NEW LUNAR METEORITE FROM THE SAHARA DESERT: NORTH WEST AFRICA 6888. S. I. Demidova[1], M. A. Nazarov[1], M. A. Ivanova[1], C. A. Lorenz[1], N. N. Kononkova[1] [1]Vernadsky Institute of Geochemistry and Analytical Chemistry, Kosygin St. 19, Moscow 119991, Russia, demidova.si@yandex.ru.

Introduction: The new lunar meteorite North West Africa 6888 was found on the Sueilila limestone plateau of Morocco in 2011. The meteorite contains both highland and mare material. Here we report the first data on petrography and mineralogy of the rock.

Results: NWA 6888 is a brownish-grey to dark green stone weighing 208 g. No fusion crust is present on the surface of the stone. The rock is an impact-melt breccia containing numerous mineral fragments and lithic clasts embedded into a fine-grained impact-melt matrix. In some areas the matrix has a fragmental texture and contains rare glass fragments and spherules. These features are typical for regolith breccias. There are two parts of the breccia in the studied polished section: the main portion is represented by a feldspathic breccia and a small attached fragment is a basaltic breccia. The lithic clasts (0.1-2 mm in size) are mainly impact-melt breccias, granulites and probably igneous rocks of anorthositic, gabbroic and gabbro-noritic compositions. The charactersitic feature of the meteorite is the presence of abundant mare basalts and Fe-rich lithologies.

NWA 6888 is moderately weathered. There are many cracks in the stone. The most abundant secondary phases are carbonates, unidentified phyllosilicates and Fe hydroxides. The same secondary products were found in the NWA 482 meteorite [1]. Surprisingly, the majority of NWA 6888 olivine grains are replaced by phyllosilicates. However it should be noted that the polished section was made from an outer part of the stone.

Mineral chemistry. Lithic clast and mineral fragments are similar in mineral chemistry. Mafic phases are variable in composition. Pyroxenes are represented by orthopyroxenes, pigeonites and minor augites varying in MG# from 86 to 10. Olivine ranges from Fo_{63} to Fo_{5}, no Mg-rich olivines were found (Fig. 1). Plagioclase is $An_{89-98}Or_{0-1}$. Accessory minerals are Al-Ti chromite, Cr-ulvospinel, ilmenite (0.2-4.0 wt.% MgO), troilite and Fe-Ni metal (0.1-2.3 wt.% Co and 0.7-9.5 wt.% Ni). One grain of schreibersite was found.

Lithologies. Based on mineralogy and mineral chemistry two main groups can be indentified in the meteorite: highland and mare rocks.

Highland material is represented by rocks of anorthositic, noritic and gabbro-noritic compositions. Rare troctolitic anorthosites are present. Granulites are typical among highland lithic clasts (Fig. 2a). Highland rocks consist of orthopyroxene ($En_{62-84}Wo_{2-5}$), pigeonite ($En_{55-81}Wo_{5-18}$), augite ($En_{55-81}Wo_{5-18}$) (Fig. 3). Relict olivine grains (Fo_{53-57}) are present. Plagioclase is $An_{91-98}Or_{0.4}$. Accessories are Al-Ti chromite and ilmenite (3.8 wt.% MgO). On the plot of MG# versus An content, the highland rocks fit into the FAN and HMS fields and into the gap between these two suites (Fig. 4).

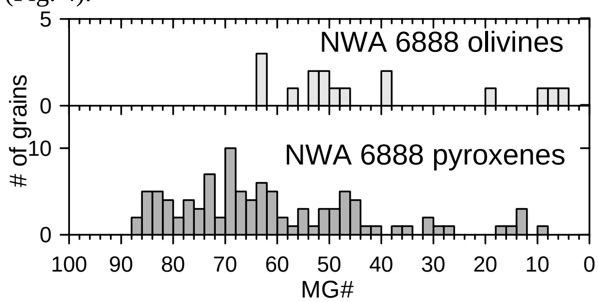

Fig. 1. MG# of mafic phases in NWA 6888.

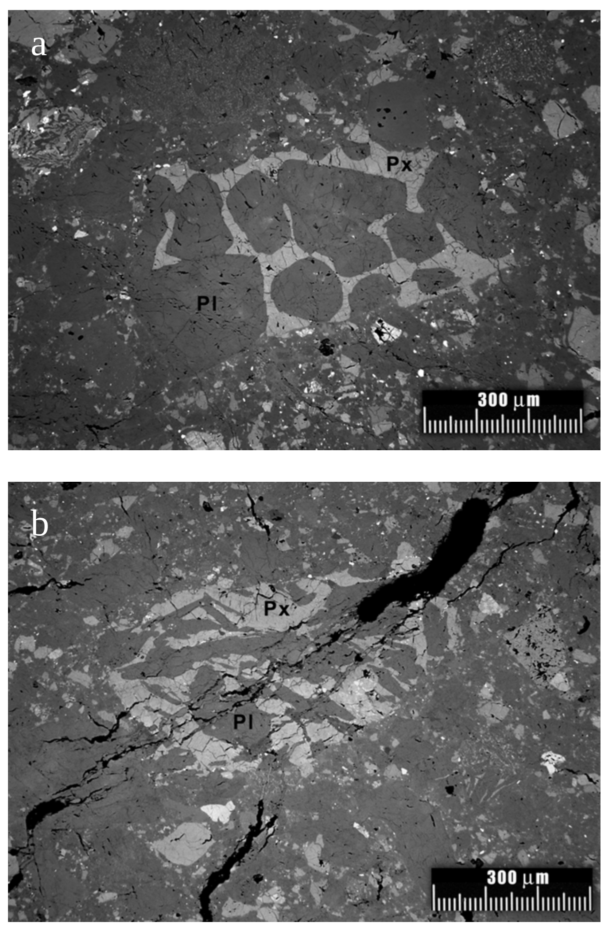

Fig. 2. Lithic fragments in NWA 6888 (in reflected light): a) granulitic clast; b) basaltic clast.

Two granulitic clasts of a gabbro-noritic composition (1-1.4 mm in long dimension) contain both Mg-rich pyroxene (MG# 76-81) and olivine replaced by phyllosilicates. A grain of Zr-rich armolcolite was found in one of the clasts. The rocks granulites belong to the HMS suite and are set close to the large cracks in the studied section.

Mare rocks are represented by VLT basalts that have ophitic to subophitic textures and show huge variations of mineral chemistry (Fig. 2b). Pyroxenes of the rocks are Fe-rich and vary from pigeonites to ferroaugites ($En_{8-70}Wo_{6-28}$) (Fig. 3). Plagioclase is $An_{91-96}Or_{0-1}$. Olivine (Fo_{7-63}), silica and ilmenite are present as minor phases. The ilmenite composition (0.2-1.0 wt.% MgO) is typical for mare rocks [2].

There are also Fe-rich rocks in the meteorite. The rocks consist of fayalite, ferroaugite, silica and ilmenite. Such rocks were described in some mare basalts and thought to be the late-stage crystallization products of a basaltic magma [2].

NWA 6888 contains glass fragments and spherules variyng from anorthositic to basaltic compositions. All of them are characterized by MG# 51-72. Two mafic glasses have TiO_2 content 0.6-1.1 wt.%, MG# 52-66 and are richer in MG# than Luna 24 VLT basalts [3] but similar to that of Apollo 17 VLT basalts [4]. However Al_2O_3 content (13-16 wt.%) of the glasses is higher than that of VLT rocks and is similar to that of some Apollo 14 high-Al basalts [5]. The enhanced Al content of the glasses may be explained by some admixture of highland material.

Discussion: NWA 6888 is a mingled meteorite containing typical highland rocks and VLT-mare basalts. No KREEP component is present. Most mingled lunar meteorites contain a small portion of a KREEP component. There are only 4 mingled meteorites which contain only traces of KREEP material: Kalahari 008/009, NWA 4884, Dho 1180 and SaU 300/NWA 4932 [6]. All of these have some specific characteristics and are distinctive from NWA 6888. The lack of KREEP material suggests that NWA 6888 was ejected from a lunar region located far away from the Imbrium basin area, which is enriched in KREEP rocks.

The presence of the HMS granulites suggests that Mg-rich olivines should occur in the meteorite, however no olivines with Fo content >63 were found, suggestsng that high-Mg olivines were totally replaced by phyllosilicates. NWA 6888 appears to be one of the most altered NWA lunar meteorites which are mostly fresh. Abundant phyllosilicates point to some intensive aqueous alteration experienced by the meteorite. However some Fe-Ni metal survived the alteration. During the Early Holocene wet phase known as the African Humid Period (14.5-11 ka ago) the Morocco region currently occupied by the Sahara desert was vegetated and contained permanent lakes [7]. There were two other humid periods in this region: ~50-45 ka and ~120-110 ka ago [8]. Therefore we suggest that the terrestrial age of NWA 6888 could be more than 11 ka but less than 120 ka. The terrestrial ages of lunar meteorites are mainly less than 100 ka [see 1].

NWA 6888 is similar to NWA 482 in secondary alteration products but NWA 482 is a highland meteorite and does not contain any mare material [1].

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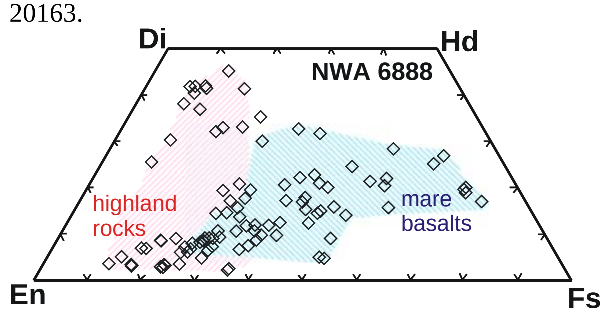

Fig. 3. MG# of mafic phases in NWA 6888.

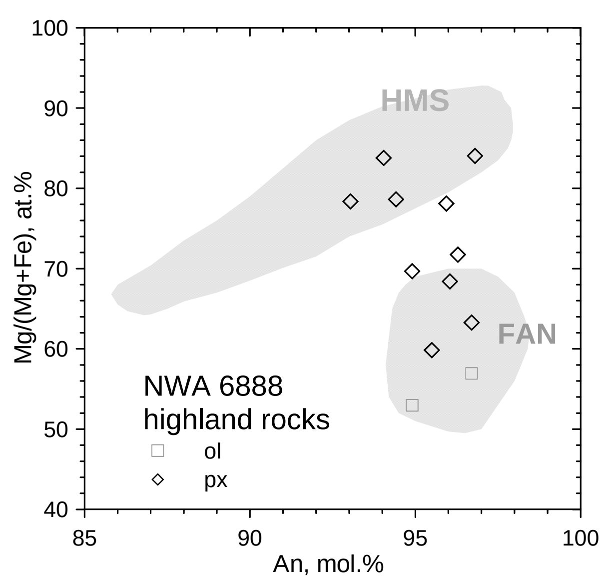

Fig. 4. MG# vs An content of NWA 6888 highland rocks.