A PRISTINE AMOEBOID OLIVINE AGGREGATE PROTOLITH FROM THE VIGARANO CV3 CHONDRITE E. S. Bullock[1] and G. J. MacPherson[1], [1]Department of Mineral Sciences, National Museum of Natural History, Smithsonian Institution, Washington, DC. 20560. Email: BullockE@si.edu or MacPhers@si.edu

Introduction: Amoeboid olivine aggregates (AOA) are irregularly shaped inclusions found within all carbonaceous chondrites except CI [1,2]. Their bulk compositions are intermediate between those of anorthite-rich (Type C) calcium-aluminium rich inclusions and chondrules [2], and consist mostly of fine-grained olivine plus enclosed refractory nodules of spinel, pyroxene, feldspathoids, Fe-Ni metal, and rarely melilite [1-5]. In heavily altered meteorites such as the oxidized CV3s, AOAs are themselves altered and some primary phases (esp. melilite) in the refractory nodules are partially to completely replaced by secondary phases [1]. AOAs in reduced CV3 chondrites such as Efremovka and Leoville are much less altered, but have experienced intense parent body compaction and shock [4]. Highly pristine AOAs have been found in the unique chondrite Acfer 094, but these are very small and melilite is extremely rare [6].

We recently discovered a new AOA in Vigarano, designated Vigarano 3137 F5 (Figure 1), that is approximately 0.5cm by 0.4cm and has experienced only minor secondary alteration. Most importantly, one of the enclosed refractory nodules contains abundant unaltered gehlentitic melilite that is amenable to Al-Mg isotopic studies (in planning). This inclusion may be the best example available of the protoliths of the AOAs observed in most CV3 chondrites.

Method: The inclusion was studied using an FEI Nova NanoSEM 600 scanning electron microscope, equipped with a Thermo Electron energy dispersive X-ray spectrometer. The SEM was operated at 15kV, with a beam current of 2-3 nA. Full-spectrum X-ray images were collected for the entire inclusion, allowing the bulk composition of the inclusion to be calculated by summing the spectra of all (~ 10^{10}) pixels in the image.

Results and Discussion: The olivine within Vigarano 3137 F5 is fine-grained (<50 µm) and magnesium-rich over a narrow composition range (Fo_{1-7}, average Fo_3; Fig. 2). Olivine grains in the interior of the inclusion show virtually no compositional zoning; those near the margins are slightly zoned and somewhat more iron-rich overall.

Spinel-rich nodules up to ~200 µm in size are abundant throughout Vigarano 3137 F5, invariably rimmed by aluminous diopside. Most spinel is near-end-member $MgAl_2O_4$, but some grains contain up to 9.5 wt% FeO. Many spinel grains enclose small (<3 µm) grains of Ti-rich fassite. Most of the anorthite in the refractory nodules has been altered to feldpsathoids, but sparse small grains are preserved near the outer margins of some nodules. Feldspathoids are mostly nepheline with lesser sodalite. Pyroxene in the refractory nodules is bimodal in composition (Fig. 3). Pyroxene rims around both the spinel-rich nodules and the melilite-rich spherule are primarily aluminous diopside (~0-2 wt% TiO_2) that become more titanium-rich near the contact with spinel. Pyroxene grains enclosed within spinel contain 6-23 wt%TiO_2 and 20-28 wt% Al_2O_3 and at least 30% of the Ti is estimated to be Ti^{3+}.

One large (~ 300 µm) refractory spherule is very melilite-rich (Figs. 4-5), and contains also spinel and timy perovskite grains. The melilite is virtually unaltered, and has an average composition of $Åk_9$ over the range $Åk_2$ to $Åk_{25}$ (Fig. 2).

The bulk composition of Vigarano 3137 F5 is within the range of AOA from other carbonaceous chondrites [4] (Figure 6). Its highly porous textures and refractory mineralogy testify to a highly primitive nature. Most exciting is the presence of unaltered and highly gehlenitic melilite. There have been very few Al-Mg isotopic studies of AOAs, some of which gave initial $^{26}Al/^{27}Al$ ratios close to the canonical value [7] of $5x10^{-5}$ and others much lower [8]. Vigarano 3137-F5 will allow additional constratins to be placed on the timing of formation of this important type of inclusion.

References: [1] Hashimoto A. & Grossman L. (1987) *Geochim. Cosmochim. Acta,* 51, 1685-1704 [2] Krot A. N. et al (2003) *Meteoritics & Planet. Sci 38 Ab# 5133.* [3] Petaev M. I. et al (2005) *Meteoritics & Planet. Sci., 40, Ab# 5247* [4] Komatsu M. et al (2001) *Meteoritics & Planet. Sci. 36, 629-641*. [5] Grossman L. & Steele I. M. (1976) *Geochim. Cosmochim. Acta, 40, 149-155.* [6] Krot A. N. et al (2004) *Geochim. Cosmochim. Acta,68, 2167-2184.* [7] Sugiura N. & Krot A. N. (2007) *Meteoritics & Planet. Sci.,42, 1183-1195.* [8] Itoh S. et al. (2002) *LPSC 33 Ab# 1490.*

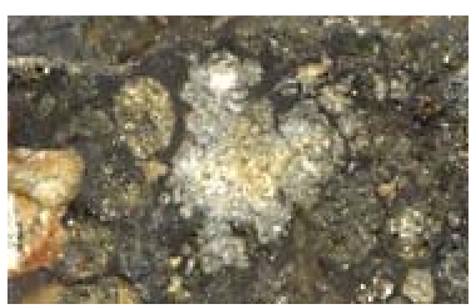

Figure 1. Ameoboid olivine aggregate Vigarano 3137 F5, before extraction and sectioning. The inclusion is ~ 4mm by 5mm.

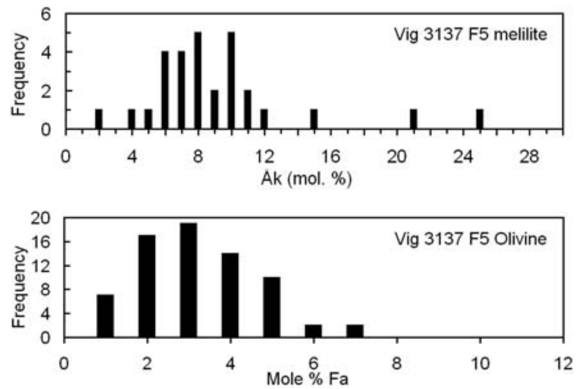

Figure 2. Histograms of melilite and olivine compositions.

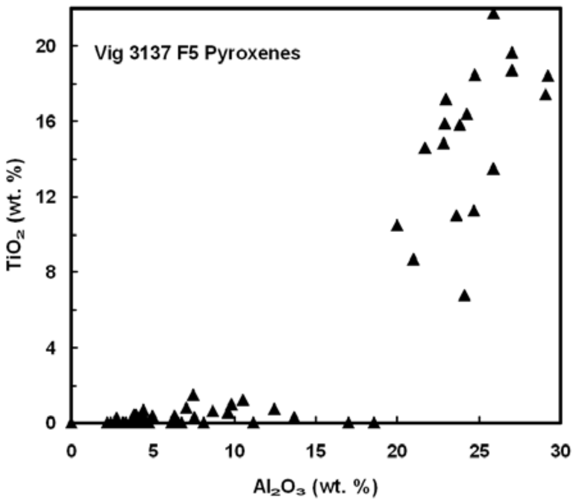

Figure 3. TiO_2 *vs.* Al_2O_3 in pyroxene in 3137 F5.

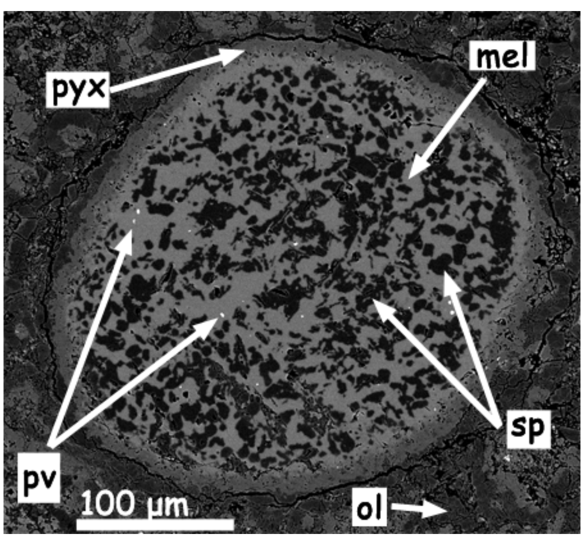

Figure 4. BSE image of the relict CAI in Vigarano 3137 F5. The melilite is highly gehlenitic and unaltered, and occurs with spinel and minor perovskite surrounded by a diopside rim. Pyx = pyroxene, mel = melilite, sp = spinel, ol = olivine, pv = perovskite.

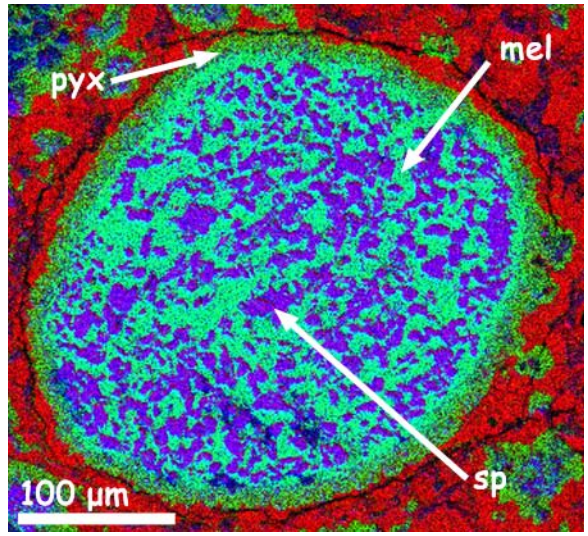

Figure 5. False colour element map of the relict CAI. Ca = green, Mg = red, Al = blue. Abbreviations as before.

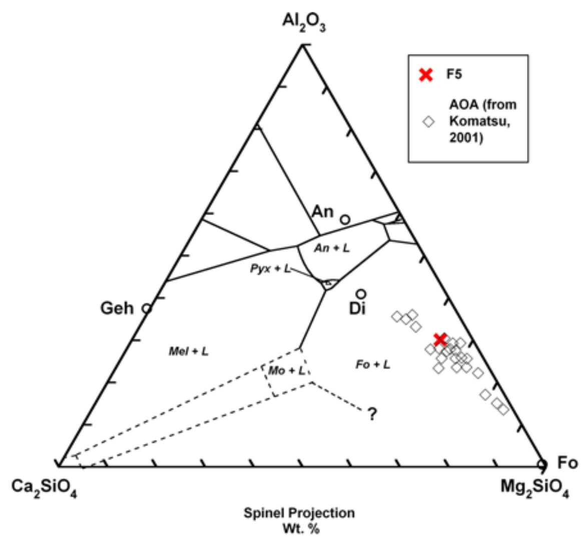

Figure 6. Bulk composition of Vigarano 3137 F5 (red cross), compared with bulk compostion of AOA from other carbonaceous chondrites (data from [3]).