PETROGRAPHY AND MINERALOGY OF LUNAR FELDSPATHIC BRECCIA NORTHWEST AFRICA 11111

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Introduction: Lunar meteorites are an important source of material from the Moon. They have greatly increase the diversity of highland materials beyond those collected by Apollo and Luna missions, and present challenges to the Lunar Magma Ocean (LMO) theory [1-5]. Northwest Africa 11111 is a new found feldsparthic breccia with gray shock melt veins. The Fe/Mn ration of olivine in clast and matrix range from 77.77 to 111.3, from 70.9 to 113.5, respectively. The Fe/Mn ratio of pyroxene are in the range of 39.5-80.8 [6]. These are the strong evidence of its lunar origin. Here we present a preliminary report on the petrography and mineralogy of NWA 11111, and discuss its potential science values.

Analytical methods: A petrography study was performed on a polished thick section of this meteorite using an optical microscope.

Raman spectra of NWA 11111 were measured by Renishaw inVia® Raman Microscope in Shandong University, Weihai, China. We employed green laser (532 nm) for excitation and measured Raman shift range of 100~2000 cm^{-1} with a spectral resolution better than 1 cm^{-1}. Before each measurement, a Si wafer was used as the wavelength calibration standard. 100× objectives were used for the fine-grained alteration phase analysis and the spatial resolution of laser spot is better than 1 μm.

Back-scattered Electron (BSE) image of NWA 1111 section was obtained with FEI SEM in Shandong University. Chemical composition of minerals were determined using an Oxford INCA EDS (IE250X-Max50) with an ultrathin windowed Si (Li) detector.

Petrography and Mineralogy: The NWA 11111 section was about 1.5 cm × 2.8 cm in size. This rock has a polymica feldspathic breccia texture mainly composed of various types of lithic clasts (anorthosite, gabbro, norite, and fragment breccia), mm-sized crystal clasts (pyroxene, plagioclase, olivine, with minor ilmenite) and impact melts. The drak recrystallized matrix is composed of fine-grained plagioclase, pyroxenes, and minor olivine, ilmenite and glass. In the rimes and fractures of this section, Ba sulfate was detected, which is due to terrestrial weathering.

Aorthosite clast: The anorthosite clasts are the most aboudant in this meteorite. This lithic clast are composed of plagioclase and minor pyroxene and olivine. Plagioclase (An_{95-99}) all show irregular fractures. Mafic minerals uneven distributed in this clast. The anhedral olivine (Fo_{75}) is the main phase of these mafic minerals.

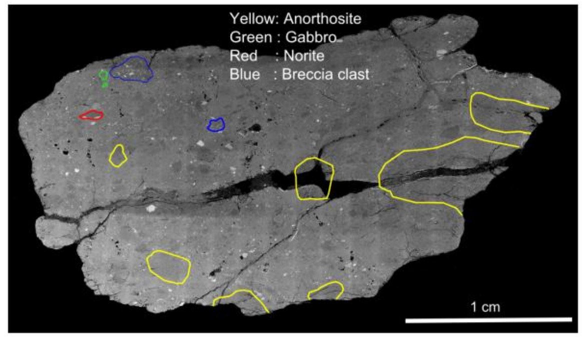

Figure 1 BSE image of NWA 11111

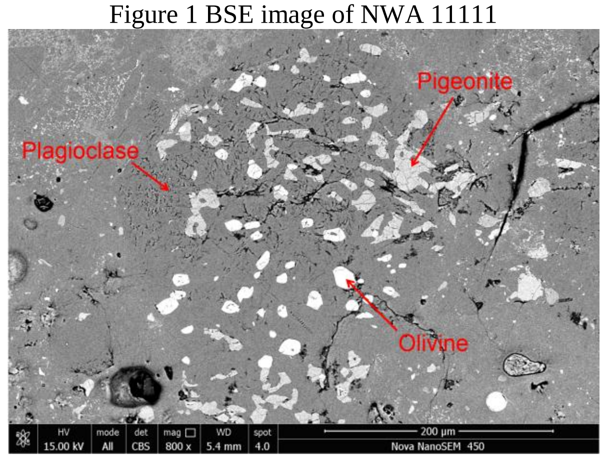

Figure 2 Gabbro clasts in NWA 11111

Gabbro clasts: This clast consists of plagioclase, pyroxene and olivine. All these mafic minerals are subheral-anhderal, 10-20 micron in size. Pigeonite show very fine-scale exsolution lamellae of augite.

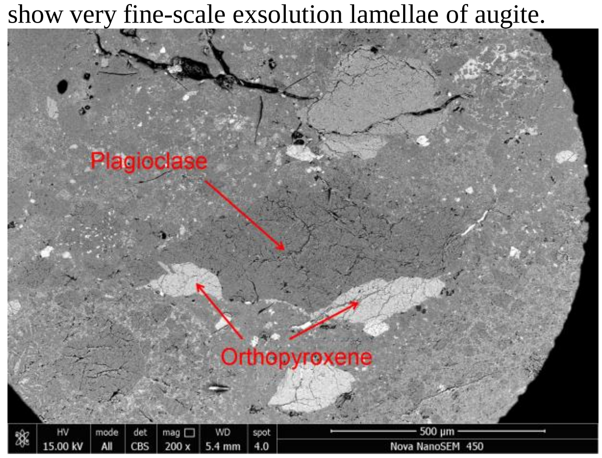

Figure 3 Norite clasts in NWA 11111

Norite clasts: Plagioclase ($An_{95\text{-}99}$) is 200 micron in size and show irregular fractures. Raman spectra of this mineral exhibits one peaks centered at 508 m^{-1}. This is clearly due to shock effects. However, the impact shock does not transform plagioclase into maskelynite. The chemical analysis suggests the pyroxenes in this clast are all pigeonites ($Fs_{33}Wo_2En_{65}$).

Figure 4 Impact melt vein in NWA 11111

Impact melts: This meteorite contains large amount of impact-generated glasses, veins and clasts. Many of these impact melts preserve round or enlongated vesicles. Fine-grained crystal fragments can be seen in the veins and most of them are plagioclases.

Plagioclase: Plagioclase is the most aboudant crystal fragments in this rock. As mentioned above, Raman spectra of plagioclase fragments in the bulk matrix and lithic clast show only one strong peak near 500cm^{-1} and they are not totally transformed into maskelynite. However, in one plagioclase grain, we notice that from the core to its rim, the two-peak pattern of the Raman peak at 500cm^{-1} become continuously weaken while the intensity of the peak gradually decreases. This suggests that the rim of this plagioclase turned into the isotopic impact glass, but its core still preserve the long range order.

Pyroxene: Pyroxenes exist in various lithic clasts and bulk matrix. The pyroxene show wide chemical variations. At least 3 species of pyroxene have been identified in this rock: orthopyroxene, augite, pigeonite. We note that the minerals do not exhibit compositional zoning while the exsolution are quite common. This suggests it underwent prolonged annealing in the solid state after crystallization. This microstructure could be used to infer the cooling history of host rock.

Discussions and conclusions: NWA 11111 contains various lithologies and many minerals fragments. It represents a mixture of pristine rocks in lunar highland crust. The mafic lighologies, including gabbro and norite are unusuall among lunar meteorite.

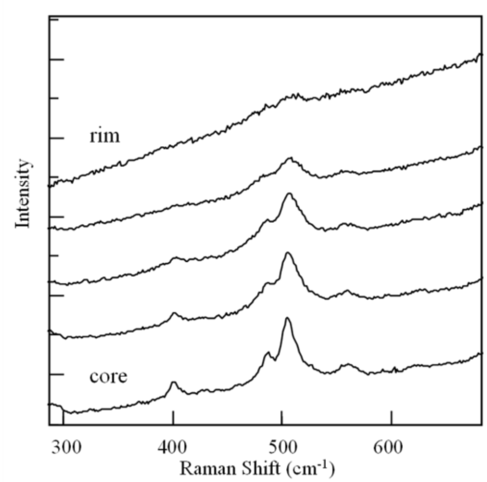

Figure 5 Raman spectra of a plagioclase clast in the bulk matrix

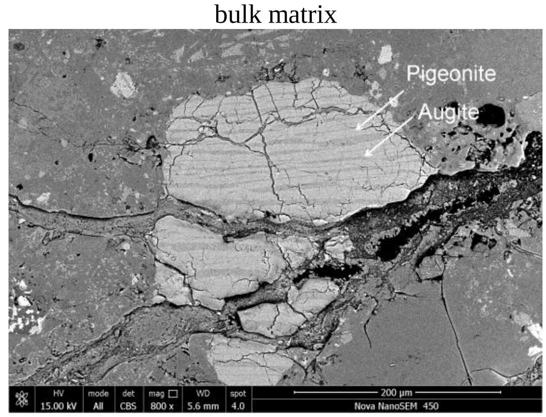

Figure 6 Exsolution of pigeonite with augite lamellae

This meteorite offers an unique sampling of the diversity of lithologies found within the lunar highland. Fine exsolution of augite in pigeonite are indicators of petrologic history. The plagioclase grain that show gradual change of Raman peak near 500cm^{-1} could be taken as the sample for investigating the crystal transformation during impact and the formation mechanism of maskelynite.

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References: [1] Korotev et al. (2003) *GCA*, 67, 4895-4923. [2] Korotev et al. (2006) *Chemie der Erde*, 65, 297-346. [3] Day et al. (2006) *GCA*, 70, 5957-5989. [4] Joy and Arai (2013) *Astronomy & Geophysics*, 54, 4.28-4.32. [5] Gross et al. (2014) *EPSL*, 388, 318-328. [6] Meteoritical Bulletin Database, https://www.lpi.usra.edu/meteor/metbull.php?code=64747