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METAL IMPACTOR FRAGMENT FOUND IN LUNAR REGOLITH BRECCIA METEORITE NORTH WEST AFRICA 10989.

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Introduction: The composition of material delivered to the inner Solar System throughout history remains a mystery [1,2]. Lunar meteorites, unlike samples returned from Apollo and Luna missions, provide a rich resource for understanding the whole surface of the Moon [3]. Here we analyse a recently discovered lunar regolith breccia meteorites, North West Africa (NWA) 10989 (Fig. 1 A), to see whether it holds preserved impactor material. We consider the implications of its existance under the context of regolith evolution and *in-situ* resource utilisation.

Methods: At the University of Manchester, the petrology of NWA 10989 was analysed using the following methods: (1) an ESEM to obtain whole sample merger and close-up BSE images, qualitative EDX point spectra, and whole sample EDS elemental maps; (2) a Raman spectrometer to identify Fe-oxide phases; (3) an EPMA to quantitatively measure major element concentrations; (4) a Broad-ion beam (Argon) mill to polish; and (5) an Oxford Instruments EBSD with AZtec software to study crystallographic structure.

Methods: The 1 cm sized fragment of NWA 10989 we investigated specifically contains highland granulites, glassy impact melt breccias (GIMBs), clast-rich impact melt breccias (CIMBs), monomineralic pyroxene and rare mare basalt fragments. These clasts are held within a glassy matrix that includes impact melt spherules and Fe-Ni metal. The Fe-Ni metal is dominantly contained within a single 1.90 × 0.85 mm grain (Metal_1) along with several other smaller grains and abundant fine particles in the matrix (Figs. 1 A & B).

Results: The metal grains are composed of predominantly kamacite (low-Ni), enriched in K (0.16-0.22 wt%). Metal_1 also contains minor amounts of taenitic (high-Ni) material and K-rich schreibersite. Comparison between the metals' compositions and the meteoritic field suggest they are similar asteroid-derived meteorite groups, and thus could indicate and exogenous origin [4]. However, silicates in contact with and ocassionally embedded within Metal_1 (Fig. 1 B) reflect native lunar compositions.

Metal_1's internal microstructure consists of an aggregate of 50-150 µm sized variably orientated grains (Fig. 2 A & B). The colour gradients within grains indicate the presence of lattice bending, which in places advanced to sub-grain development.

Discussion: The compositional dichotomy between the native lunar silicates and the sizeable, apparently exogenous, Fe-Ni metal suggests either (i) an almost intact fragment of meteorite or (i) a precipitate from an impact melt sheet composed of a vaporised impactor and lunar target rock mixture. Metal_1's complex internal structure, indicative of crystal plastic deformation, could be attributed to strain during regolith reprocessing.

This study advances current knowledge in ISRU through evidence of impactor survival and modification on the surface of the Moon, plus it aids in understanding what material was delivered to the inner solar system during its history.

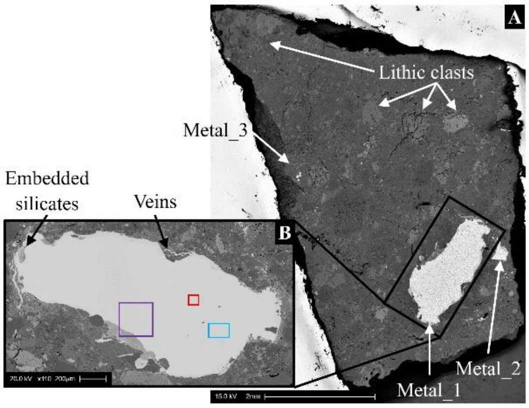

Figure 1: (A) Whole sample BSE image, *(B)* Metal_1 close-up BSE image with EBSD areas shown

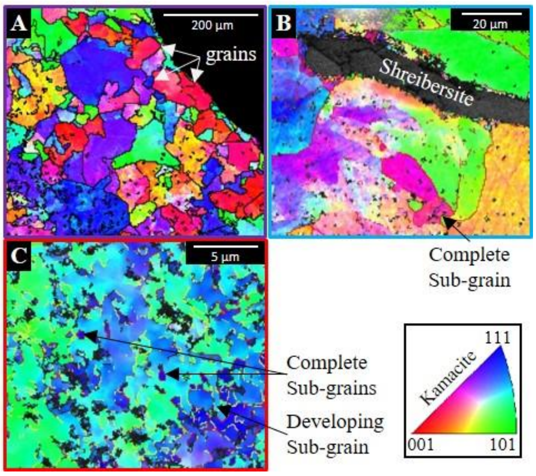

Figure 2: Inverse pole figures of parts of Metal_1, indicated in Fig. 1 B, where colours represent lattice orientation corresponding to the triangle key.

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References: [1] Hartmann W. et al. (2000) In: R. Canup and K. Righter, eds. Tuscon: University of Arizona Press, 805-826. [2] Joy K. H. (2012) *Science*, 336(6087), 1426-1429. [3] Jolliff B. L. et al. (2000) *JGR*, 105, 4197-4216. [4] Goldstein J. I. and Yakowitz H. (1971) *P. Lunar. Plant. Sci*., 2, 177-191.