MAFIC GRANULITIC IMPACTITE NORTHWEST AFRICA 3163: A UNIQUE METEORITE FROM THE DEEP LUNAR CRUST. A. J. Irving[1], S. M. Kuehner[1], R. L. Korotev[2], D. Rumble, III[3] and G. M. Hupé, [1]Dept. of Earth & Space Sciences, University of Washington, Seattle, WA 98195 (irving@ess.washington.edu), [2]Dept. of Earth & Planetary Sciences, Washington University, St. Louis, MO 63130, [3]Geophysical Laboratory, Carnegie Institution, Washington, DC 20015.

Discovery: A fresh 1634 gram stone almost completely coated by a thin, transparent, pale greenish fusion crust, which was found in Mauritania (or possibly Algeria) in August 2005, is probably the largest known specimen of a lunar crustal granulite among returned samples and meteorites (Figure 1).

Figure 1. Complete 1634 gram stone, showing clasts visible through the transparent fusion crust.

Petrology and Mineral Compositions: The fresh, pale gray interior of this specimen has multiple shock fractures (with very minor calcite coatings) and some thin glass veinlets (Figure 2). This rock is a poikiloblastic recrystallized breccia, with larger grains of plagioclase (~70%) enclosing much smaller grains (less than 100 microns across) of pyroxene (~20%), olivine (~10%) and accessory Ti-chromite

Figure 2. Complete 13 cm wide slice of NWA 3163, showing fine fractures and glass-filled veinlets.

(Cr/(Cr+Al = 0.714 - 0.736, Mg/(Mg+Fe) = 0.121 - 0.143, TiO_2 = 9.1-18.4 wt.%), ilmenite, troilite and metal (containing ~15 wt.% Ni) - see Figure 3.

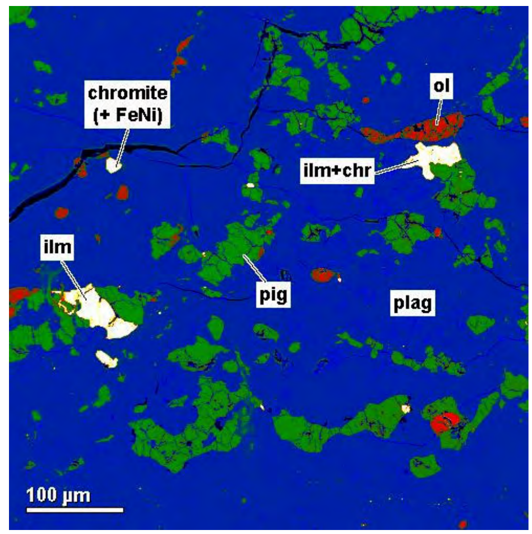

Figure 3. False-color BSE image. Note the extremely fine grainsize of mafic silicates and oxides.

There are textural remnants of larger, white plagioclase clasts and also of ophitic diabasic clasts (multiple plagioclase grains within optically continuous pyroxene). Anorthitic plagioclase ($An_{97.4-98.2}$) has been converted by shock almost entirely to maskelynite (although domains of birefringent, less shocked feldspar remain) - see Figure 4.

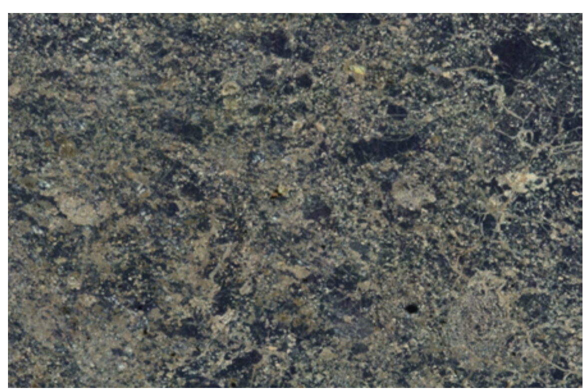

Figure 4. Cross-polarized thin section image, showing maskelynite (dark) and very fine grained olivine and pyroxene. Width of field = 8 mm.

Pigeonitic pyroxene grains have very fine scale exsolution lamellae of augite ($Fs_{14.5\text{-}16.1}Wo_{40.2\text{-}40.5}$, FeO/MnO = 41.7-43.8) within orthopyroxene ($Fs_{32.0\text{-}33.9}Wo_{4.4\text{-}5.8}$, FeO/MnO = 55.5-61.2). Olivine has a narrow range of compositions ($Fa_{38.0\text{-}40.9}$) and high FeO/MnO ratios (91.7-110) diagnostic of lunar rocks. Mineral compositions are characteristic of ferroan anorthositic igneous rocks from the ancient lunar highlands, and this specimen is a hornfelsic granulitic breccia or impactite (using terminology of [1]).

Oxygen Isotopic Compositions: Replicate analyses of bulk material by laser fluorination gave $\delta^{17}O$ = 2.663, 2.833, 2.809, 2.785, 2.782; $\delta^{18}O$ = 5.082, 5.472, 5.479, 5.407, 5.335; $\Delta^{17}O$ = -0.005, -0.040, -0.067, -0.054, -0.019 per mil, respectively. Unlike Apollo samples [2] and most lunar meteorites, these values lie to varying extents below the terrestrial fractionation line (assuming a slope of 0.525 [3]). Two out of several other feldspathic breccias analyzed in the same laboratory also exhibit this: NWA 482 ($\delta^{17}O$ = 2.47, 2.73; $\delta^{18}O$ = 4.84, 5.36; $\Delta^{17}O$ = -0.071, -0.084 per mil, respectively) and NEA 001 ($\delta^{17}O$ = 2.26, 2.48; $\delta^{18}O$ = 4.40, 4.78; $\Delta^{17}O$ = -0.050, -0.030 per mil, respectively). Most of these deviations appear to be beyond the experimental uncertainty and require explanation.

Bulk Chemical Compositions: Among feldspathic lunar meteorites NWA 3163 is distinctive in being relatively mafic (5.8 wt.% FeO) but with very low concentrations of incompatible elements (Figure 5 and [9]) and siderophile elements (e.g., 2 ppb Ir).

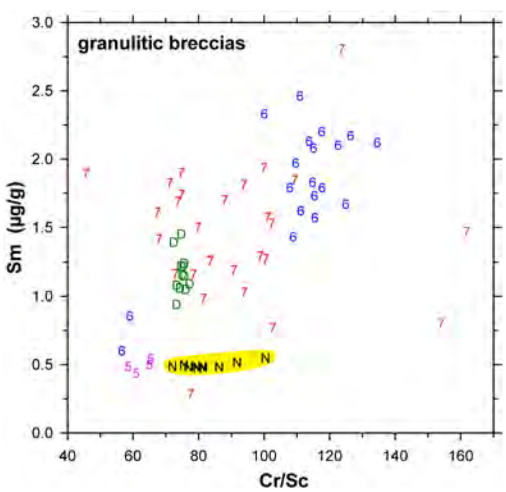

Figure 5. Comparison of NWA 3163 subsamples (N) to Apollo 15, 16 and 17 granulitic breccias (5, 6, 7 [4, 5]) and Dhofar 026 (D [6, 7]). Cr/Sc serves as a proxy for Mg/Fe in feldspathic lunar rocks [8].

In comparison with Apollo samples, NWA 3163 is most similar in composition to unique ferroan granulitic breccia 15418 [4, 6] - points 5 in Figure 5.

Petrogenesis and Conditions of Equilibration in the Lunar Crust: The petrology and composition of lunar granulitic rocks have been discussed by [1, 4, 5]. Other meteoritic specimens of lunar granulitic rocks (Dhofar 026 [6], Dhofar 733 [10] and another Oman stone [11]) all contain more magnesian olivine than NWA 3163. We interpret NWA 3163 to be an annealed microbreccia produced by burial metamorphism deep in the ancient lunar crust of impact-comminuted anorthositic and olivine gabbroic to diabasic rocks. However, it is uncertain as to how (and when) the calcic plagioclase was converted largely to maskelynite. The fact that Apollo granulitic samples also contain maskelynite [1, 4, 5] suggests that this transformation was related to much earlier impact events than that which ejected this meteorite from the Moon. Coexisting pyroxene compositions in exsolved pigeonites indicate high equilibration temperatures of 1070°C [12], which in turn probably imply depths of tens of kilometers for a projected ancient selenotherm.

Implications For Future Lunar Missions: If granulitic rocks like NWA 3163 are typical of lithologies present in the deeper lunar crust, then similar materials may be exposed within large impact basins, such as South-Pole Aitken. Because of their extremely fine grain size and compact, gray glassy appearance, they are quite unlike the typical soil and regolith breccias returned by the Apollo missions (and indeed the dominant lithologies found as lunar meteorites). Astronauts on future planned missions to this region of the Moon may well encounter such rocks and should be trained to expect them.

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