SEQUENCES OF CARBONATE MINERALIZATION IN THE CM CARBONACEOUS CHONDRITES REVEALED BY THE WINCHCOMBE METEORITE.

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Introduction: All of the CM carbonaceous chondrites contain carbonates, which formed by parent body aqueous alteration at ~4,563.4 Ma [1]. They show a considerable range in mineralogy and chemical composition, which tracks the degree of alteration of the host meteorite [2]. Calcite is the most abundant mineral and occurs in all CMs. Aragonite has been recorded only from the mildly altered meteorites, and dolomite in the more highly altered ones [3]. Ankerite and breunnerite have been described just from Queen Elizabeth Range (QUE) 93005 [4].

The carbon and oxygen stable isotopic compositions of carbonates provide a 'snapshot' of the properties of precipitating fluids, e.g., their provenance, extent of interaction with the host rock, and temperature. However, in order to construct a narrative of parent body aqueous alteration these snapshots need to be placed in the correct sequence. The relative ages of the different minerals have been difficult to determine because carbonates are scarce such that intergrowths or cross-cutting relationships are rare. Here we report petrographic and microstructural observations from Winchcombe, a recent CM fall, which provide good evidence for the sequence of carbonate mineralization.

Materials and methods: Winchcombe fell on 28th February 2021 in Gloucestershire, England. It is a breccia of CM lithologies that range from completely hydrated (CM2.0) to moderately altered (CM2.6) [5]. We studied carbonates in C-coated thin sections P30540, P30552 and P30555 loaned by the Natural History Museum, London. P30540 and P30552 were studied at the University of Glasgow using a Zeiss Sigma field-emission SEM, and P30555 at Oxford Instruments (OI) using a Hitachi SU70 SEM equipped with an OI Symmetry S2/UltimMax 65 EBSD/EDS detector. EBSD data were acquired with OI Aztec v6.0 software and processed using OI AZtecCrystal v2.3.

Results: Thin section P30555 contains both aragonite and calcite, with the latter being more abundant. In several areas the two minerals are juxtaposed. The calcite occurs as a cluster composed of small, undeformed grains with faceted shapes. By contrast the aragonite displays prominent deformation microstructures – twins (some curved), intragranular misorientation, and subgrains. Low angle boundaries show rotation about <100>, and weighted Burgers vectors are preferentially parallel to <001> and <010>. P30552 contains mainly calcite, and many grains show cathodoluminescence zoning indicative of crystal growth into fluid-filled pores. Most grains are rimmed by fibers of coherently interstratified tochilinite/serpentine, but some have been completely replaced by tochilinite/serpentine fibers intergrown with finely crystalline Mg-serpentine. P30540 contains both calcite and dolomite, and one composite grain has a core of calcite that is rimmed by phyllosilicate and overgrown by euhedral dolomite crystals.

Discussion: Our observations indicate that the Winchcombe carbonates formed in at least three discrete episodes. Aragonite was first to crystallize then was deformed, probably by an impact, and its microstructures are consistent with dislocation creep. As adjacent calcite is undeformed, it must have grown after aragonite and the impact event. Calcite was then partially or completely replaced by tochilinite and serpentine. Subsequently, fluids became supersaturated with respect to dolomite, which in some cases precipitated as an overgrowth on calcite-phyllosilicate substrates.

The findings from Winchcombe are consistent with oxygen isotopic data from the CM Lonewolf Nunataks 94101 showing that aragonite grew before calcite [6]. They also agree with interpretations of $\Delta^{17}O$ and clumped isotope temperature measurements of carbonates in the CM Allan Hills 83100 indicating that dolomite precipitated after calcite and from fluids that were hotter and had interacted more with anhydrous silicates [7]. A caveat is that multiple generations of same carbonate mineral may have formed in Winchcombe, in common with other CMs [8, 9], and more observations are needed in order to test this model of carbonate mineralization. Nonetheless, Winchcombe shows how petrographic and microstructural studies can reveal the mineralization history of the CMs during aqueous alteration.

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