DIVERSITY OF BASALTS IN LUNAR FELDSPATHIC METEORITES

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Introduction: Basalts are probes of the planetary interior. Numerous studies on lunar basalts have revealed the heterogeneity of the lunar mantle and provided crucial constraints on the distinct chemical reservoirs formed during the early evolution of the Moon [1]. However, most of this knowledge is derived from lunar basalts returned by the six Apollo missions, which are biased as they are confined within or nearby the chemically anomalous Procellarum KREEP Terrane. Lunar meteorites originate from random sites on the lunar surface [2], and the current collected total mass (887 kg by April 2022) has exceeded two times of samples returned by all lunar exploration missions [3]. Most lunar meteorites are feldspathic breccia, and many of them are composed of not only feldspathic highland rocks but also small proportions of basalt fragments. These tiny lithologies provide important new insights into the diversity of basaltic magmatism on the Moon, especially from regions not sampled by the Apollo and Luna missions [4]. In this study, we investigated the mineralogy of basalt clasts in three lunar feldspathic meteorites.

Samples and Method: The analyzed samples were carbon-coated thick sections of Northwest Africa (NWA) 11109, NWA 11110, and NWA 10203. The meteorites were investigated by scanning electron microscope and associated energy dispersive spectrometer operated at 15 keV accelerating voltage.

Result and Discussion: NWA 11109 is a fragmental lunar breccia. It includes minerals, lithic, and impact melt clasts in a dark matrix. Two basaltic clasts are observed in one section. Basalt clast 1 is olivine-bearing and contains abundant plagioclase (>60 vol%). All of the plagioclase has an anorthitic composition (An_{91-98}). Pyroxene ($Wo_{9-38}En_{44-62}Fs_{17-30}$) forms a linear trend from augite to pigeonite. Olivine is relatively homogeneous with Fo in the range of 62-65. Basalt clast 2 is ~1 mm in size and contains two groups of olivine. Most of the olivine grains are relatively Mg-rich (Fo_{62-67}), while the others have a Fe-rich composition (Fo_{9-12}). Pyroxene and plagioclase have similar compositions to those of clast 1 ($Wo_{4-42}En_{44-67}Fs_{14-42}$ and $Ab_{2-11}An_{88-98}Or_{0-1}$, respectively). Their average grain size is about 200 µm, indicating a slow cooling rate of NWA 4898 parent magma. Accessory minerals discovered in clast 2 include ilmenite, silica, and Al-Ti-chromite. Despite the modal mineral difference, the nearly identical mineral composition of clast 1 and 2 suggest they have a similar, if not identical, origin.

NWA 11110 contains fine-grained mineral debris in the anorthositic matrix. One ~500 µm basaltic clast with subophitic texture is discovered. Minerals span a large range of composition with pyroxene of $Wo_{11-40}En_{3-50}Fs_{29-78}$ and anorthite of An_{95-100}. A small amount of Mg-rich olivine (Fo_{61-63}) intergrow with pyroxene and plagioclase. Fayalite (Fo_{6-7}) also occurs within the mesostasis, together with accessory minerals including ilmenite, silica, and troilite.

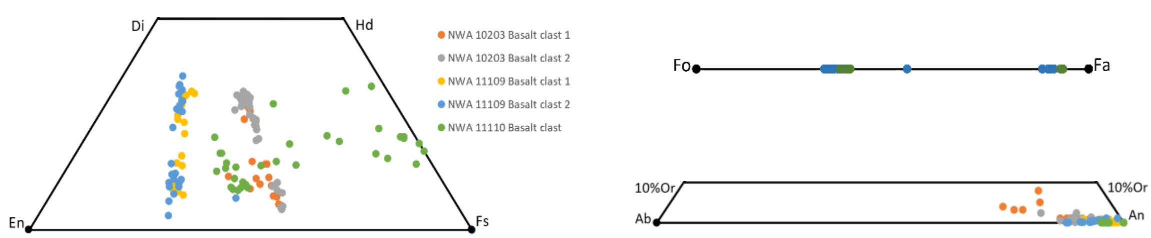

Fig. 1 Mineral composition of basalt clasts in NWA 10203, NWA 11109 and NWA 11110.

NWA 10203 is a polymict breccia and two basaltic clasts with similar grain size (~ 450 µm) and textures are found in our section. Basalt clast 1 has relatively Fe-rich pyroxene ($Wo_{6-37}En_{33-48}Fs_{30-54}$) and alkali-rich plagioclase ($Ab_{7-24}An_{72-92}Or_{1-9}$). Ilmenite of various sizes (10-60 µm) exists in the grain boundary of plagioclase and pyroxene. The pyroxene ($Wo_{6-38}En_{32-40}Fs_{28-54}$) and plagioclase ($Ab_{6-16}An_{81-92}Or_{0-2}$) composition in clast 2 are similar, thus they likely to originate from the same protolith.

The moderately mafic and KREEP-bearing nature of NWA 10203, NWA 11109, and NWA 11110 indicates a nearside origin [3], probably nearby mare-highland boundaries. NWA 10203 is said to be paired with NWA 11110, but the bearing basalts in the two samples from our study are clearly different. It is either they are not paired or the mixing of basaltic materials is heterogenous at a millimeter scale. Our data demonstrate the diversity of basalt in lunar feldspathic meteorites, and future mineral minor and trace element investigation would help characterize the origin and fractionation processes experienced by these basalts.

References: [1] Shearer, C. K. et al. (2006). *Reviews in Mineralogy and Geochemistry* 60:365–518. [2] Korotev R. L. (2005). *Chemie der Erde* 65:297–346. [3] Korotev, R. L (2021) *https://meteorites.wustl.edu/lunar/*. [4] Warren P. H. and Kallemeyn G. W. (1991) *Geochimica et Cosmochimica Acta* 55:3123–3138.