ALTERATION OF CARBONATE IN THE AGUAS ZARCAS AND TARDA CARBONACEOUS CHONDRITES

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Introduction: Carbonate minerals in carbonaceous chondrites have been related to the degree of alteration within their parent bodies, constituting up to 2.8 vol% of CM chondrites [1,2]. We are studying the carbonate-bearing mineral assemblages in aqueously altered carbonaceous chondrites, and in particular the relationship between carbonate, phyllosilicate and tochilinite mineralization, to understand the evolution of alteration fluids and associated Fe-redox in CM parent bodies. As recent falls, Aguas Zarcas and Tarda in particular offer the chance to determine the origin of carbonate-bearing assemblages with minimal terrestrial overprints.

Samples and Methods: The samples investigated include polished thin sections of carbonaceous chondrite meteorites Aguas Zarcas (CM2), Jbilet Winselwan (CM2), and Tarda (C2-ung). The Aguas Zarcas specimen had been collected within 5 days of the fall. Tarda is also a fall meteorite and Jbilet Winselwan a find, both from Morocco.

BSE imaging has been obtained of carbonates and surrounding features in the thin sections, and EDX measured, using a FEI Quanta 650 FEG-SEM at the University of Leicester Advanced Microscopy Facility.

Results: Aguas Zarcas contains crystalline calcite ($Mg_{27}Cc_1Sd_{72}$) grains, the majority of which can be found with tochilinite-cronstedtite-rich intergrowths (Figure 1A), consistent with other CM chondrites [1,2], but the meteorite may be lacking dolomite. Located throughout the matrix there are isolated grains of calcite measuring up to ~50 μm in size, as well as some smaller grains within serpentine-rich altered chondrules with compositionally cronstedtite-like serpentine directly surrounding the calcite grains (Figure 1B).

Calcite-dolomite carbonates ($Mg_{23}Cc_{73}Sd_4$) in Jbilet Winselwan are small (<20 μm) and typically appear mixed with serpentine/tochilinite formations. Other more Ca-rich grains ($Mg_5Cc_{93}Sd_2$) have also been observed. However, Jbilet Winselwan is a find, and terrestrial $CaCO_3$ has been observed on the surface of the sample. Therefore determining the extraterrestrial carbonate history within this meteorite sample may be difficult.

Siderite ($Mg_2Cc_{95}Sd_3$) formations have been observed in Tarda with a mottled texture and usually associated with the more prominent poorly crystalline serpentine and/or Fe-bearing saponite located in pores between grains of forsteritic olivine (Fo_{99}) and Fe-sulphides (Figure 1C), throughout regions up to 400 μm in size.

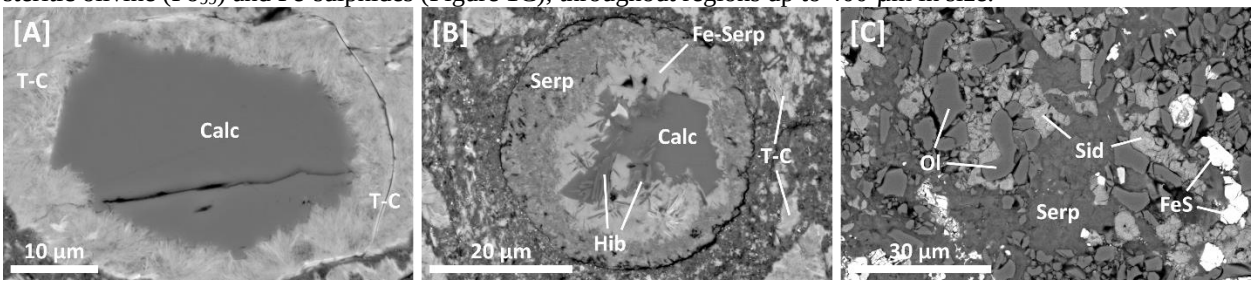

Figure 1. BSE images of carbonates in CM2 Aguas Zarcas [A-B] and C2-ung Tarda [C]. [A] shows calcite (Calc) within tochilinite-cronstedtite-rich (T-C) intergrowths. [B] Calcite is within a chondrule replaced by serpentine (Serp), including cronstedtite-like serpentine directly surrounding the calcite grain, with minor inclusions of hibonite (Hib). [C] shows siderite (sid) and serpentine replacing or filling pores between the olivine (Ol) and Fe-sulphide (FeS) grains.

Discussion: In this study we aim to constrain the history of carbonate formation, with regard to hydrous mineralogy within carbonaceous chondrites, and better understand the evolution of the fluids from the bicarbonate-rich to the tochilinite/siliceous-rich fluids. An early stage of CM parent body alteration includes HCO_3^- saturated aqueous fluids replacing some precursor ferromagnesian silicates, which would be consistent with our petrographic survey of the carbonates in CM2 meteorite Aguas Zarcas. As the HCO_3^- anions were exhausted in the parent body fluids, carbonate precipitation ceased and the associated Fe-redox buffer also ended. As hydrous fluid activity continued, this switch in fluid chemistry was associated with the partial replacement of the calcite grains in Aguas Zarcas by serpentine or tochilinite-cronstedtite-rich phases. However, the siderite in Tarda is different to the CM2, but similar to those found in another C2-ung meteorite, Tagish Lake, where siderite fills pores but also apparently replaces the serpentine [3].

Further analyses of the calcite in Aguas Zarcas and the siderite in Tarda will involve constraining the relation between these carbonates and the associated tochilinite and phyllosilicate formations, including FIB-TEM and synchrotron XANES analyses, and continuing our previous studies of carbonaceous chondrite aqueous alteration [4].

References: [1] De Leuw S. et al. (2010) *Meteoritics & Planetary Science* 45:513–530. [2] Rubin A. E. et al. (2007) *Geochimca et Cosmochimica Acta* 71:2361-2382. [3] Zolensky M. E. et al. (2002) *Meteoritics & Planetary Science* 37:737–761. [4] Hicks L. J. and Bridges J. C. (2020) *LPSC LI*, Abstract #2869.