**NORTHWEST AFRICA 10986: AN IMPACT-MELT BRECCIA FROM THE LUNAR HIGHLANDS .** S.E. Roberts[1], M.M. Jean[1], M. B. Sueilem[2], and L.A.Taylor[1], [1]Planetary Geosciences Institute, Department of Earth and Planetary Sciences, University of Tennessee, Knoxville TN 37996; [2]Smara Refugee Camps of Western Sahara, Tindouf, Algeria. srober76@vols.utk.edu

**Introduction:** The anorthositic highlands of the Moon have been the least studied domain on the Moon [1]. Our knowledge of this complex terrain is generally based on returned samples from the Apollo 16 and Luna 20 missions. In support of these returned samples, the investigation into the geochemical evolution of the lunar highlands, along with the formation of the Moon from a Lunar Magma Ocean (LMO), can be investigated further with new evidence from lunar meteorites [2].

A new meteorite was found on November 15, 2015 in Grarat Zawi, Mahbed, Western Sahara. Weighing 108.2 g, this meteorite was recently approved by the Nomenclature Committee of the Meteoritical Society as NWA 10986 (**Fig. 1**). The planetary heritage of this meteorite as originating from the Moon is based on the Fe and Mn abundances in pyroxenes and olivines (**Fig. 2**) [3,4]. Furthermore, the large modal abundance of plagioclase indicates that NWA 10986 is sourced from the highlands (**Fig. 1**).

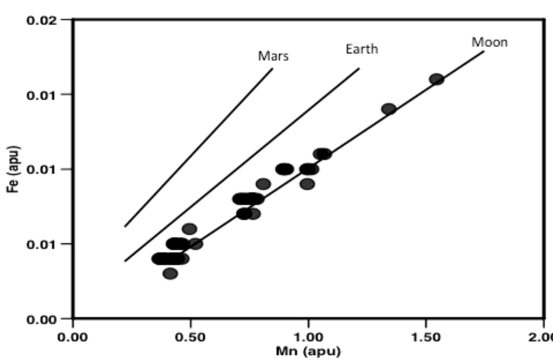


**Figure 2:** Fe and Mn in olivines found in NWA 10986, which indicate a lunar origin.

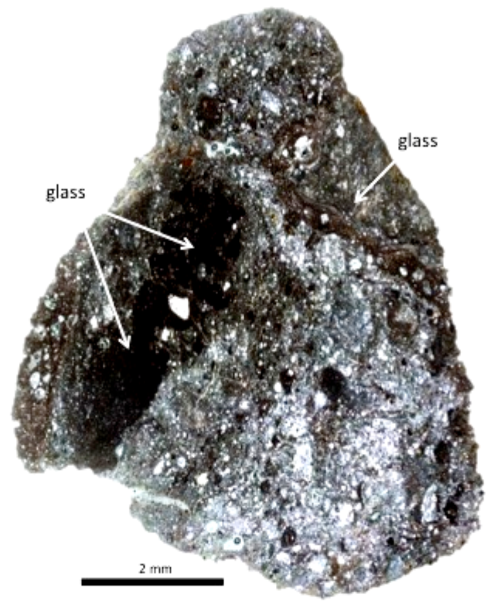


**Figure 1:** PPL photomicrograph of NWA 10986.

Meteorite NWA 10986 is interpreted as an impact-melt breccia with an unusually large amount of impact-generated glass (**Fig. 1**). The different textures observed within the impact glass indicate multiple generations of melting from repeated impacts. Brown to black devitrified glass-swirls encompass heavily fragmented and brecciated lithic clasts and mineral fragments to create a complex matrix bound by glass.

The textural and geochemical variety of clasts found in this impact-melt breccia reflects the diversity of lithologies found within the highlands. Plagioclase-rich clasts represent ~ 40 % of the meteorite and range in size from 1.4 to 0.1 mm in diameter. Clasts have

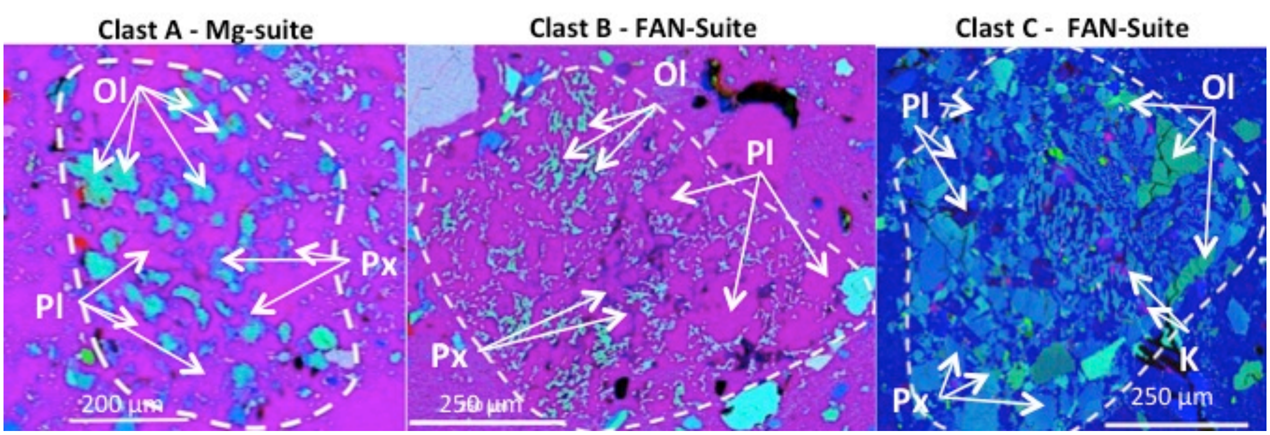


**Figure 3:** Combined element maps of clasts from NWA 10986. Element maps for Clast A and B are Si Kα, Fe Kα, and Ca Kα. The element map for Clast C is Si Kα, Fe Kα, and K Kα. Pink areas within Clast C indicate high-K.

been repeatedly subjected to multiple impact and melting events resulting in a breccia-in-breccia formation and the partial to complete consumption and melting of clasts during impact events. Occasional, small, round, impact-melt breccia clasts (0.1 to 0.6 mm) with randomly oriented plagioclase grains are present in the matrix.

Large broken plagioclase grains and small olivines and pyroxenes (0.2 to 0.6 mm) are found within the glass-bound matrix. Crystallization of impact-glass melt around the outside perimeter of the meteorite has resulted in large areas of fine-grained 'haystack' textured plagioclase patches. Evidence of terrestrial alteration is seen in barite and calcite veins crosscutting brecciated materials.

**Methods and Results:** Major- and minor-element analyses and element maps were collected with a Cameca SX-100 electron microprobe at the University of Tennessee. Analyses were collected using a 1-µm beam with a probe current of 30 nA and an accelerating voltage of 15 KeV for all minerals with the exception of plagioclase, when a 5 µm beam and a probe current of 10 nA was used.

The An content of plagioclase combined with the Mg# in the mafic minerals can be used to determine if this lunar highland rock consists of components from the Mg-suite, ferroan anorthosite (FAN) suite, or alkali suite from the lunar highlands [5]. The An content along with the Mg# in mafic minerals for the clasts in NWA 10986 suggest that materials that comprise this impact-melt breccia include Mg-suite and FAN highland lithologies, contrary to many lunar meteorites (**Fig. 4**).

Individual clasts within NWA 10986 were selected for further investigation. We highlight three unique clasts: Clast A (Mg-suite; **Fig. 3**) is poikilitic, with granular olivines surrounded by pyroxenes and plagioclase. Clast B (FAN; **Fig. 3**) has large anhedral plagioclase surrounding pyroxenes and olivines in a poikilitic texture. Clast C (FAN; **Fig. 3**) is a subophitic clast, with subhedral pyroxenes and minor olivines enclosed by plagioclase. Some pyroxenes exhibit an intergrowth texture with plagioclase. Mg-chromite is a minor phase in Clast C.

**Discussion:** The pyroxene compositions of the three clasts reflect the range observed in all clasts identified within NWA 10986 (**Fig. 4**). The least evolved pyroxenes from Clast A show a linear trend from pigeonite to augite, which are indicative of primitive parent melts. Whereas the highly evolved pyroxenes, including pyroferroite, found in Clast C, suggest extensive fractionation. This is also observed as K-rich areas, representative of a late-stage melt with a KREEP component [5] (**Fig. 3**).

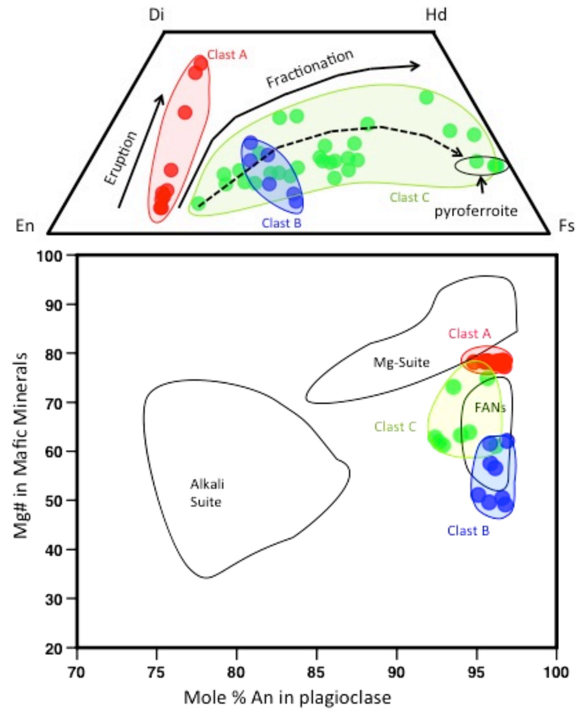


Figure 4: Pyroxene compositions reflect the range of clast types within NWA 10986. Pyroferroite is found with the pyroxenes in Clast C. Clast types represent Mg-Suite and FAN suite lithologies.

The clasts contained within this meteorite represent the evolution of the highlands as postulated by the LMO theory, from the formation and fractionation of the FAN suite, as captured by Clasts B and C, to the later intrusion of primitive Mg-suite rocks, represented by Clast A. The inclusion of both FAN and Mg-suite lithologies within this meteorite reinforces the spatial relationship of both suites in the highlands.

The impact induced creation of this meteorite allowed it to record the surface of the Moon from where it was sourced. This complex impact-melt breccia is in itself a representative of the thorough mixing of all of the highland rocks within the regolith. The large amount of "splash glass" found in the outside perimeter of this meteorite is unusual. The formation of this "splash glass" could be from melted regolith and possibly represent the composition of the breccia as a whole.

**References:** [1] Lucey, P., et al., (2006) *Rev. Min. & Geochem.* 60. [2] Korotev, R.L., (2005) *Chem. der. Erd*., 65. [3] Karner, J., et al (2003) *Am. Min.,* 88. [4] Papike et al., (2003) *Am. Min*., 88. [5] Shearer, C.K., et al., (2006) *Rev. Min. & Geochem.* 60.