THE APPLICATION OF ELECTRON BACKSCATTER DIFFRACTION TO A TRIDYMITE-DIOPSIDE-ENSTATITE CRYSTAL AGGREGATE IN MASON GULLY (H5): UNDERSTANDING ITS FORMATION AND IMPLICATIONS FOR METAMORPHISM. K. A. Dyl[1,2], A. Halfpenny[1,2], N. E. Timms[1], S. M. Reddy[1], and P. A. Bland[1]. [1]Department of Applied Geology, Curtin University, GPO Box U1987, Perth, WA 6845, Australia. Email: katie.dyl@curtin.edu.au. [2]CSIRO Earth Sciences and Resource Engineering, 26 Dick Perry Avenue, Kensington, Perth, WA 6151, Australia.

Introduction: Ordinary chondrites are the most common meteorite in our collections, accounting for ~85% of samples. As undifferentiated remnants from the early Solar System, they contain important information about the conditions both prior to and during planet formation. Understanding the origin of these rocks, and the conditions they experienced within their parent body, is thus essential in determining how objects accreted and the nature of planetesimals in the early Solar System.

The H chondrite parent body has been the subject of numerous recent studies in this regard. While many argue in favor of a ~100 km progenitor with a traditional "onion shell" structure [e.g., 1-3], there is also evidence for a more complex history that may include regolith processes [4,5]. Furthermore, many observations also indicate that water may play an important role during metamorphism [e.g., 6,7].

Mason Gully (H5) is the 2nd recovered fall tracked using the Desert Fireball Network [8]. It contains a rare crystal aggregate with many similarities to a cristobalite-pyroxene assemblage studied by [9]. We have characterized this object and used electron backscatter diffraction (EBSD) to understand its growth, relationship to the meteorite, and metamorphism.

Methods: A 120 μm section was prepared in conjunction with tomographic data in order to bisect the assemblage of interest. Initial characterization was performed at the Centre for Microscopy, Characterization, and Microanalysis at the University of Western Australia using the TESCAN VEGA3 SEM.

Full crystallographic orientation (EBSD) data were obtained from automatically indexed Kikuchi diffraction patterns collected using a Bruker e-flash detector fitted to a Zeiss Ultraplus FEG SEM at CSIRO Kensington (WA). Coincident EDS data were collected using a Bruker XFlash 5030 detector. An accelerating voltage of 20 kV in high current mode was used. The EBSD data were collected using the Bruker Quantax Espirit 1.9 software, using a step size between measurements of 2.29 μm. Data were post-processed using Oxford Instruments Channel 5 software.

Results: The inclusion is composed of diopside, enstatite, and tridymite with textures reminiscent of those described in [9] (Figure 1). We note that in leiu of cristobalite, tridymite is the main SiO_2 phase present in the core. To our knowledge, tridymite has not been identified in ordinary chondrites; it has been found in enstatite chondrites, eucrites, and irons [10]. Diopside and enstatite crystals radially extend out from the central tridymite core. Outward of this are rims of diopside, followed by enstatite in regions where the host-inclusion interface has been preserved. There is also a region at the interface that underwent subsequent reaction/recrystallization to quartz (shown in Fig. 1 inset).

The SiO_2 polymorphs were identified via EBSD. The tridymite is orthorhombic, and crystals are wedge-shaped. The recrystallized quartz in Mason Gully is indexed having a trigonal symmetry, implying α-quartz. We observe albite twinning in most plagioclase; diopside grains occasionally exhibit lamellar twinning.

As expected, the pyroxene growth texture varies radially with respect to the tridymite core. We therefore analyzed crystallographic preferred orientations (CPOs) by dividing the data into 7 different regions and analyzing their individual pole figures. These regions were delineated according to the tridymite grain boundaries as we hypothesize that the pyroxene grains grew from their surfaces. A clustering of grains indicates the fast growth direction for the pyroxenes.

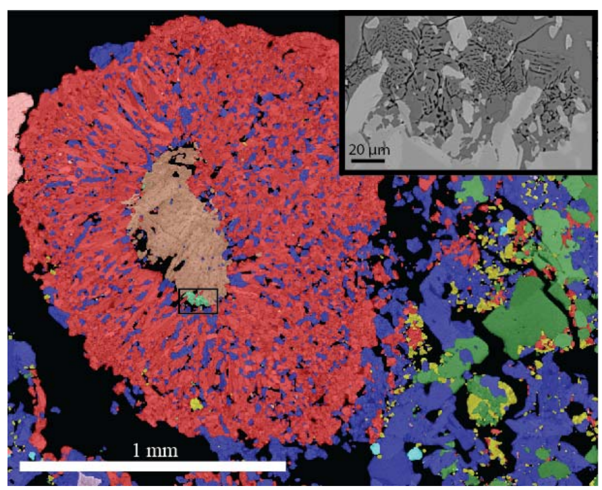

Figure 1: Phase map of Mason Gully aggregate with EBSD band contrast map underlaid. Colors correspond to diopside (red), enstatite (blue), olivine (green), albite (yellow), tridymite (coral), Fe metal (pink), troilite (cyan), and quartz (teal). Inset: BSE image of quartz region.

Pole figures for diopside in {100} are shown in Figure 2; this symmetry plane is presented because it displayed the strongest CPOs. These relate to the orientation of the tridymite/pyroxene boundary from which they have grown. They are growth-related textures, confirming that this object formed *in situ*; there is no indication that shock or brecciation played a role in its formation or later metamorphism. Therefore, the *a* axis is the fast growth direction, consistent with other studies of diopside crystallization kinetics [11].

In contrast to diopside, the enstatite CPOs are all characterized by a single cluster in <001>; thus, the *c* axis is the fast growth direction in this mineral. It is perpendicular to the growth direction of diopside, implying that the two different pyroxenes are also exerting growth controls on one another.

Discussion: Previous work studying surface nucleation and growth into glass found that crystal orientations differ between nucleation (*b* axis preferred) and crystal growth (*a* axis preferred); they attribute this change to the excess Ca that builds up at the crystallization front within the glass (observed in EDS analyses) [11]. This would suggest that Ca was present during the crystallization of this object in Mason Gully. While reaction between SiO_2 and olivine explains the pyroxene coronae, the source of Ca is unclear. Feldspar/chondrule mesostases are an option; however, albite is only present in minor amounts at the interface between the host and aggregate. If Ca did come from these phases, considerable mass transport within the host must be invoked.

These growth textures, coupled with the lack of grain misorientation and lamellar twinning in diopside, imply that this object crystallized into void space; it is not consistent with formation directly from another phase. This is supported by the considerable macroporosity still present in Mason Gully [12]. The outer pyroxene rims, however, may record a different growth process, whether it's due to exhaustion of a reactant, changing conditions, reactions with the bulk rock, or a combination of these factors.

Conclusions: We have characterized a unique, tridymite-bearing crystal cluster in Mason Gully (H5), providing new insight into the metamorphic conditions present in ordinary chondrites. Diopside CPOs show that the growth orientation has been controlled by the the tridymite-pyroxene phase boundary as the clusters approximate poles to this surface. The bulk of the object therefore grew *in situ*, likely into surrounding void space, and and requires a source of Ca. The outer rim(s) may record metamorphic reactions between the object and the host meteorite.

References: [1] Trieloff M. et al. (2003) *Nature,* 422, 502-506. [2] Kleine T. et al. (2008) *EPSL,* 270, 106-118. [3] Henke S. et al. (2013) *Icarus*, 226, 212-228. [4] Kessel R. et al. (2007) *GCA,* 71, 1855-1881. [5] Ganguly et al. (2013) *GCA,* 105, 206-220. [6] Grossman J. N. et al. (2000) *Meteoritics & Planet. Sci.,* 35, 467-486. [7] Dyl K. A. et al. (2012) *PNAS,* 109, 18306-18311. [8] Towner M. C. et al. (2011) *Meteoritics & Planet. Sci.,* 74, 5124. [9] Olsen E. J. et al. (1981) *EPSL,* 56, 82-88. [10] Dodd R. T. (1981) *Meteorites-A Petrologic-Chemical Synthesis.* [11] Wisniewski W. et al. (2012) *Cryst. Growth Des*., 12, 5035-5041. [12] Dyl, K. A. et al. (2011) *Meteoritics & Planet. Sci.,* 74, 5507.

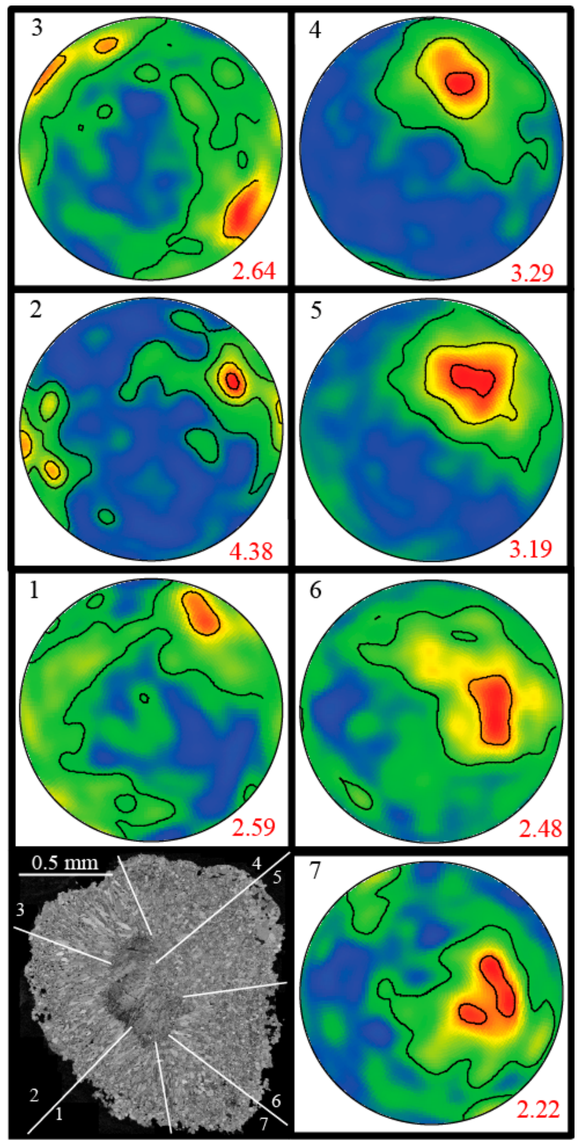

Figure 2: A band contrast map of the object (lower left) with the selected regions identified and numbered. The contoured pole figures (equal area, lower hemisphere, half width 15°, cluster size 3°) for diopside in {100} are all shown. The corresponding region number is in black; the red number is the maximum MUD (multiple of uniform density).