A NEW TYPE OF FOREIGN CLAST IN A POLYMICT UREILITE: A CAI OR AL-RICH CHONDRULE.

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Introduction: Polymict ureilites are breccias interpreted to represent regolith formed on a ureilitic asteroid [1-3]. They consist of ~90-95% clasts of various ureilite types (olivine-pyroxene rocks with Fo 75-95), a few % indigenous feldspathic clasts, and a few % foreign clasts [4-20]. The foreign clasts are diverse, including fragments of H, L, LL and R chondrites, angrites, other achondrites, and dark clasts similar to CC [6,7,9-19]. We report a new type of foreign clast in polymict ureilite DaG 999.

Methods: Clast 8 in Dar al Gani (DaG) 999/1 (Museum für Naturkunde) was discovered during a survey of feldspathic clasts in polymict ureilites [19,20]. It was studied by BEI, EMPA, and X-ray mapping on the JEOL 8530F electron microprobe at ARES, JSC.

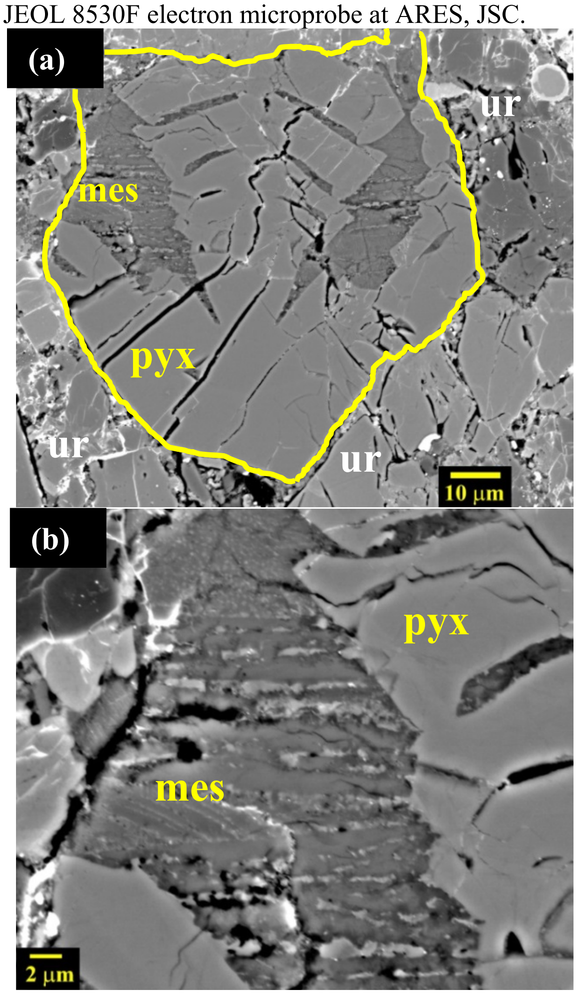

Fig. 1. BEI of clast 8 in DaG 999/1. (a) View of whole clast, in matrix of fragmented ureilitic material (ur). Clast contains pyroxene (pyx) and mesostasis (mes). (b) Higher magnification image showing fine pyroxene in mesostasis.

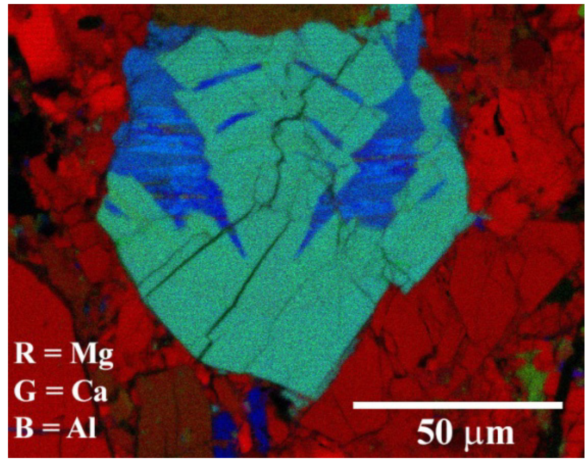

Fig. 2. Combined Mg-Ca-Al X ray map of clast 8.

Petrography and Mineral Compositions: Clast 8 is sub-rounded to irregular in shape, ~85 µm in diameter, and consists of ~68% pyroxene and 32% mesostasis (by area). Part of the pyroxene (top half of clast in Fig. 1a and 2) shows a coarse dendritic morphology; the rest appears massive. Mesostasis may be glassy and contains fine needles/grains of pyroxene. The pyroxene has very high CaO (23.5 wt.%) and Al_2O_3 (19.7 wt.%), with the formula:

$$(Ca_{0.91}Mg_{0.63}Fe_{0.01}Al^{VI}_{0.38}Cr_{0.01}Ti_{0.05})_{1.99}Si_2O_6.$$

The bulk mesostasis also has very high Al_2O_3 (~26 wt.%). A bulk composition for the clast was obtained by combining modal abundances with phase compositions (Table 1, Fig. 3).

Table 1.	pyroxene		mesostasis (broad beam)		bulk
	avg (7)	*stdev*	avg (5)	*stdev*	comp
SiO_2	42.8	*0.6*	48.4	*2.2*	44.6
TiO_2	1.8	*0.2*	0.81	*0.19*	1.5
Al_2O_3	19.7	*0.7*	26.1	*2.6*	21.8
Cr_2O_3	0.38	*0.05*	0.02	*0.02*	0.3
FeO	0.42	*0.24*	2.0	*0.6*	0.9
MgO	11.8	*0.6*	5.5	*1.8*	9.8
MnO	0.02	*0.01*	0.02	*0.01*	0.02
CaO	23.5	*0.4*	13.3	*1.9*	20.2
Na_2O	bdl		0.5	*0.3*	0.2
K_2O	bdl		3.8	*1.2*	1.2
Total	100.4	*0.2*	100.3	*1.8*	100.5
Mg#	98.0	*1.2*			
Wo	58.5	*1.4*			

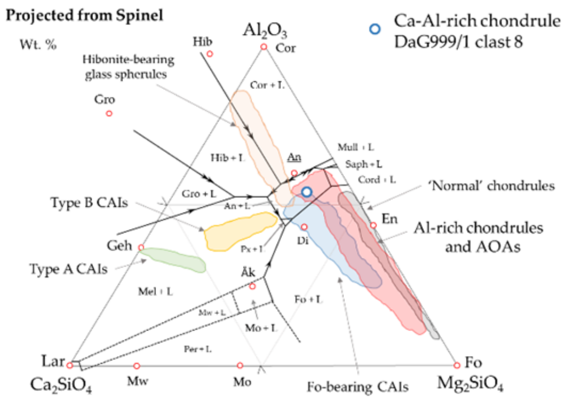

Fig. 3. Composition of clast 8, projected from spinel onto the ternary Mg_2SiO_4-Ca_2SiO_4-Al_2O_3 [21]. Clast 8 lies in the primary phase field of anorthite + spinel + liquid (all primary phase fields on this diagram are spinel saturated). Clast 8 has no spinel in the exposed section (Figs. 1,2). Thus this diagram cannot be used to predict its crystallization sequence, but is useful for showing compositional relationships among cosmochemical objects (e.g., CAIs and chondrules) for comparison with clast 8.

Discussion: The pyroxene in clast 8 has a Ca-Al-(Ti)-rich (fassaitic) composition that is clearly distinct from compositions of pyroxenes in main group ureilites [22] or indigenous feldspathic clasts in polymict ureilites [4-8]. It also has significantly higher Al than fassaite in angrites (up to ~12 wt.% [23]), which occur as xenoliths in polymict ureilites. Ca-Al-Ti rich pyroxenes are most commonly found in CAIs, Al-rich chondrules and other types of refractory inclusions in chondrites [21,24-31]. However, the clast 8 pyroxene matches only the most Al-Ca-rich of these, e.g., pyroxenes in type B CAIs in CV3 chondrites [25,30,31], a pyroxene-hibonite spherule and a pyroxene-anorthite-spinel fragment from unique CC Acfer 094 [29], and one Al-rich chondrule from Chainpur (LL3.4) [21].

The mineralogy of clast 8 is not consistent with the mineral assemblages of any of these objects (since it lacks hibonite, spinel and/or anorthite), which suggests that it is unrepresentatively sectioned or is a fragment of a more mineralogically diverse object. Its bulk composition (Table 1; Fig. 3) is similar to bulk compositions of some Al-rich chondrules, as well as those of Type C CAIs (which plot in the sp+An+L field in Fig. 3), although it is enriched in silica relative to type C CAIs [e.g., 31]. This suggests a more likely affinity to Al-rich chondrules, although most Al-rich chondrules have less Al-Ca-rich pyroxene [21,26,27]. These bulk compositional comparisons may not be definitive, however, if the clast is unrepresentatively sampled.

One of eleven Al-rich chondrules from UOCs described by [21] has textural and compositional characteristics that make it a possible progenitor type for clast 8. This chondrule (Chainpur 1251-14-2) is anorthite-porphyritic, with an interstitial dendritic intergrowth of pyroxene (similar in composition to that in clast 8) and plagioclase [21]. Clast 8 is conceivably a fragment from the interstitial area of such an object. The occurrence of glassy mesostasis (in clast 8) rather than plagioclase may not be a significant difference; it could result from a difference only in cooling rate. Al-rich chondrules with glassy mesostasis are rare, and known occurrences are Ca-poor [26], unlike clast 8.

Polymict ureilites are known to contain xenoliths of various chondrites (including OC, R and CC) as well as individual ferromagnesian and silica-pyroxene chondrules probably derived from OC or RC [6,9,15,16,18]. This is the first report of an individual chondritic refractory inclusion as a xenolith in a polymict ureilite. An RC-like sample from anomalous polymict ureilite Almahata Sitta contains CAIs, but they are spinel-rich and not similar to clast 8 [13,14]. Further studies of this clast (which, unfortunately, may not be possible), or the discovery of additional (more representative?) materials of this type would be needed to determine the exact nature of this xenolith and the type of chondrite from which it is derived.

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