**NORTHWEST AFRICA 1401: A POLYMICT CUMULATE EUCRITE WITH A UNIQUE FERROAN HETERADCUMULATE MAFIC CLAST.** David W. Mittlefehldt[1] and Marvin Killgore[2], [1]NASA/Johnson Space Center, Houston, TX (david.w.mittlefehldt@nasa.gov), [2]Southwest Meteorite Lab, Payson, AZ (swmtlab@goodnet.com).

**Introduction:** The howardite, eucrite and diogenite (HED) clan is the largest suite of achondrites available for study. The suite gives us a unique view of the magmatism that affected some asteroids early in solar system history. One problem with mining the HED clan for petrogenetic information is that there is only limited petrologic diversity among the rock types. Thus, discovering unusual HED materials holds the potential for revealing new insights into the petrologic evolution of the HED parent asteroid. Here we report on petrologic study of an unusual, 27 gram polymict eucrite, Northwest Africa (NWA) 1401. The thin section studied (~20 x 10 mm) contains one large, ferroan clast described separately. The remainder of the rock, including mineral fragments and other, smaller lithic clasts, forms the host breccia.

**Host Breccia:** NWA 1401 is a metamorphosed, fragmental breccia dominated by material from a moderately coarse-grained, mafic parent rock (Fig. 1). The host breccia is composed mostly of mineral fragments; lithic clasts are subordinate. Pyroxene fragments are up to 1.8 mm, plagioclase fragments are up to 1.2 mm, silica fragments are up to 0.8 mm, and chromite fragments are up to 0.5 mm. Excluding the ferroan clast, the largest lithic clast is about 2 mm in size, while the largest impact-melt clast is 1.4 mm in size. The mineral fragments are angular, but have rounded corners, and grains generally have sutured margins (Fig. 1).

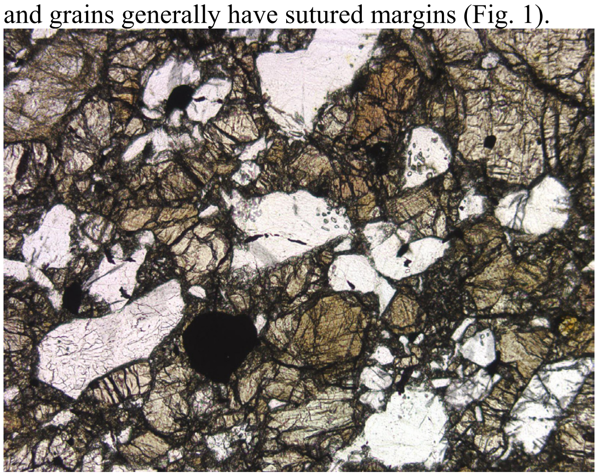

Fig. 1. Host breccia composed mostly of mineral fragments of pyroxene (brown), plagioclase (white) and chromite (black). Many mineral fragments are angular but with rounded corners, and sutured margins are typical. Field of view is 2.3 x 1.7 mm.

Pyroxene mineral fragments are dominantly pigeonites intermediate in mg# between those of basaltic eucrites (Sioux County) and cumulate eucrites (Moore County) (Fig. 2). These pyroxenes typically have coarse augite exsolution lamellae. Low-Ca pyroxene hosts have an average composition of $Wo_{8.9}En_{39.3}Fs_{51.9}$ with an mg# of 43.1. Augite lamellae have an average composition of $Wo_{38.0}En_{32.7}Fs_{29.3}$ with an mg# of 52.8. Discrete augite grains of this composition are also present. These pyroxenes are similar in Fe/Mg to those in ferroan cumulate eucrite Y-791195, and in some mafic clasts from polymict eucrite Petersburg (Fig. 2). Three magnesian low-Ca pyroxene grains have an average composition of $Wo_{2.5}En_{72.8}Fs_{24.7}$ with an mg# of 74.7; within the range observed for diogenite orthopyroxenes (Fig. 2). Few pyroxenes have compositions between these magnesian grains and the majority pyroxenes, and some of them do not contain coarse exsolution lamellae. Pyroxenes from the 2 mm clast have an average mg# of 54.2. One ferroan augite grain was found in the host breccia, with a composition similar to pyroxenes in the ferroan clast. No pyroxenes similar in composition to those of noncumulate eucrites (e.g. Sioux County) were found. Rims of the magnesian and ferroan pyroxene grains have compositions approaching those of the majority of pyroxenes (Fig. 2). Relict pyroxene grains in the largest impact melt clast are identical to the majority of pyroxenes in the host breccia (Fig. 2). Plagioclase mineral fragments show a limited range of compositions: $An_{87.9-92.1}Ab_{7.8-11.8}Or_{0.2-0.3}$. Plagioclase grains from the 2 mm clast fall within this range.

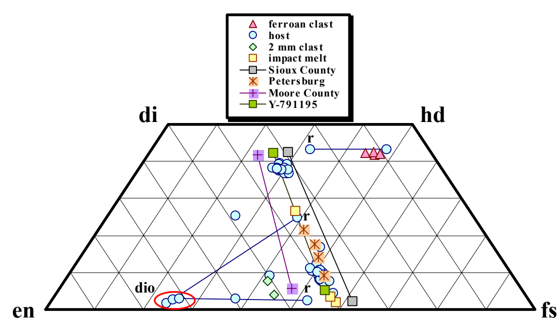


Fig. 2. Pyroxene compositions for NWA 1401 compared to select eucrites and a field for diogenites (dio). Rims (r) of magnesian and ferroan host breccia grains (joined by tie-lines) approach the Fe/Mg of the majority of pyroxenes. Eucrite and diogenite data from [1-4] and Mittlefehldt, unpublished.

**Ferroan Clast:** Approximately 20% of the thin section is a single igneous clast ~8.4 x 5.6 mm in size, terminated by the fusion-crusted edge of the section. It is composed of ~70% tabular, euhedral to subhedral plagioclase grains up to 2 mm in length and ~30% ferroan augite forming a framework partially to completely enclosing the plagioclase grains (Fig. 3). Fine-grained accessory phases include a silica polymorph, chromite, ilmenite, troilite and metal. The plagioclase grains are heterogeneously distributed. On one side, numerous plagioclase grains are in contact and only minor ferroan augite is present. On the other, the plagioclase texture is more open, with individual grains surrounded by ferroan augite (Fig. 3). Much, possibly all, of the ferroan augite is in optical continuity, and thus is a single, ~cm-sized poikilitic grain enclosing numerous plagioclase euhedra-subhedra. This texture is identical to that of heteradcumulates of layered mafic intrusions [5].

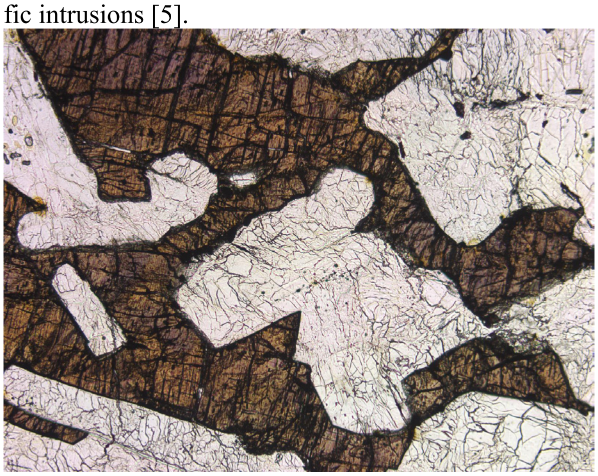

Fig. 3. Ferroan clast composed of mostly euhedral-subhedral plagioclase (white) enclosed in ferroan augite (brown). All of the pyroxene is part of a single grain. Field of view is 2.3 x 1.7 mm.

The pyroxene framework in the clast is homogeneous in composition, averaging $Wo_{42.2}En_{11.9}Fs_{45.9}$ with an mg# of 20.7 (Fig. 2). The ferroan augite contains no exsolution lamellae resolvable with the electron microprobe. Plagioclase grains in the clast are more alkalic, and show a limited range in compositions: $An_{83.2-86.2}Ab_{13.4-16.2}Or_{0.4-0.6}$. There is no overlap in the compositional ranges of host and clast plagioclase grains.

**Discussion:** NWA 1401 is a polymict breccia, containing materials from at least four, and probably more, distinct parent lithologies. The discussion here presumes that the thin section studied is representative of the stone. Diogenitic orthopyroxenes are rare; we estimate that they comprise <0.5% of the section. This is too small an amount to allow classification as a howardite. The majority of pyroxenes are intermediate in composition between those of basaltic eucrites and typical cumulate eucrites. Similar pyroxene compositions are present in mafic clasts in the polymict eucrite Petersburg [1, 6], and in the ferroan cumulate eucrite Y-791195 [4]. The mafic clasts from Petersburg are melt compositions [1, 6], thus two distinct modes of origin are possible for the NWA 1401 parent rock. The majority of pyroxenes in NWA 1401 are coarsely exsolved similar to those in Y-791195 [7], but unlike the fine-exsolution lamellae in pyroxenes in Petersburg mafic clasts [6]. This suggests that the parent rock for the majority of pyroxenes, and thus the bulk of the breccia, was a cumulate. Absent trace element data, we tentatively conclude that NWA 1401 is a polymict cumulate eucrite, rather than a polymict breccia of magnesian basalts. The change in compositions of pyroxene rims towards those of the majority pyroxenes, the rounding of angular fragments, and the sutured grain margins demonstrate that the breccia was mildly metamorphosed after assembly.

The ferroan clast is unusual, and possibly unique among known HED lithologies. The texture (Fig. 3) suggests that it was formed by heteradcumulus growth in the pore spaces of a plagioclase crystalline "mush." The iron-rich composition of the pyroxene (Fig. 2) shows that it crystallized from a very evolved melt, near the terminal stage of fractional crystallization of a mafic intrusion. Plagioclase floatation could plausibly occur in the dense, iron-rich magma, forming a porous crystalline plagioclase layer at the roof of a magma chamber. Heteradcumulus growth of additional plagioclase on the rims of the accumulated grains and ferroan augite in the pores forming large, poikilitic grains then occurred. Although some fine-grained mesostasis phases (silica, ilmenite, metal, troilite) are present, their modal abundance appears too low for such a ferroan rock. This suggests that the last dregs of melt were expelled from the rock, and didn't crystallize in place. However, this could also simply indicate cm-scale heterogeneity in this coarse-grained rock. We tentatively conclude that the ferroan clast represents a unique heteradcumulus ferroan HED lithology.

**References:** [1] Mittlefehldt D. W. (1979) *GCA, 43,* 1917. [2] Mittlefehldt D. W. (1990) *GCA, 54,* 1165. [3] Mittlefehldt D. W. (1994) *GCA 58,* 1537. [4] Mittlefehldt D. W. and Lindstrom M. M. (1993) *Proc. NIPR Symp. Ant. Met. 6,* 268. [5] Wager L. R. and Brown G. M. (1967) *Layered Igneous Rocks,* W.H. Freeman, 588 pp. [6] Buchanan P. C. and Reid A.M. (1996) *GCA, 60,* 135. [7] Takeda H. (1991) *GCA 55,* 35.