MINERALOGY AND PETROLOGY OF LUNAR METEORITE NWA 3136: A GLASS-WELDED MARE REGOLITH BRECCIA OF MIXED HERITAGE. S.M. Kuehner[1], A.J. Irving[1], D. Rumble, III[2], A.C. Hupé[3] and G.M. Hupé[3], [1]Dept. of Earth & Space Sciences, University of Washington, Seattle, WA 98195, kuehner@u.washington.edu, [2]Geophysical Laboratory, Washington, DC 20015, [3]The Hupé Collection.

Introduction: An oriented 95.1g shield-shaped stone with partial thin, pale brown fusion crust was found at an unspecified location in Algeria or Morocco in April 2004. The specimen has a thin, dark weathering varnish, but the interior is a very fresh, black, hard, vitreous-looking rock with small white to yellowish clasts. Minor calcite and barite are presumably a result of desert weathering. Optical and microprobe examinations reveal that it is a well consolidated, polymict breccia consisting of mineral and lithic clasts derived predominantly from mare basalts but with a smaller proportion (~20%) of highlands lithologies. The matrix consists mainly of comminuted minerals and clasts in a very fine grained, mostly crystalline and partly vitreous, material with common metal-dusted agglutinate fragments. Some clasts are of earlier regolith breccias. Oxygen isotope analyses of two whole rock fragments by laser fluorination gave $\delta^{18}O$ = +5.83, +5.96, $\delta^{17}O$ = +3.06, +3.10, $\Delta^{17}O$ = -0,03, -0.05 per mil, respectively.

Clast Petrography and Mineral Chemistry: Angular to sub-angular mineral clasts (500µm to sub-micron) were identified using EDS. These include anorthite, orthopyroxene, ferropigeonite, ferrosilite and pyroxferroite, olivine (ranging to nearly pure fayalite), ilmenite, Ni-poor Fe metal, troilite, Cr-bearing ulvöspinel, and rare pentlandite, baddeleyite, and a Ce-Ca-Fe-bearing, Zr-rich titanate (probably zirconolite). A detailed textural and WDS examination of 9 lithic clasts in one thin section and one polished rock chip shows that they comprise 3 petrogenetic lithologies. All 9 clasts are rounded, mafic, and the majority have a basaltic texture, whereas others are equigranular. Exsolution lamellae were not observed in any pyroxene or oxide grains.

Clast 1. A 2mm x 1.3mm basalt clast with subophitic texture. Plagioclase laths (An97-88) up to 400µm in length are partially enclosed in strongly zoned clinopyroxene (mg#=68.2-18.2; Wo13.7-24.2; 0.5-2.3wt% TiO_2). A reddish-brown interstitial glass with mg#=4.0 contains up to 6.7wt% TiO_2. Rare accessories are Cr-bearing ulvöspinel and troilite.

Clast 2. Partially impact-melted chromite-bearing olivine microgabbro. Over half of this 2mm x 1.7mm clast consists of a fine, quench-textured intergrowth of olivine, plagioclase, clinopyroxene, and chromite grains with larger relict plagioclase fragments. A grain boundary glass separates the primary interlocking grains of olivine (Fo73.4-43.3; more Fe-rich towards the melt), plagioclase (An95.7-85.7), clinopyroxene (mg#=68.2-63.6, Wo23.5-14.3; more Mg-rich toward the melt) and chromite.

Clast 3. This 620µm x 430µm clast is an equigranular olivine-bearing norite with accessory ilmenite and Fe-Ni metal. Plagioclase (An94.1-91.4, Or1.1-2.2), olivine (Fo67.4-67.5) and orthopyroxene (mg#=65.2-66.6, Wo5.1-8.3) are weakly zoned.

Clast 4. A 450µm x 500µm granular, olivine-bearing gabbronorite clast with accessory Fe-Ni metal, ilmenite and chromite enclosed within a 3mm x 4.5mm, rounded regolith fragment. Olivine (Fo67.3-64.5), clinopyroxene (mg#=78-77, Wo 38.6-40.5), orthopyroxene (mg#=73.9-73.1, Wo5.0-4.1), and plagioclase (An96.1-92.8, Or1.4-0.6) have little compositional variation.

Clast 5. A 450µm x 200µm subophitic olivine basalt with accessory baddeleyite, troilite, ilmenite, ulvöspinel, and silica-hedenbergite intergrowths. The mafic phases are strongly zoned toward Fe-rich compositions: olivine, Fo42.5-10.8; clinopyroxene, mg#=47.4-16.0; the plagioclase is relatively sodic and homogeneous, An91.9-88.8, Or0.6-0.4.

Clast 6. A 200µm x 900µm silica-bearing microgabbro. The clinopyroxene is strongly zoned with rim compositions reaching pyroxferroite (mg#=66.5-12.1, Wo23.4-17.3). Plagioclase is An 97.1-90.5. Blocky grains of ilmenite and ulvöspinel are intergrown, and fayalite forms a narrow selvage between ilmenite and any adjacent hedenbergitic clinopyroxene.

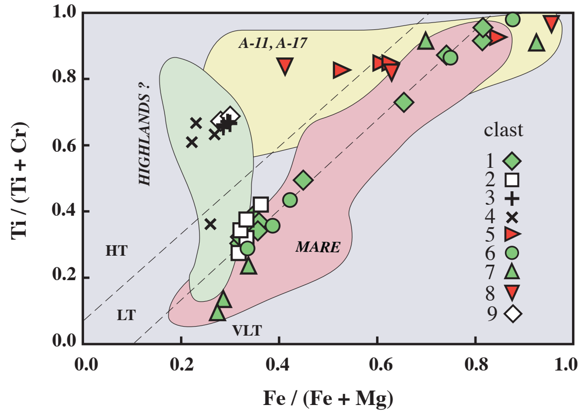
Clast 7. A 1.2mm x 1.2mm subophitic silica-bearing olivine basalt. Pigeonite cores (mg#=72.6, Wo8.0) are strongly zoned to rims of pyroxferroite (mg#=7.5, Wo25.7). Plagioclase has a narrow compositional range (An95.3-94.1) and olivine is Fo70.3-59.5. Accessories are troilite and chrome-spinel.

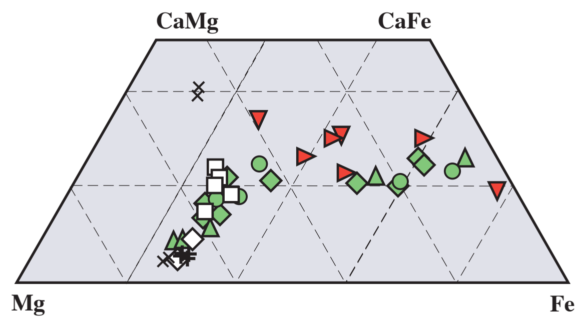
Clast 8. A 750µm x 400µm basalt fragment with intergranular olivine (Fo63.6-57.4) and strongly zoned clinopyroxene (mg#=58.7-4.3, Wo33.4-18.8). Plagioclase is An 90.3-74.7, Or0.5-2.7. This clast is unique in having 200µm x 40µm blades of ilmenite, with accessory baddeleyite and troilite.

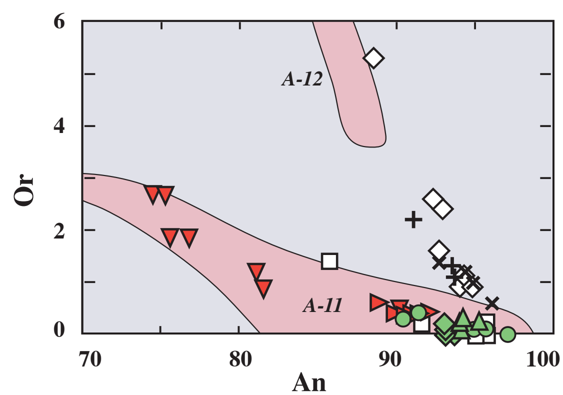
Clast 9. A 750μm x 550μm orthopyroxene-olivine-bearing anorthosite with accessory merrillite. Olivine (Fo66.0-65.4) and orthopyroxene (mg#=71.8-69.9, Wo4.7-9.3) grains are equant, and comprise <1% of the clast. K-rich plagioclase compositions range from An94.9-88.6, Or5.3-0.9.

Glass Spheres: Several 20-60μm spheroidal to ellipsoidal or fragmentary glass particles (pale yellow to brown in thin section) with variable composition are scattered throughout the meteorite matrix. One texturally homogeneous sphere has nearly pure anorthite composition, and others contain relict phases and/or quench crystallites. Each of the 20 glasses analyzed have Mg/Al < 1, and likely are of impact origin [1]. All compositions are also too FeO-poor and Al_2O_3-rich to be pristine mare volcanic glasses [2], and fall along a mixing line of predominately mare components with a lesser highlands contribution.

Discussion: Zoning patterns (Fig. 1) in pyroxenes from basaltic and gabbroic lithologies (clasts 1, 2, 6 and 7) follow the correlated Ti and Fe enrichment trend characteristic of very low Ti (VLT), and/or low Ti (LT) mare basalts [3]. Pyroxene compositions from granular textured noritic clasts 3 and 4 and the anorthosite clast 9 (Fig 1) fall within a field of possible highlands lithologies [3]. Such a clast population is very similar to that in polymict regolith breccia Y793274 [3]. However, NWA 3136 also includes a population of baddeleyite-bearing basaltic clasts (clasts 5, 8) containing somewhat more calcic pyroxenes (Fig. 2) that follow a separate high Ti, low Cr zoning trend (Fig. 1) similar to that observed in pyroxenes from Apollo 11 and 17 high Ti basalts [4]. Plagioclase analyses define two trends (Fig 3). A trend of rapid Or enrichment with decreasing An is defined by the noritic clasts 3 and 4 and the anorthosite clast 9. These feldspars fall within the ferroan anorthosite field of [5] based on An vs mg#, but are unusual in being both Or and An-rich. They are quite similar to some plagioclase analyses from Apollo 12 gabbros [6] that were discounted as being possible beam overlaps with K-rich glass. A trend of Ab enrichment is defined by plagioclase in basaltic- and gabbroic-textured clasts and is consistent with a mare origin [7]. These petrographic and mineral chemical characteristics showing multiple sources for the NWA 3136 clasts are supported by the INAA study of [8] who independently identified highlands, mare, and possible KREEP components in this meteorite.







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