LUNAR METEORITE NORTHEAST AFRICA 003-B: A NEW LUNAR MARE BASALTIC BRECCIA.

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Introduction: Northeast Africa 003-B (NEA 003-B) is the brecciated lithology of a new, 124 g lunar meteorite Northeast Africa 003 (NEA 003) found in November 2000 (6 g stone) and in December 2001 (118 g stone) in northern Libya in wadi Zam Zam area [1]. Approximately 25% of the larger stone consists of the NEA 003-B lithology, which is basaltic breccia consisting of well consolidated glassy impact-melt matrix that contains scattered mineral fragments of the NEA 003-A lithology (low-Ti olivine-rich basalt) and two larger lithic clasts of low-Ti mare basalt lithologies. The present study is directed at the breccia portion of the meteorite.

Petrography and Mineral Chemistry: The brecciated portion of NEA 003 meteorite has a very sharp contact with the attached low-Ti olivine-rich basalt NEA 003-A. Weathering grade is low, calcite and gypsum veinlets are present.

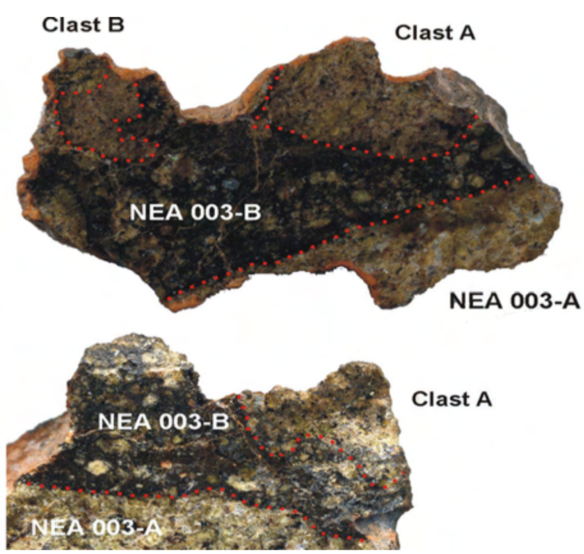

Figure 1. Photograph of two sections of specimen Northeast Africa 003-B lunar basaltic breccia.

The rock consists of two low-Ti basalt clast (clast A and clast B) and glassy impact melt matrix (Fig. 1).

Impact melt matrix contains scattered mineral fragments with chemical composition identical to minerals in NEA 003-A. The impact melt surrounds the sharp clast boundaries as well as fills the space between the scattered mineral clasts. It commonly includes vesicles and schlieren. The representative chemical composition of impact melt is shown in Table 1. No regolith component was found in the matrix.

Clast A. Clast A is a low-Ti olivine mare basalt with porphyritic texture of olivine (Fo_{71-40}), zoned pyroxene ($En_{6-57}Wo_{9-39}$) and plagioclase (An_{85-92}), (Fig. 3.). Olivine an pyroxene show extensive symetrical zoning with gradual iron enrichment. All plagioclase is totally converted to maskelynite. The Clast A contains late-stage mesostasis composed of silica, Fe-rich pyroxene and pyroxferroite, plagioclase, ilmenite, troilite, apatite, whitlockite and fayalitic olivine with Si-K-rich glass and pockets of K-Ba-rich glass. Opaque phases include predominatly ilmenite, ulvöspinel, chromite, troilite and trace Fe-Ni metal. Shock veins and impact melt pockets are present throughout the sample.

Mineral modes, determined by image analysis from X-ray maps and BSE images, are (vol%): olivine = 10.6; pyroxene = 56.7; plagioclase = 28.1; ilmenite = 1.5; spinel = 0.5; mesostasis+impact melt = 2.6.

The Fe/Mn atomic ratios in pyroxenes are (Fe/Mn = 42-93 atom%) and olivines (Fe/Mn = 91-119 atom%). Undulatory to mosaic extinction of olivine and pyroxene crystals, presence of numerous cracks and fractures indicate the intensive shock processes.

Clast B. The smaller clast shows similar porphyritic texture to Clast A. Typical composition of main minerals is: olivine (Fo_{48-32}), zoned pyroxene (En_{18-51} Wo_{9-41}) and plagioclase (An_{85-94}). Olivine crystals show only week zonation. Zoning in pyroxenes is clear and symmetrical. Identically with Clast A, olivine and pyroxene were affected by intensive shock processes and all plagioclase was converted to maskelynite. The presence of late-stage mesostasis is rare and it is composed of silica, Fe-rich pyroxene, plagioclase, ilmenite and troilite. Opaque phases include ilmenite, ulvöspinel, troilite and trace Fe-Ni metal. Impact melt pockets and veins are common.

Mineral modes, determined by image analysis from X-ray maps and BSE images, are (vol%): olivine = 12.2; pyroxene = 59.5; plagioclase = 24.3; ilmenite = 1.4; spinel = 0.5; mesostasis+impact melt = 2.1.

The Fe/Mn atomic ratios in pyroxenes are (Fe/Mn = 42-93 atom%) and olivines (Fe/Mn = 91-119 atom%).

Chemical Composition: The concentrations of major elements were estimated using EMPA analyses of mineral phases and mineral modes determined by image analysis from X-ray maps and BSE images. REEs concentrations of Clast A were estimated from LA-ICP-MS analysis done for individual minerals and mineral modes. These calculated whole-rock compositions and REEs concentrations may have large errors, but this technique can yield the reasonable approximations of whole-rock composition of the lithic clast. The estimated whole-rock major and rare earth element concentrations are presented in Table 1 and Fig. 2.

Majors	wt%			REEs	ppm
	Clast A	Clast B	impact melt		Clast A
SiO2	44.6	45.0	43.6	La	9.2
TiO2	1.9	1.8	2.1	Ce	23.6
Cr2O3	0.4	0.6	0.6	Nd	15.6
Al2O3	9.7	10.1	8.6	Sm	4.8
FeO	21.0	20.9	22.8	Eu	1.2
MnO	0.3	0,3	0.3	Gd	6.6
MgO	10.9	9.9	12.9	Tb	1.2
CaO	10.5	10.7	8.5	Dy	8.6
Na2O	0,4	0.2	0,2	Ho	1.9
K2O	0,2	0.1	0,1	Er	5.6
Total	**99.9**	**99.6**	**99.7**	Tm	0.9
				Yb	6
				Lu	0.8

Table 1. Chemical composition of major (Clast A, B and impact melt) and REE elements (Clast A) of Northeast Africa 003-B lunar meteorite.

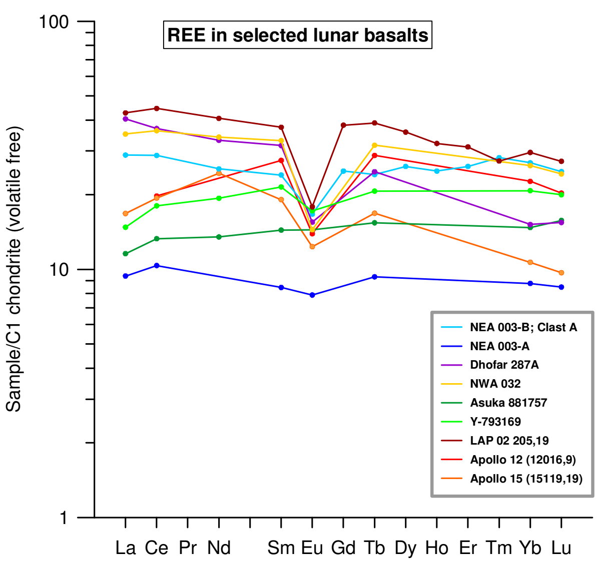

Figure 2. Volatile-free, chondrite-normalized plots of estimated REEs in NEA 003-B; Clast A and selected lunar basalts. REE concentrations are normalized to values of [3] multiplied by the factor 1.36. Data source for other selected lunar basalts is [4] and [6].

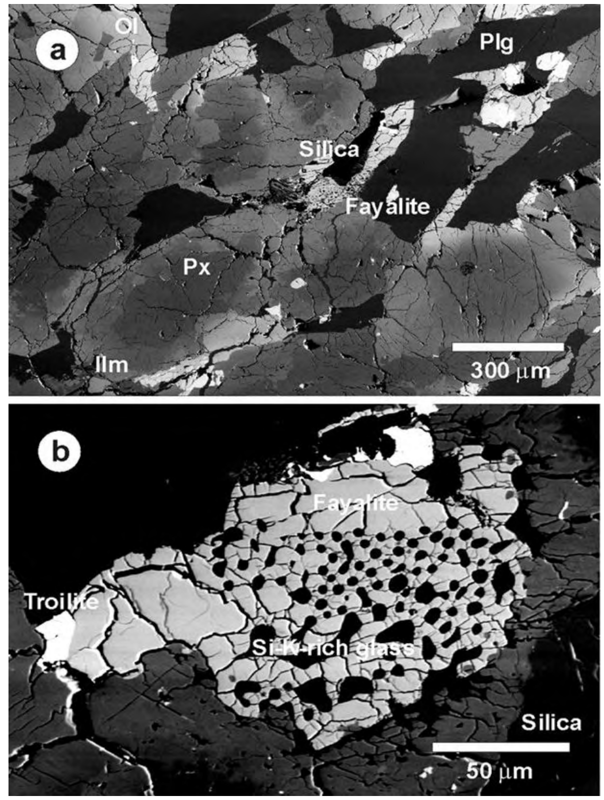

Figure 3. (a) BSE image of the texture of basaltic Clast A-olivine (Ol), extremely zoned pyroxene (Px), plagioclase (Plg), ilmenite (Ilm), silica (Silica) and fayalite (Fayalite). (b) BSE image of fayalite contains inclusions of Si-K-rich glass.

Discussion: NEA 003-B is a brecciated part of the new lunar meteorite, dominated by different mare-basalt lithologies. Both lithic clasts present in the impact melt matrix correspond to olivine-rich low-Ti mare basalt suite with more evolved chemical composition when compared to NEA 003-A mare basalt. When compared to Dhofar 287B breccia, NEA 003-B contains no VLT lithologies, glasses or regolith components. The lithic clasts are similar in texture, mineralogy, chemistry and REE pattern to Apollo 12 and Apollo 15 low-Ti mare basalts [2]. The presence of low-Ti basaltic rocks in NEA 003 meteorite could be related to the progressive fractionation of single parent low-Ti melt. The subsequent impact could expose the basalts from different depths and cause the cementation of the basalt ic fragments.

References: [1] Haloda J. et al. (this volume); [2] Papike J.J. (1998) in Planetary Materials, *Reviews in Mineralogy, 36*, ch. 5, M.S.A.; [3] Anders E. and Grevessen N. (1989) *Geochimica et Cosmochimica Acta* 53:197-214; [4] Fagan T. J. et al. (2002) *Meteoritics & Planetary Science* 37: 371-394; [5] Anand M. et al. (2003) *Meteoritics & Planetary Science* 38: 485-499.; [6] Anand M. et al. (2004) LPSC XXXVI: 1626.