CALCIC PLAGIOCLASE-RICH CLASTS RESEMBLING THE NWA 7325 UNGROUPED ACHONDRITE IN POLYMICT UREILITES.
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Introduction: Ureilites are the second largest group of achondritic meteorites. They are dominated by olivine and pyroxene, with other minor phases, like graphite, metals, and sulfides [1,2]. Polymict ureilites are breccias representing regolith from the ureilite parent body [3,4]. They contain fragments of other meteorite types, as well as clasts of nearly pure plagioclase. Previous studies argued that these plagioclase-rich clasts represent two, distinct ureilitic melt lithologies: the "albitic" lithology, with plagioclase of An_{0-32} (molar Ca/(Ca+Na+K)*100 = 0-32), and the "labradoritic" lithology, with An_{33-69} plagioclase [3]. In this study, we discuss the origin of Ca-plagioclase clasts (An_{70-100}) in two polymict ureilites, Dar al Gani (DaG) 999 and Northwest Africa (NWA) 10657, and compare these clasts with the plagioclase (and other minerals) in NWA 7325, a unique, ungrouped achondrite that also contains Ca-plagioclase (An~90) [5,6,7,8]. Our goal is to determine the origin(s) of these clasts.

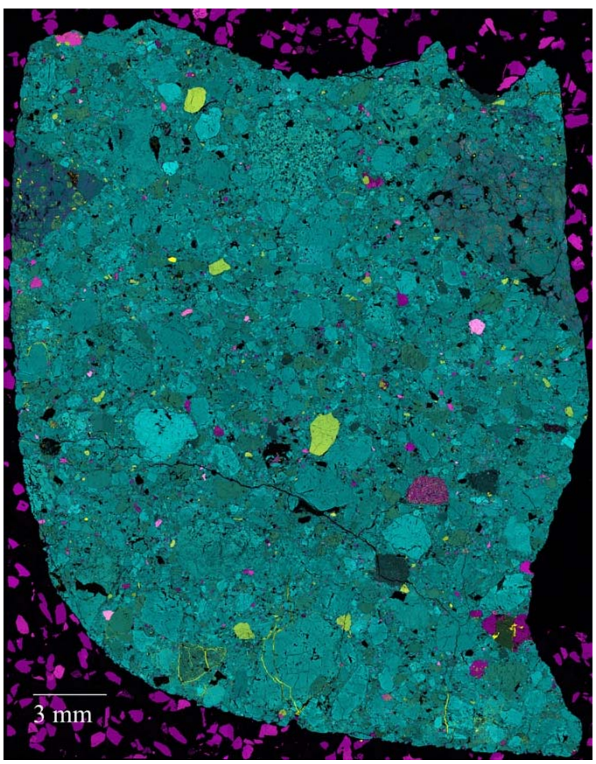

Figure 1. *X-ray map of NWA 10657_004: cyan (Mg), magenta (Al), and yellow (Ca). Most fragments are ureilitic olivine (cyan), with two chondritic clasts in the top half on either side, high-Ca pyroxenes (lime), and small plagioclase grains (various pinks). Ca-plagioclase grains are pale pink.*

Method: The JEOL 7600F field emission scanning electron microscope, at Johnson Space Center (JSC), was used to obtain X-ray maps (Fig. 1) at 15 keV and 30 nA. The JEOL 8530F field emission electron microprobe, also at JSC, provided quantitative mineral compositions. A complete survey of plagioclase clasts larger than 90 μm was conducted on section DaG 999 (51 clasts) and NWA 10657_004 (82 clasts). Four plagioclase clasts were analyzed in NWA 10657_MZ and one in NWA 10657_003. Initial surveys were run at 15 keV and 10 nA and 20s on peak and background. For higher precision analysis of FeO and MgO, the Ca-plagioclase clasts were reanalyzed using 15 keV, 25 nA, and longer count times (80 s).

Oxygen 3-isotope ratios of five Ca-plagioclase clasts (three from NWA 10657_MZ and two from DaG 999) were analyzed using secondary ion mass spectrometry on the CAMECA IMS-1280 at the University of Wisconsin with a 15 μm spot size and precisions of 0.3‰ (2σ). Several spots were analyzed per clast. These analyzed clasts have plagioclase with An and FeO contents similar to NWA 7325 (Fig. 2). In one clast (DaG 999 clast 16) olivine was analyzed as well as plagioclase.

Results: *General petrography.* The thin section NWA 10657_004 represents a typical polymict ureilite [9]. The sample contains 1% feldspathic material (excluding chondritic clasts). Four out of 36 Ca-plagioclase clasts studied contain primary mafic mineral grains. The remaining clasts consist of only plagioclase. In previous work, the "albitic" lithology represented 66% of the plagioclase clasts and Ca-plagioclase clasts represented 8% [3]. This study found a significantly larger proportion of Ca-plagioclase clasts; only 44% of the "albitic" lithology and 32% of Ca-plagioclase lithology.

Plagioclase composition. The FeO contents of the Ca-plagioclase in these clasts ranges from 0.1-0.9 wt% (Fig. 2). Four of these clasts have An and FeO of plagioclase similar to plagioclase in NWA 7325 [5,7,8]. Two have An and FeO within the range reported for angrites [10]. Average MgO content in the Ca-plagioclase clasts ranges from 0.03-0.35 wt%. Most clasts have MgO in plagioclase similar to plagioclase in NWA 7325, as measured by [7], though [5] reports significantly higher values for MgO. Higher An slightly correlates with lower MgO wt%, tending toward angritic composition.

Mafics. Four clasts contain primary mafic minerals in addition to Ca-plagioclase: clast 16 in DaG 999 and clasts 17, 53, and 81 in NWA 10657_004 (Fig. 3). Two of these (clasts 53 and 16), as well as four others in polymict ureilites [7], have a combination of mg# (molar (MgO)/(MgO+FeO)*100) in mafics and An in plagioclase similar to those of NWA 7325 (Fig. 3). The Wo contents of pyroxene in clasts 53 and 16 also match that of NWA 7325. Clast 17 has slightly lower An and mg# than NWA 7325. Clast 81 has mg# similar to NWA 7325, but lower An than in NWA 7325.

Oxygen isotopes. The oxygen isotope ratios of plagioclase in the five analyzed clasts are consistent with those of plagioclase in NWA 7325 [7,8]. These data are along the CCAM line on a 3-oxygen isotope plot with $\Delta^{17}O$ values of −0.98±0.24‰ (2SD) and in the upper range of bulk ureilite data.

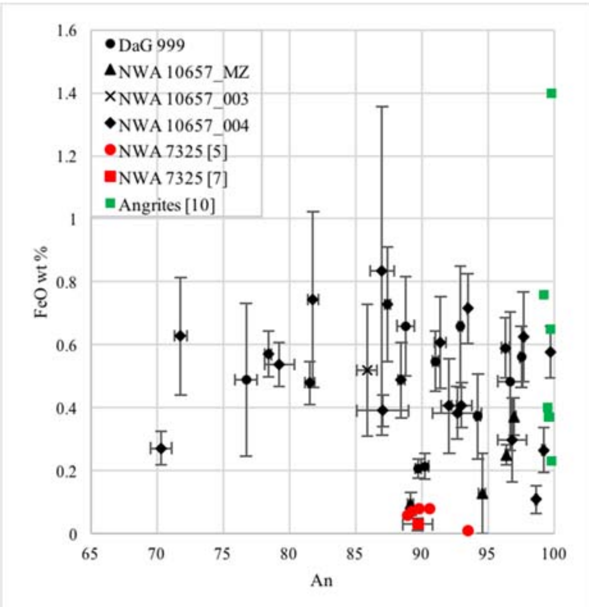

Figure 2. *Average FeO wt% versus average An content in Ca-plagioclase clasts. Analyses here are black, NWA 7325 data is red [5,7], and angrite data is green [10].*

Discussion: This study shows that Ca-plagioclase clasts form a significant population in some polymict ureilites. Data from the 36 clasts studied indicates that there are no overall trends of varying FeO or MgO with An in plagioclase, suggesting multiple clast origins. Some of the most calcic clasts have mineral compositions similar to angrites, which are known as xenoliths in polymict ureilites [13,14]. Oxygen isotope compositions of our analyzed clasts are not like angrites [16] but are consistent with NWA 7325 [7]. Though the clasts plot in the upper range of ureilites, arguments made by [7,12,15] suggest that they are foreign and not derived from the ureilite parent body.

NWA 7325 consists of Ca-plagioclase (An~90), Mg-olivine (Fo~98), and Ca-Mg-pyroxene (mg#~98, Wo~45), which does not match any known meteorite (Fig. 3) [5,6,7,8]. However, [7] noted its similarity to

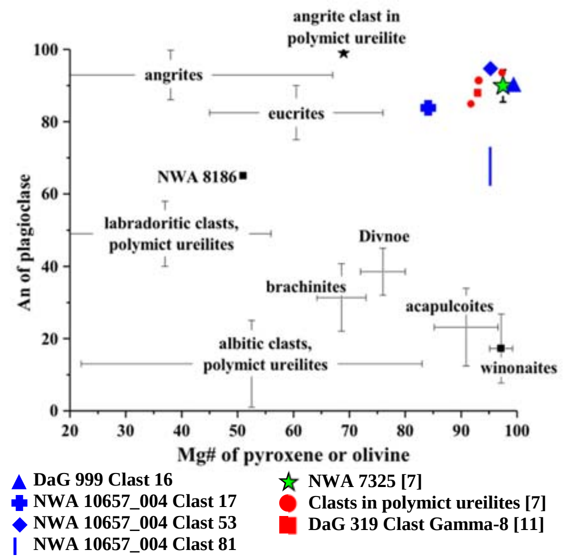

Figure 3. *Plot of An of plagioclase verses Mg# of pyroxene or olivine compared with various achondrites. NWA 7325 data from [7] and angrite in a polymict ureilite from [14].*

some rare clasts in polymict ureilites. The plagioclase in NWA 7325 shows distinctive remelting textures, with complex assemblages of recrystallized phases. Eleven of the Ca-plagioclase clasts in this study show textures similar to those in NWA 7325 plagioclase, yet only one has An and FeO contents identical to NWA 7325. Possible conclusions are: 1) most of the Ca-plagioclase clasts in polymict ureilites are not related to NWA 7325; 2) some of the Ca-plagioclase clasts in polymict ureilites are pieces of NWA 7325-like asteroids and are more varied than NWA 7325 itself; and/or 3) FeO and MgO in plagioclase were redistributed during remelting in a way that is not yet understood.

Nonetheless, NWA 7325 and the Ca-plagioclase clasts in polymict ureilites are unique compared with other known meteorite types (Fig. 3) and may represent pieces from a previously unrecognized parent body. Future work on these clasts will include trace element analysis and petrologic modeling.

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