ALLENDE 10 B 41: MEGACHONDRULE, OR IMPACT MELT CLAST?

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Introduction

Recent examination of the Allende CV3 carbonaceous chondrite revealed a large, rounded object, ~1.6cm in diameter (figure 1), designated "Allende 10 B 41". Initial examination of this object shows similarities to objects found in other chondrites known as "mega-chondrules" [e.g. 1-3]; however there are several differences compared to typical chondrules. Here we explore the possibility that this object instead represents an impact melt clast within a CV3 chondrite.

Method

FEI NOVA NanoSEM 600 SEM: bulk compositional data & BSE images.
Jeol 8900 Superprobe: Quantitative chemical data for major elements.

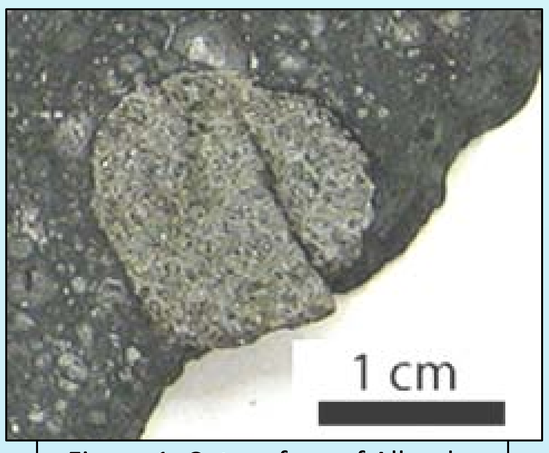

Figure 1. Cut surface of Allende, showing inclusion Allende 10 B 41

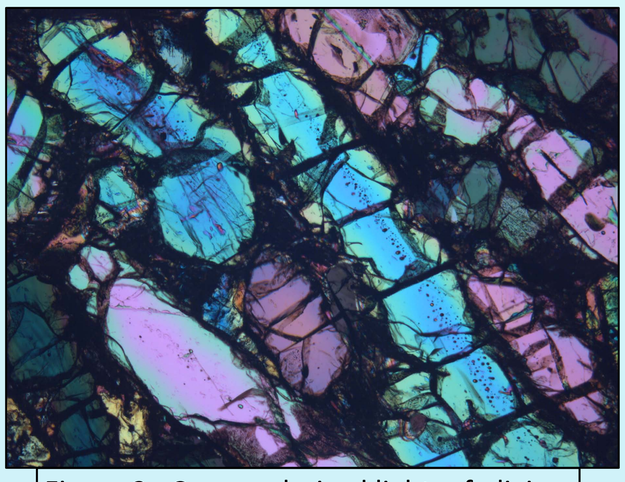

Figure 2 . Cross-polarized light of olivine

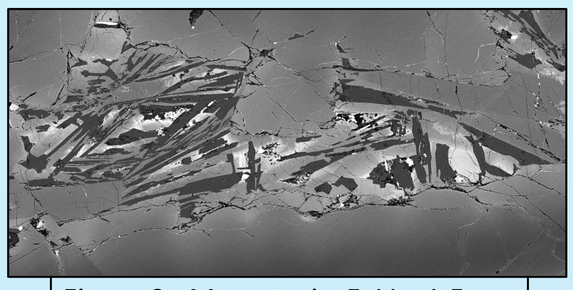

Figure 3 . Mesostasis. FoV = 1.5mm

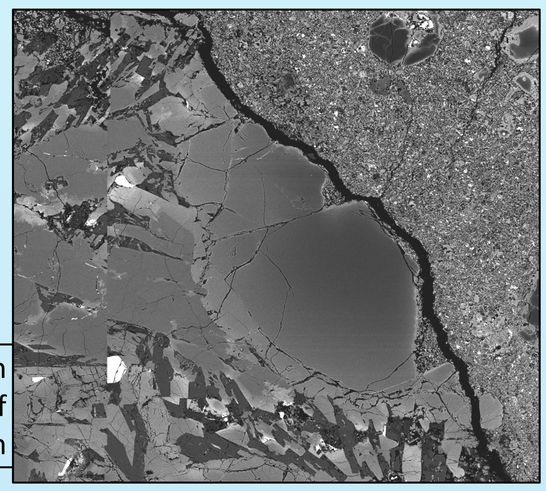

Figure 5. Broken olivine grain in direct contact with matrix of Allende. Field of view = 1mm

Results

Olivine: coarse-grained, normal zoning from Fo_{63-88}, same range in the core and towards the edge (figure 2, 5, 6).
Pyroxene: Coarse-grained, augite.
Chromite: Small (~50 µm)
Opaque material: Fe metal/ magnetite fills fractures within olivine (figure 6).
Bulk composition: see Table 1, consistent with bulk Allende [4]. Ratios of Ca/Al and Mg/Si consistent with bulk Allende [4], but not with typical chondrules.

	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.

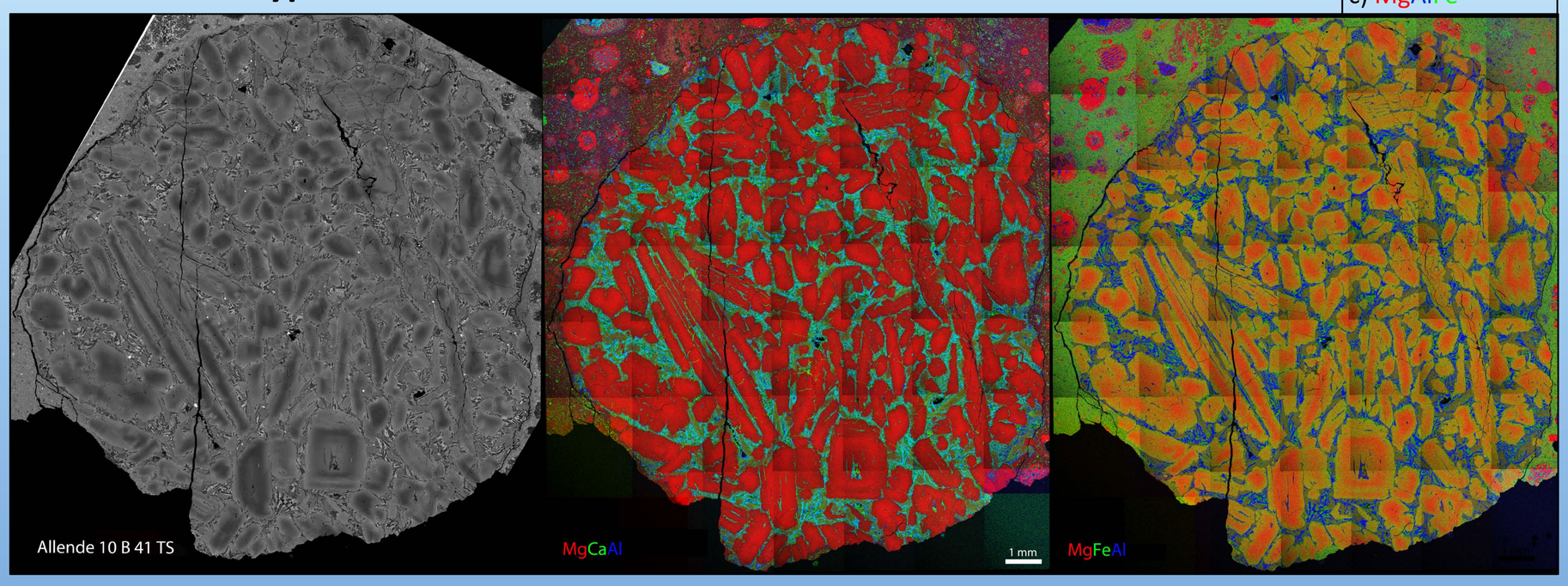

Figure 4. BSE image and false-color element maps of Allende 10 B 41. a) BSE; b)MgAlCa; c) MgAlFe

Discussion

Initially thought to be a "megachondrule" based on rounded shape and porphyritic texture, BUT some key differences:
- **Lack of fine-grained rim**
- **Bulk composition closer to bulk Allende than to typical chondrules (Table 1; data from [4]).**
- **Mg/Si ratio consistent with melt formed from bulk Allende**
- **Localized melting has been shown to produce very similar textures to those shown here [5].**

Was it molten?

Yes, based on porphyritic texture and smooth zoning profiles within olivine grains.
Coarse grain size suggests either slow cooling or a lack of nucleation sites.
Presence of normally zoned olivine crystals in direct contact with matrix suggests this was once a larger object that underwent comminution before incorporation into the parent body (figure 5).

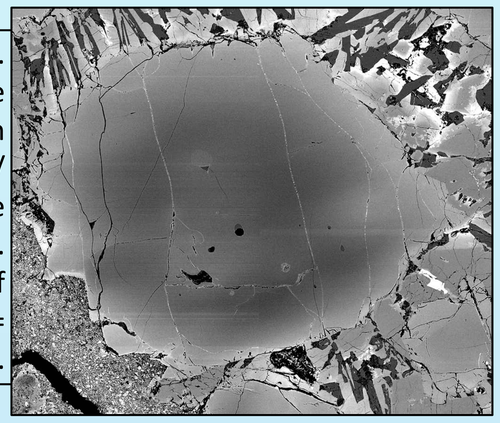

Figure 6. Olivine with metal/ magnetite stringers. Field of view = 1mm.

So: how did this clast form?

Possibly by shock. Although Allende has a shock grade S1, well below that required for minimum melting, it does contain some olivine grains that exhibit planar fractures, a shock feature [6, 8].
If this clast is an impact melt, it potentially could have formed prior to accretion, and undergone fragmentation and rounding before incorporation into the Allende parent body .

What next?

Future analysis of the oxygen and Al-Mg isotopic systematics will help to determine whether this is a megachondrule or an impact clast.

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.