THE CONSPICUOUS COMPOUND CHONDRULE-CAI CONUNDRUM: A CASE STUDY WITHIN THE BRECCIATED CM2.2 LITHOLOGY OF THE CARBONACEOUS BRECCIA AGUAS ZARCAS

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Introduction: Compound-chondrule CAIs (CCCAIs) are rare occurences within carbonaceous chondrites, having only been reported sporadically within most major groups (CO **[1]**, CV **[2]**, and CH **[3]**) and only once reported within another CM chondrite, Paris (CM2.7) **[4]**. These rare objects have been described as CAIs enclosing chondrules **[5] [4]** or as chondrules enclosing CAIs **[6]**. Here we report the finding of the "cockerel", a CCCAI discovered within the brecciated CM2 carbonaceous chondrite *Aguas Zarcas* that falls within the latter category. This is in addition to the "CCRO" (Compound Chondrule Refractory Object) which was previously reported in *Aguas Zarcas* **[7]**.

Methods: The identification of the refractory inclusions was done using sample-wide Ca-Al-Mg Energy-Dispersive X-ray Spectroscopy (EDS) maps in conjunction with Backscattered Electron (BSE) images of two polished blocks and three thin sections of the *Aguas Zarcas* meteorite. These geochemical maps were obtained using a Zeiss Sigma Variable Pressure Analytical Scanning Electron Microscope (SEM; accelerating voltage of 20 keV; carbon coated ~10 nm thickness) at the University of Glasgow.

Results: *Aguas Zarcas* is a polymict carbonaceous breccia composed of five main lithologies **[8]** (two metal-rich ones, a brecciated CM, and two distinct carbonaceous ones). In our study, we find that all of our samples are contained within the brecciated CM lithology. Using Rubin's scale **[4, 9]** for determining the degree of aqueous alteration within CMs, the main textural and petrological criteria indicate a main CM2.2 lithology comprising three distinct clast CM lithologies **[10]**. In **Fig. 1**, the cockerel's CAI (circled in white) is enclosed within a circular chondrule (circled in yellow) mainly composed of forsterite and Al-diopside. The CAI itself is composed of spinel surrounded by calcite. Ti-Ca elemental maps reveal the presence of perovskite alongside the spinel within the CAI. The entirety of the assemblage is contained within a Fine-Grained Rim (FGR), composed of very fine (submicrometric) grains of olivine as well as iron-nickel sulphides (e.g., pentlandite), as are most larger objects within the CM brecciated lithology of *Aguas Zarcas*. However, the CCCAI is within a CM clast (circled in blue in the BSE image in **Fig.1**) seemingly less aqueously altered than the rest of the main CM2.2 lithology, corresponding to an estimated CM2.2-2.3 (based on the scale provided by **[11]**, expanded from **[4, 9]**). A similar observation can be made concerning the "CCCRO" (first CCCAI reported in *Aguas Zarcas* **[7]**). Further characterisation of these clasts will be done by measuring the "FeO"/SiO_2 and S/SiO_2 ratios of the Tochilinite-Cronstedtite Intergrowth (TCI) clumps.

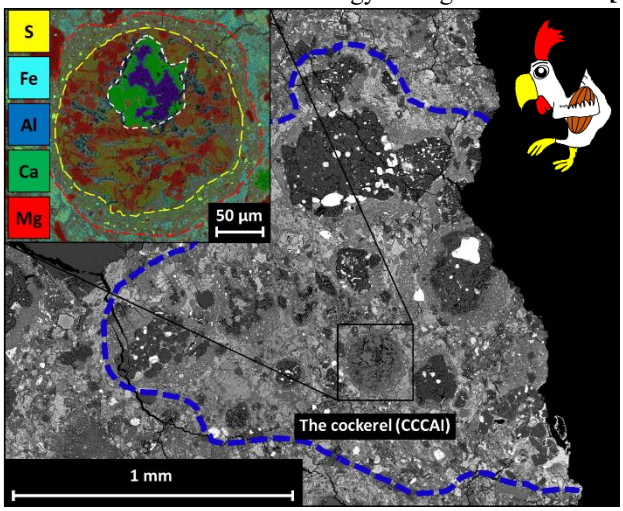

Fig. 1. *The cockerel in its natural habitat:* EDS layered image (top-left corner) of a CCCAI designated as the "cockerel" due to the distinctive shape of the CAI's Al-rich phase (diopside; represented in blue). The BSE image is of one of the studied polished sections of *Aguas Zarcas* (AZ_P2).

Discussion: The existence of CCCAIs are proof that chondrules have interacted with CAIs prior to their incorporation within the CM parent body. These interactions could potentially have been either through transient heating events during which the CAIs would have been incorporated within the melted ferromagnesian chondrules or perhaps the CAIs served as nuclei for the formation of these chondrules. Further studies are required and will include Electron Backscatter Diffraction maps in order to provide crystal orientation maps, alongside Secondary-Ion Mass Spectrometry analyses in order to determine their origin and their role within the formation of the Solar System.

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