A CV CHONDRITE CLAST IN A CK CHONDRITE?

T.L. Dunn[1], K.N. Robak[1], and J. Gross[2,3,4,5] [1]Department of Geology, Colby College, Waterville, ME 04901 (tldunn@colby.edu). [2]Department of Earth and Planetary Sciences, Rutgers University, Piscataway, NJ 08854. [3]Department of Earth and Planetary Sciences, American Museum of Natural History, New York, NY 10024. [4]ARES, NASA Johnson Space Center, Houston (JSC) TX 77058. [5]Lunar and Planetary Institute, Houston TX 77058 .

Introduction: The physical evolution of asteroids is driven by multiple episodes of collisional processes, such as excavation of materials, mixing, and reaccretion [e.g., 1]. Brecciated meteorites and meteorites containing xenolithic clasts provide evidence of these dynamic impact-dominated parent body histories. Though the number of meteorites containing foreign clasts is not well constrained, brecciation is common among many groups of meteorites (e.g., CI, CM, and CV carbonaceous chondrites, aubrites, mesosiderites, and HEDs) [1]. In fact, a recent study by [2] suggests that 27% of ordinary chondrites - the largest group of meteorites - are breccias.

Recently, we purchased a 4 g slice of Northwest Africa (NWA) 11241, which was initially classified as a CV chondrite. This sample contains an ~8 x 5 mm chondritic clast (Fig. 1). The boundary between the clast and the host meteorite is very sharp, and the clast is texturally distinct from the host, suggesting that the clast and the host meteorite represent material from two parent asteroids.

Here, we characterize the texture and mineralogy of the chondritic clast in order to determine its parent body. We also reexamine the initial classification of NWA 11241, as it is petrographically similar to the CK chondrites.

Fig 1. Slice of NWA 11241 showing the angular clast.

Host Meteorite: In its initial classification, NWA 11241 was described as consisting of "granular chondrites, some relatively coarse-grained (600±300 um), plus fine-grained elongate amoeboid CAIs in a fine grained matrix" [3]. The sample is described as having a shock stage of S2 and a low weathering grade [3]. NWA 11241 was classified as a CV chondrite based on its petrography and the compositions of olivine ($Fa_{0.4-39}$, N=3), orthopyroxene ($Fs_{0.7-1.0}Wo_{0.9-1.1}$, N=2), and diopside ($Fs_{0.5-9.5}Wo_{45-50}$, N=3) [3].

However, we suggest that NWA 11241 has been misclassified as a CV chondrite and is instead an unequilibrated (type 3) CK chondrite. The CV and CK3 chondrites are often misclassified due to their similar mineral chemistries [e.g., 4,5]. Though olivine in equilibrated CK (type 4-6) chondrites is homogeneous, with compositions near ~Fa_{31} [6], chondrule olivine in CK3 chondrites is zoned, with FeO-poor cores and FeO-rich borders [e.g., 7]. For example, in DaG 431, chondrule olivine ranges from $Fa_{0.57}$ to $Fa_{33.4}$ [7]. These compositions are consistent with the initial analyses of olivine in NWA 11241. Pyroxene also cannot provide an unambiguous classification, as CV and CK3 chondrites contain similar compositions of low- and high-Ca pyroxene [8]. Though compositions of magnetite can be used to distinguish between the two groups [9], magnetite was not analyzed in the initial classification of NWA 11241.

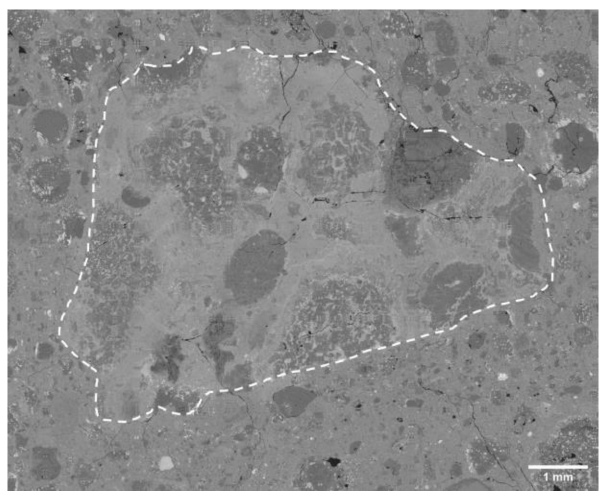

Fig. 2. Back-scattered electron (BSE) image illustrating the petrography of the clast and the host. Chondrules in the clast are larger than those in the host, and the clast has a higher chondrule/matrix ratio.

Although the mineral chemistry of NWA 11241 does not provide an unequivocal classification, petrographic differences between the two groups can aid in their identification. The most prominent textural difference between the CV and CK chondrites is the abundance of chondrite components. CK chondrites have higher abundances of matrix material and fewer CAIs than CV chondrites [e.g., 5,10,11]. Mean chondrule diameters are also slightly smaller in the CK chondrites, though there is significant overlap in the range of sizes [7,10,11]. BSE imaging of the thin section (Fig. 2) illustrates that that the host sample consists of a high volume of matrix (~70%) and relatively small chondrules (0.5-0.9 mm). Visual inspection of the full slice (Fig. 1) also reveals a low abundance of CAIs. These characteristics are consistent with the CK chondrites (Fig. 2). Though we will need to obtain additional chemical analyses to confirm this classification, the petrography of NWA 11241 is consistent with the CK chondrites.

Clast Description: The chondritic clast, which has a surface area of 44 mm^2, consists of mm-sized chondrules (mostly porphyritic olivine (PO) & porphyritic olivine pyroxene (POP)) and refractory inclusions surrounded by a fine-grained matrix that is brown in transmitted light. Chondrules comprise ~55% of the clast. The chondrules are relatively large, ranging in size from 1.2 mm to 3 mm, with an average size of 1.8 mm. The largest inclusion (1.7 mm) is a coarse-grained CAI, possibly a forsterite-bearing type B (Fig. 3) [13]. The two smaller inclusions (~1 mm) are elongated, fine-grained spinel-rich inclusions. Extensive fracturing is present throughout the clast, and this fracturing continues into the host meteorite. Chondrules along the boundary of the clast and host meteorite are broken, indicating that the clast is fragmental.

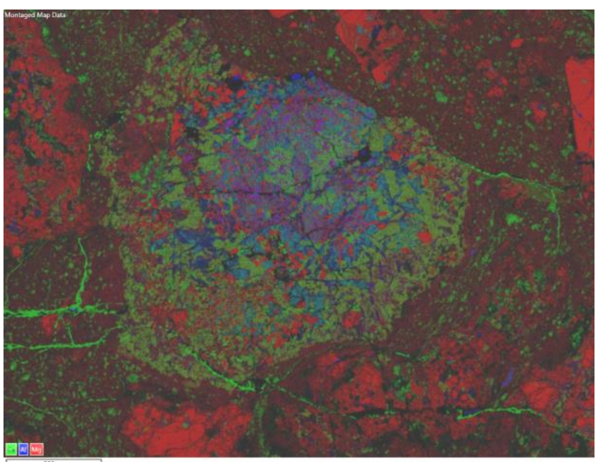

Fig 3. RGB (Mg, Ca, Al) image of the largest refractory inclusion. The presence of olivine (red) in addition to spinel, pyroxene, and anorthite or hibbonite suggest that this is a forsterite-bearing type B CAI.

All chondrules are Type 1, low-FeO chondrules with olivine compositions ranging from $Fa_{0.5-3.7}$. Both enstatite ($En_{97.4}Wo_{0.9}$) and diopside ($Fs_{2.0}Wo_{36.3}$) are present in the POP chondrules. Some chondrules contain sulfides and oxides, and one chondrule has a sulfide rim. All sulfides analyzed are Ni-rich (17-21 wt%), but they do not contain enough Ni to be pentlandite ($(Fe,Ni)_9S_8$). All oxides analyzed are Cr-bearing magnetite (0.7-1.6 wt% Cr_2O_3). We did not analyze individual matrix phases, but the average bulk composition of the matrix (in wt%) is: SiO_2 = 30.6, MgO = 15.5, Na_2O = 0.14, Al_2O_3 = 2.8, P_2O_5 = 0.24, CaO = 3.9, TiO_2 = 0.05, K_2O = 0.11, MnO = 0.17, FeO = 37.8, and Cr_2O_3 = 0.29.

Clast Provenance: The large PO and POP chondrules, chondrule/matrix ratio, and presence of CAIs within the clast are consistent with the CV chondrites. The presence of FeO-poor chondrule olivine, Ni-rich sulfides, and Cr-bearing magnetite confirms this classification. The CV chondrites are subdivided into oxidized and reduced subgroups based on oxidation state [12]. The Ni content of sulfides in the clast indicates that it belongs to the oxidized subgroup [11].

Parent Body Evolution: The fragmented nature of the CV_{ox} clast indicates that it was either derived from (1) a different asteroid or (2) another location on the host asteroid. If the host rock is a CK chondrite, then this sample illustrates mixing of CV and CK chondrite material. Though this supports the assertion that the CV and CK chondrites originated from the same region of the solar nebula [14], it does not provide any insight into whether both groups are derived from the same parent asteroid.

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