ALLENDE 10 B 41: MEGACHONDRULE, OR IMPACT MELT CLAST? E. S. Bullock[1], N. G. Lunning[2] and T. J. McCoy[1], [1]Department of Mineral Sciences, National Museum of Natural History, Smithsonian Institution, Washington, DC, USA. Email: BullockE@si.edu. [2]Department of Earth and Planetary Sciences, University of Tennessee, Knoxville, TN 37996.

Introduction: A recent examination of a slice of the Allende CV3 carbonaceous chondrite has revealed a large, rounded object, ~1.6cm in diameter. Initial examination of this object shows similarities to a class of objects previously found in ordinary and carbonaceous chondrites known as a "mega-chondrule" [e.g. 1-3]; however further examination also reveals several differences compared to typical chondrules. In this work, we explore the possibility that this object, designated "Allende 10 B 41", instead represents an impact melt clast within a CV3 chondrite.

Method: Bulk compositional data and high-resolution back-scattered electron images were obtained using the FEI NOVA NanoSEM 600 scanning electron microscope (SEM) at the Smithsonian Institution, operated at 15kV with a sample current of 2-3 nA and a Thermo-Noran energy dispersive X-ray analytical system. Quantitative chemical data for major elements was obtained using the Jeol 8900 Superprobe at the Smithsonian, operating at 15kV and 20nA, using Probe for EPMA software.

Results: The exact dimensions of the whole object are not known, but it is ~1.6cm in maximum diameter on the cut surface (figure 1).

Allende 10 B 41 has a porphyritic texture, and consists primarily of coarse-grained olivine in a glassy mesostasis, associated with grains of pyroxene and plagioclase (figure 2). Zoning within olivine grains can clearly be seen in both back-scatter electron images and in false-colour element maps (figure 2,3). Electron probe traverses across olivine grains show normal zoning from Fo_{63-88}. There is no difference in the range of composition between grains in the core of the object and those towards the outer edges. Pyroxene grains, up to ~200 µm, are also present – these have a composition consistent with augite. Small grains of chromite (~50 µm) are found throughout the object. Fractures within the olivine grains are filled with an opaque material – this appears to be either Fe metal or magnetite, although the fine size of these materials make it difficult to obtain reliable compositional data.

The bulk composition of 10 B 41 was determined through SEM analysis of the exposed surface of the object in thin section. The result is given in Table 1, and is consistent with the composition of bulk Allende [4], although richer in MgO and SiO_2. The ratios of Ca/Al and Mg/Si however are consistent with the ratios obtained for bulk Allende by [4], but not with typical chondrules.

One of the most interesting features of 10 B 41 is the presence of multiple normally-zoned olivines that have broken faces directly in contact with the matrix (figure 3), indicating that this was once a larger object.

Discussion: Allende 10 B 41 initially appeared to be a "megachondrule", based on its rounded shape and internal texture. The porphyritic texture suggests that this object crystallized from a melt; the coarse grain size implies that it either cooled slowly, or there was a lack of nucleation sites. Zoning within individual olivine grains is smooth, also suggesting crystallization from a melt. Closer examination however reveals several important differences to chondrules. Unlike "typical" chondrules in a CV3 chondrite, 10 B 41 does not have a fine-grained rim enclosing it. The presence of normally-zoned olivine crystals at the edge of the object that appear to have been broken suggest that this is a fragment of a once-larger object (figure 3).

We suggest that 10 B 41 could have formed by impact melting of CV3 chondritic material. The bulk composition of this object is similar to that of 'bulk' Allende (Table 1). In addition, the ratio of Mg/Si in the bulk inclusion is consistent with melt formed from bulk CV3 material, and is clearly different from that of "typical" chondrules (Table 1; data from [4]). Localized melting of Allende matrix has been shown to produce textures very similar to that seen in this object [5]. Future analysis of the oxygen and Al-Mg isotopic systematics will help to determine whether this is a megachondrule or an impact clast.

The shock classification system developed for ordinary chondrites can reasonably be applied to carbonaceous chondrites. By this scale, Allende has a shock grade S1 [6]. The shock pressure corresponding to S1 is well below that required for minimum melting; incipient melting corresponds to a shock grade of S4 and bulk rock melting requires pressures greater than those for S6 [7]. Although rare, Allende does contain some olivine grains that exhibit planar fractures, a shock feature [6, 8]. The impact event that formed these shock features may have occurred prior to accretion [8]. If this clast is an impact melt, it potentially could have formed prior to accretion, and undergone comminution before incorporation into the Allende parent body.

References: [1] Weisberg M.K. et al (1988) *Meteoritics* 23: 309-310 [2] Ruzicka A. et al (1998) *GCA* 62: 1419-1442 [3] Weyrauch M. & Bischoff A. (2012) *MaPS* 1-14**.** [4] Jarosewich E. (1990) *Meteoritics* 25: 323-337. [5] Caillet C. et al (1993) *GCA* 57: 4725-4743. [6] Scott et al. (1992) *GCA* 56, 4281-4293 [7] Bischoff, A. & Stoffler, D. (1992) *Eur. J. Mineral.* 4: 707-755. [8] Ashworth J.R. & Barber D.J.(1975) *EPSL* 27: 43-50.

Figure 1. Cut surface of Allende, showing inclusion Allende 10 B 41.

	Allende 10 B 41	Bulk Allende	Chond. "A"	Chond. "C"
Na_2O	1.12	0.45	0.11	10.6
MgO	28.46	24.62	10.82	15.17
Al_2O_3	4.34	3.27	31.61	17.78
SiO_2	40.24	34.23	29.79	40.19
Cl	0.12	-	-	-
K_2O	0.06	0.03	0	0.55
CaO	3.16	2.61	26.76	5.28
TiO_2	0.09	0.15	0.99	0.12
Cr_2O_3	0.39	0.52	0.06	0.19
MnO	0.16	0.18	0.02	0.1
FeO	22.66	27.15	0.37	8.77
Ca/Al	*0.98*	*1.1*	*1.14*	*0.4*
Mg/Si	*0.92*	*0.93*	*0.47*	*0.49*

Table 1. Bulk composition of 10B41 versus average bulk composition of Allende and typical Allende chondrules (wt% oxide) [4], ratios for Ca:Al & Mg:Si.

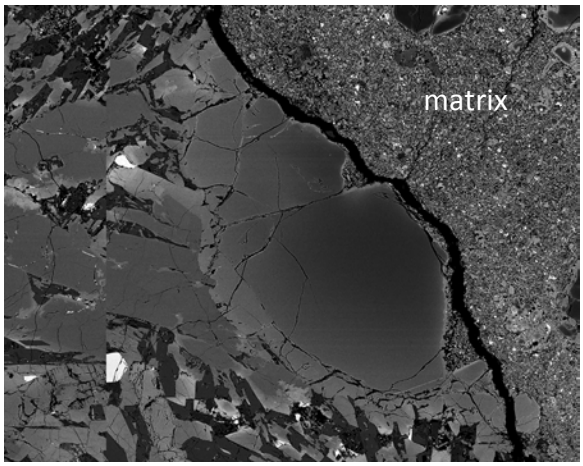

Figure 3. Olivine grain at the edge of 10 B 41. Field of view is 1mm.

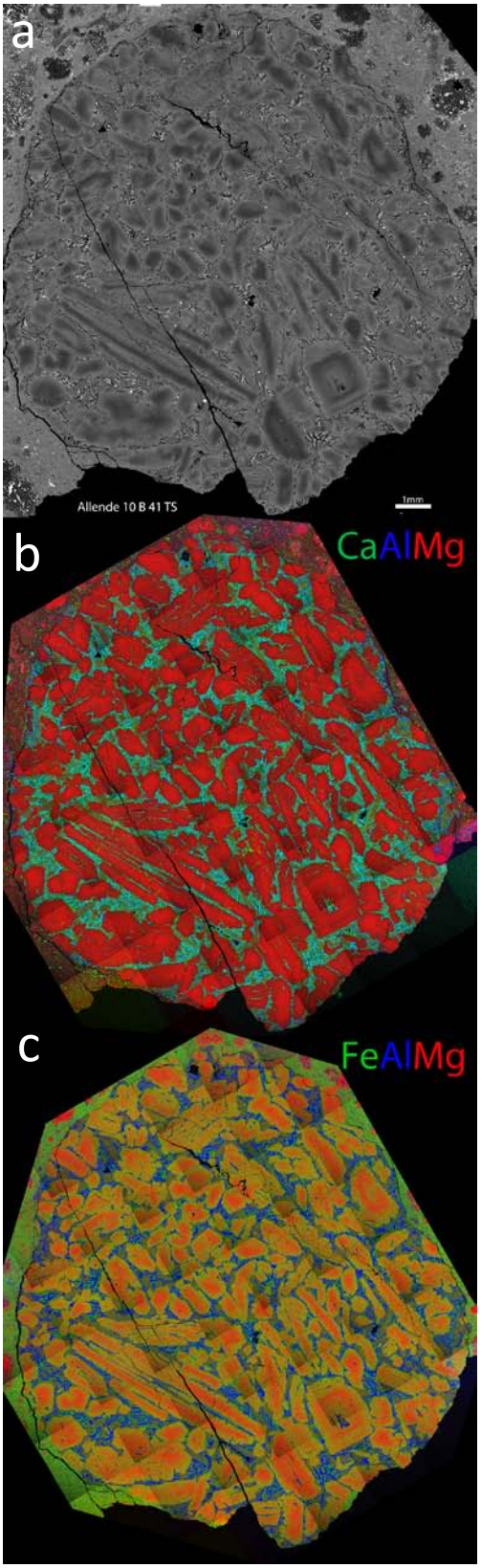

Figure 2. a) Back-scatter electron mosaic of Allende 10 B 41, with b) false-colour RGB X-ray maps of CaAlMg and c) FeAlMg. Scale bar is 1mm.