1978. [8] Korotev et al. (2004) *LPSC XXXV,* Abstract #1416. [9] Wieczorek et al. (2006) In *New Views of the Moon, Rev. Mineral. Geochem.* Vol. 60. pp. 221-364.