Lunar Fragmental Breccia NWA 10989: Implications for the Evolution of the Lunar Crust

Conference or Workshop Item

LUNAR FRAGMENTAL BRECCIA NWA 10989: IMPLICATIONS FOR THE EVOLUTION OF THE LUNAR CRUST

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Introduction: Lunar meteorites derive from material ejected at escape velocity from impact events on the Moon. The ejected material is subsequently caught by Earth's gravitational field and falls as a meteorite [1]. Lunar meteorite compositions correlate with isotopic chemistry and radiometric age ranges of Apollo samples, validating their origin. New lunar meteorite Northwest Africa (NWA) 10989 is classified as a polymict fragmental breccia [2,3]. Fragmental breccias are common in the lunar crust, and are a mixture of compositionally variable rock and mineral fragments, sourced from different parent lithologies and fused together in a finer grained matrix [4]. The meteorite is grouped with several other stones, some of which have also been classified as fragmental breccias, and others as regolith breccias [2].

In a 1 cm sized fragment of the meteorite a large (~2.4×1.1 mm) metallic grain was observed by Martin Goff, who donated the sample to us for further study. Recent studies of large metallic components of lunar breccias have hypothesized an impactor-derived origin [5]. However, better analysis of the source of these rare metallic components is needed to address feasibility and test the likelihood of preserved material being pristine material derived from a projectile [6]. Or whether such a large metallic component could have undergone chemical reprocessing during the impact event [7] before being immobilised in its final assemblage.

Here we present an initial characterisation of the meteorite and metal components with the aim to understand the origin of metal in lunar breccias, and evaluate its relevance to the wider modification of the lunar crust from impacts.

Samples and Methods: A fragment of NWA 10989 was mounted and polished. Using a Nikon Eclipse LV100N POL reflective light microscope Cool LED pE-300-W at UoM, we obtained overview images using NIS elements imaging software at 2560×1920 resolution and 10 ms exposure length. This enabled us to identify regions of interest (ROI). An EDAX ESEM at UoM was used to obtain qualitative elemental maps and BSE images of the whole sample at 500× magnification and at higher magnifications for ROI. EDS spectra provide initial insights into phase makeup. Future work will include EMPA mineral chemistry analysis.

Results: *Petrographic overview:* The sample is a seriate textured breccia composed of fragments with varying lithologies ranging in size from ~0.17 to ~2 mm in a glassy matrix. There is general lack of terrestrial weathering (i.e., CaCO3 mineralisation), with only a few veins having CaO enhancement in the elemental maps. Clasts include devitrified, microcrystalline and clast-bearing impact melt derived breccias (~60-100 μm) and lithic fragments with igneous textures (possibly derived from the Mg-Suite) [8]. Mineral fragments include large (~120-345 μm) rounded, often embayed, pyroxene crystals with curved and offset exsolution lamellae and large (~650×470 μm) angular highly fractured olivine crystals. The sample matrix is glassy including small mineral fragments and rare round impact spherules (~15-27 μm), as well as melt pockets and veinlets with many rounded vesicles (~3-16 μm).

Metal component: The BSE images and elemental maps confirm the presence of a large (~2450×1150 μm) and several smaller (~10-320 μm) metallic clasts, that are rich in Fe with minor Ni (kamacite). The metal grains are enriched in P, K and Co compared with the surrounding silicate matrix. Within the large metal fragment rare grains (~73×8 μm) of Fe-P-Ni phases are present, likely to be schreibersite [9]. The edge of the metal clast is irregularly weathering to Fe-oxide (type to be determined). The large metal grain is associated with silicate minerals (plagioclase and orthopyroxene) and several large phosphates, including both apatite and merrillite. Small FeNi metal rounded blebs (<10 μm) often occur in the silicate glassy matrix surrounding the grain, suggestive of thermal degradation of the metal fragment during the meteorite's brecciation.

Discussion and future research: The presence of numerous features including melt beads, vesicles and impact glasses are indicative of regolith breccia material, therefore could lead to a reclassification of this sample as a regolith breccia. The low mean grain size and seriate texture, as well as containing few melt beads and no agglutinates, suggests the sample is immature [10]. Moreover, the sample is made up of lithic fragments and fine matrix material in semi-equal proportions, therefore the dominant mechanism of maturation was likely to be in situ reworking [11]. However, more analysis is needed to confirm the origin of the igneous-like lithic clasts as they may instead be impact melt products, which would modify the maturity interpretation.

We plan to gather quantitative chemical analysis using EMPA and compare this with known compositions of lunar lithologies to establish the mixture that makes up the sample. On knowing the grain compositions, it may be possible to collect isotope data to age date Pb-isotopes in apatite, which will help to define the source regions and formation mechanisms of those grains. Chemical data will aid the investigation into whether the large Fe-Ni grain and its associated phosphates, as well as the phosphide included within the grain, have a meteoritical origin. Chemical composition will be applied to the Fe-Ni-P ternary phase diagram [12] to explain the cooling history of the grain and help explain the mechanism of metallic incorporation into the breccia. This along with the concluded mechanism of the bulk breccia formation will give insight into how meteoritical material and surface reprocessing has impacted the evolution of the lunar crust over time.

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