NORTHWEST AFRICA 8010: FELDSPATHIC REGOLITH BRECCIA WITH ABUNDANT CRYSTALLINE LUNAR SPHERULES H.M. Miley[1,2], C.B. Agee[1,2], R.L. Korotev[3], N. Muttik[2], M. Morgan[4], [1]Institute of Meteoritics and [2]Department of Earth and Planetary Sciences, University of New Mexico, Albuquerque, NM 87131, [3]Dept. of Earth & Planetary Sciences, Washington University, St Louis, MO, [4]Colorado School of Mines, Golden, Co 80401.

Introduction: NWA 8010 is a lunar feldspathic breccia reportedly found in Zagora, Morocco in 2013 [1]. It is a single stone, 58 grams (total known weight) with gray-brown fusion crust, and black melt veins visible through the crust. Saw cuts reveal dark breccia clasts with fragmental feldspar and light fine-grained clasts up 1-2 cm, bounded by black shock melt veins 1-4 mm wide, melt veins contain vesicles up to 1 mm. Microprobe examination of a polished mount showed this specimen to be a fragmental impact melt breccia. We observed anorthositic and gabbroic clasts, fragmental plagioclase, pyroxene, olivine, oxides and sulfides set in a cataclastic groundmass. Preliminary electron microprobe work gives the following mineral compositions: olivine Fa31.7±7.5, Fe/Mn=93±5, n=14; forsteritic olivine Fa7.4±1.5, Fe/Mn=100±16, n=2; pyroxene Fs33.8±11.1Wo17.0±9.9, Fe/Mn=57±7, n=21; plag An96.2±1.3Ab3.4±1.2Or0.4±0.2, n=10. Abundant glassy melt veins are found throughout with suspended submicron metal/sufide blebs, plumose quench crystal zones up to 1 mm wide at groundmass cooling contacts. Vesicles confined mostly in the center of melt veins. The melt veins were probed (EMPA) with a 20um defoucsed beam to give the composition: SiO_2 = 45.55±1.28, TiO_2 = 0.52±0.23, Al_2O_3 = 25.34±2.86, Cr_2O_3 = 0.13±0.03, MgO = 7.54±2.21, FeO = 5.99±1.03, MnO = 0.08±0.03, CaO = 14.35±1.41, Na_2O = 0.42±0.16, K_2O = 0.16±0.07 (all wt%), n=7. The chemical composition of impact melt (proxy for bulk composition) is that of high-alumina basalt. This lunar meteorite is particularly noteworthy because it possesses abundant crystalline lunar spherules (CLS), supporting the idea that it is composed of lunar regolith. Here we report new data on the bulk composition of NWA 8010, we also describe in more detail on the variety of clasts present, and highlight the diverse and numerous CLSs.

Methods: To determine bulk composition we analyzed seven 30–35-mg subsamples of NWA 8010 by instrumental neutron activation analysis [2]. The composition of individual minerals for purposes of clast and spherule study are acquired using electron microprobe analysis, through the use of a JEOL 8200 Superprobe. In preparation for analysis, the flat surface of the specimen is polished to a 0.3 µm finish and carbon coated. Analytical conditions include using an accelerating voltage of 15 KeV, a beam current of 20 nA and a constrained beam (0-1 µm). Data points with elevated or depleted totals (+/-2%), or which are not stoichiometric are eliminated prior to analysis.

Bulk Composition: Compositionally, the meteorite is feldspathic, but more mafic (higher Sc, Fig. 1) and richer in incompatible elements (e.g., Sm, Fig. 1) than most other feldspathic lunar meteorites [3]. Subsample composition are heterogeneous with one subsample containing a feldspathic clast (low Sc) and another containing a KREEP-bearing lithology (high Sm.). The meteorite contains a distinctly nonchondritic asteroidal meteorite component (Fig. 2), a feature usually characteristic of a component of iron meteorite [3].

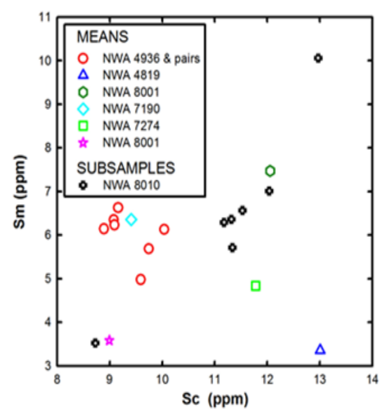

Figure 1. Comparison, in Sc-Sm space, of NWA 8010 subsamples to other lunar meteorite stones of similar composition. NWA 4936 and pairs (5406, 6221, 6355, 6470, 6570, 7190, and 7986) are similar to NWA 8010 in being glassy and vesicular.

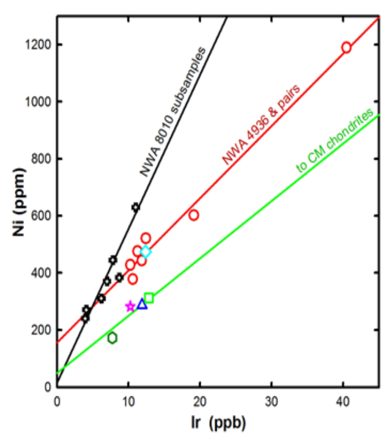

Figure 2. Comparison of siderophile element concentrations in NWA 8010 with other lunar meteorites of similar lithophile element composition. The component causing the variation in siderophile-element concentrations among NWA 8010 subsamples is not chondritic

Clasts: For NWA 8010 we define clasts as non-spherical mineral fragrments, often polymineralic in excess of 250 µm with a defined boundary from the matrix; they are distinguished from each other based off their differing texture and petrological composition [4-5].

Thus far, three different pyroxene-plagioclase dominated clasts have been identified, with other candidates (including those with olivine) to be pursued in later research. Clast-1 has plagioclase lathes suspended in a Al-rich pyroxene quench composition. Clast-2 contains anhedral pyroxene grains set in a plagioclase matrix. Clast-3 contains plagioclase laths with interstitial pyroxene.

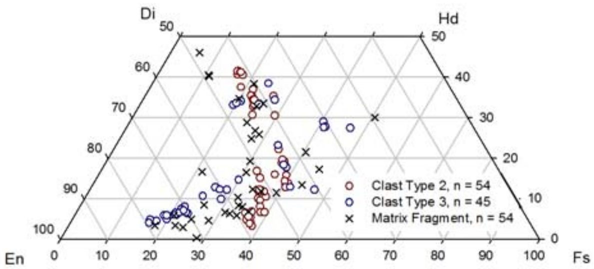

Figure 4: Pyroxene quadrilateral of clast and fragmental sources.

Spherules: Crystalline Lunar Spherules (CLS) resemble chondrules, with textures suggestive of re-crystalization and quenching. These likely formed by impact or volcanic processes, both causing the material to cool rapidily by either rapid re-crystallization or primary crystallization in free-flight. Apollo CLSs are generally found in regolith breccias, while glassy spherules and agglutinates are found in loose regolith. Thus far, impact glass beads are rare, if existent, in NWA 8010. However, it contains relative to other lunar meteorite samples a high abundance of CLSs. [6-10].

Representative examples of these are shown in Image 1. Amoung the largest CLSs contain plagioclase growth suspended in a pyroxene /olivine mesostasis, there are two major representations of this type, one with tabular plagioclase and another with granular plagioclase. There are two types of quench spheres, one with fine pyroxene outgrowth, and another with fine olivine outgrowth, these may be an occurence of devitrifed glass. Notice the fine grain rim around the quench CLS, this is a common feature, especially amoung this sub-type. The most common CLS type is a homogenous spherule, consisting of mostly micro-porphyritic plagioclase. These take on both spherical and elliptical shapes. Rarer types include: a silica - pyroxene CLS (one occurence) and sequential lithology spherules with an inner spherule of fine tabular plag set in olivine/pyroxene mesostatis surrounded by a fragmental plagioclase/ pyroxene outer spherule.

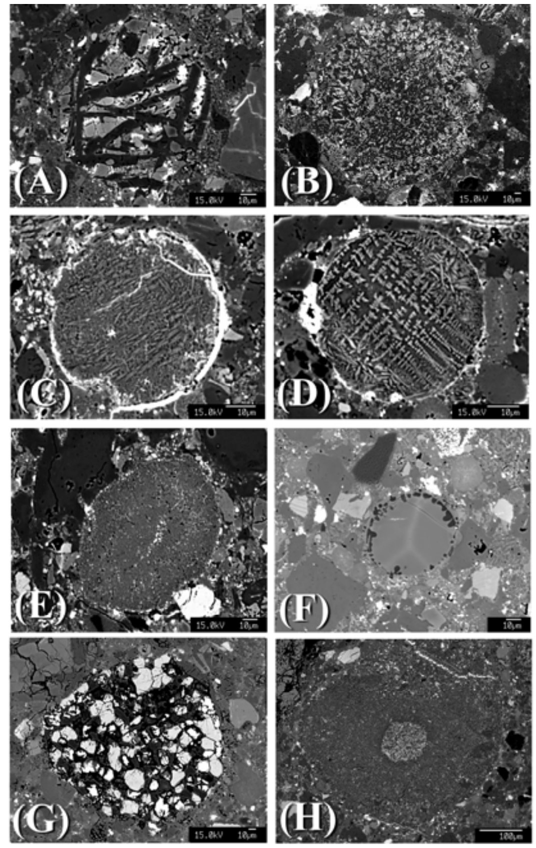

Image 1. Electron backscatter images. (A) Tabular plagioclase spherule, 750x occur 75-250 μm diameter (d) , (B) Granular plagioclase spherule, 300x, d ~ 75-250 μm, (C) Olivine quench spherule, 1400x, (D) Pyroxene quench spherule, 1500x. Quench spherules (C-D) d ~ 50-75 μm. (E) Homogenous spherule, 700x, d ~ 10-80 μm. (F) Glass bead? (G) Quartz- pyroxene spherule, 350x, d ~ 200 μm. (H) Sequential lithology spherules, x200, d ~ 400-500 μm.

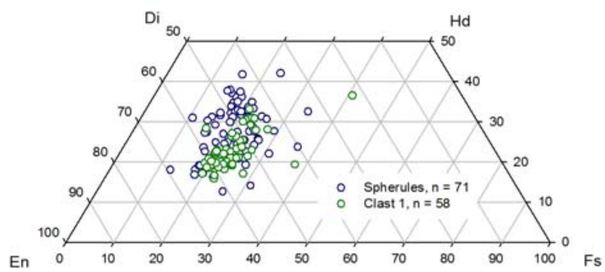

Figure 6: Pyroxene quadrilateral of Al-enriched pyroxene found in CLS and in Clast-1. The high Al-content is likely do to disequilbrium or dynamic crystallzation rapid quenching.

References: [1] Meteoritical Bulletin 102 (2013) [2] Korotev R. L. (2012) M&PS 47, 1365–1402. [3] Korotev R. L. & Irving A. J. (this conf.) Korotev R. L. (2013) LPSC 44, #1028. [4] Mercer C.N. et al. (2012) Meteoritics & Planet. Sci., 48, 289-315. [5] Santos A.R. et al. (2013) LPS XLIV, Abstract #2533. [6] Ruzicka A. et al. (2000) Meterotics & Planet. Sci., 35, 173-192. [7] Delano J. W. (2007) Meteoritics & Planet. Sci., 42, 993-1004. [8] Zellner N.E.B. et al. (2002) JGR, 107, 12.1-12.13. [9] Cohen B.A. et al. (2004) Meteoritics & Planet. Sci., 39, 1419-1447. [10] ymes S.J.K. et. al. (1997) Meteoritics & Planet. Sci., 33, 13-29.