TEXTURALLY ZONED SILICON-BEARING IRON-NICKEL METAL INCLUSIONS IN THE LUNAR FELDSPATHIC REGOLITH BRECCIA NORTHWEST AFRICA 11303.

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Introduction: Metal grains in lunar regolith provide records of space weathering and meteoroid bombardment, which contribute to our understanding of the evolution of the Moon's surface. Most of the mass of metal in lunar regolith formed by deposition of Fe-metal from micrometeorite impact induced vaporization of lunar target materials and subsequent reduction [e.g., 1]. The Fe-metal formed by space weathering associated with micrometeorite bombardment are commonly very small Fe^0 (most < 10 nm), referred to as $npFe^0$ [e.g., 1]. In rare instances, larger metal grains formed by this space weathering process have been found, such as the discovery of a ~35 μm metal grain of hapkeite (FeSi with 3.1 wt.% Ni) and associated other Fe-silicides in Dhofar 280 by [2].

Lunar regolith also commonly includes FeNi-metal that was added to the lunar surface by chondrite, pallasite and/or iron meteoroids [e.g., 3-4]. These exogenic additions are distinguished by Co and Ni concentrations consistent with metal in most asteroidal meteorites. The exogenic metals previously described in lunar regolith are silicon-poor (< 0.05 wt.% Si), if Si was included in the metal analyses [4]. In this work, we investigate metals in Northwest Africa (NWA) 11303, and particularly focus on two metal inclusions that are chemically distinct from previously described metals in lunar regolith.

Materials and Methods: We have investigated three polished thick sections of NWA 11303 that are part of the research collection of JG at Rutgers University (RU). NWA 11303 is part of the a pairing group of at least 19 lunar feldspathetic breccias with 12.9 kg cumulate mass, which NWA 8046 was the first classified member [5-6]. We have obtained quantitative and qualitative geochemical data on a selection of metal grains (> 5 μm) in NWA 11303 with the JEOL JXA-8200 Superprobe (EMP) at RU.

Results: Two round metal inclusions in NWA 11303 are concentrically zoned with smooth central interiors and polygonally-fractured exterior zones. These inclusions do not appear to be inside of larger clasts or melt units; they respectively have diameters of ~500 μm and ~30 μm. Both grains are dominated by FeNi metal with compositions consistent with an exogenic provenance [e.g., 3-4] based on averages of 5.9 and 9.0 wt. % Ni and 0.29 and 0.34 wt. % Co. There are no zoning trends with respect to Ni, Co, or P in either of these inclusions. This FeNi metal in both zoned inclusions is Si-bearing metal, with averages of 1.3 and 1.2 wt. % Si. In contrast, all other (non-concentrically zoned) metal grains in NWA 11303 analyzed by EMP in this study are effectively Si-free, but also have Ni and Co have concentrations consistent with exogenic provenances. The larger of these concentrically zoned metal inclusions contains sulfide grains that vary between the two zones: the smooth central interior has Cr-bearing sulfides (1.3-15.0 wt.% Cr), whereas in contrast, the polygonally-fractured exterior zoned has typical troilite (0.23-0.35 wt. % Cr).

Discussion: These are the first reported Si-bearing metals with Ni and Co concentrations consistent with exogenic provances found in a lunar sample. There are two potential mechanisms for the formation of these inclusions: (1) These Si-bearing metals formed by space weathering of exogenic material on the lunar surface. The Ni concentrations in the hapkeite-bearing inclusion previously found in Dhofar 280 are not high enough to be considered exogenic, but the Ni concentrations was high enough that [2] proposed there was some exogenic contribution in their precursor regolith. However, lunar space weathering has not been recognized to form sulfides akin to widely occurring $npFe^0$ [e.g., 1,7], with the caveat that np(Fe,Mg)S have been recognized in Itokawa regolith [e.g., 8]. (2) These Si-bearing metals originated from a highly reduced meteoroid and thus their Si concentrations directly reflect their provanence. Specifically, Si-bearing metal is found in aubrites, enstatite chondrites, and several ungrouped iron meteorites [9-10]. Cr-bearing sulfides (e.g., daubréelite) can be found in aubrites, enstatite chondrites, and many iron meteorites [9-10].

The combination of Si-bearing metal and Cr-bearing sulfides is more consistent with these texturally zoned metal inclusions inheriting their reduced geochemical features from their source meteoroid. Thus, these two Si-bearing metal inclusions along with the non-Si-bearing exogenic metals provide evidence that regolith that NWA 11303 formed from incorporated material from multiple geochemical distinct impactors. Direct evidence for two separate impactors have not previously been recognized in a lunar regolith sample. As exemplified by the Si- and non-Si-bearing exogenic metals in NWA 11303, recognizing inputs from multiple impactors is feasible and may be a powerful tool for connecting unpaired lunar meteorites from similar regions of the Moon and for investigating the history of impacts on the Moon.

References: [1] Keller & McKay (1993) *Science* 261:1305. [2] Anand et al. (2004) *PNAS* 101:6847. [3] Goldstein & Yakowitz (1971) *Proc. of 2nd Lunar. Sci. Conf.* 1:177. [4] Goldstein et al. (1972) *Proc. of 3rd Lunar. Sci. Conf.* 1: 1037. [5] Meteoritical Bulletin Database www.lpi.usra.edu/meteor/ [6] Korotev R. Website meteorites.wustl.edu/lunar/stones/nwa 8046.htm. [7] Domingue et al. (2014) *Space Sci Rev* 181:121. [8] Noguchi et al. (2011) *Science* 333:1121. [9] Brearley and Jones (1998) *Rev. Mineral.* 36:4-01. [10] Mittlefehldt et al. (1998) *Rev. Mineral.* 36:4-01.