

**RAPID CALCITE DISSOLUTION IN CM CARBONACEOUS CHONDRITES AND ITS IMPLICATIONS.**

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**Introduction:** Carbonates are ubiquitous in the CM carbonaceous chondrites and are believed to have formed from low temperature aqueous alteration on the CM parent body in the first 5 Myr after solar system formation [1-2]. The presence and mineralogy of carbonates is included by [3] in their classification scheme describing the extent of aqueous alteration experienced by CM chondrites. Complex carbonates and dolomite are typically associated with more altered (lower petrologic (sub)type) CM chondrites. Carbonates are therefore of particular importance for understanding the evolution of the CM chondrite parent body(ies). Of the carbonates recorded within CM chondrites, calcite is the most common, with abundances ranging up to 1.87 vol%. [4]. Calcite observed in CM chondrites can exist in four varieties: Type 1a, 1b, 2a and 2b [4].

Despite the frequent occurrence of calcite in both CM finds and falls, its presence should be considered surprising given how reactive terrestrial calcite is to weathering. The lack of significant study on the effects of terrestrial weathering on CM carbonates should be addressed given the significance of these minerals to understanding the aqueous processing on the asteroid parent body. This study sets out to investigate mechanisms and rates of calcite dissolution within the CM chondrite Murchison.

**Methods:** Calcite grains were studied in two sections of Murchison (sections: P19258 and P19261) (CM2.5, [3]). Murchison was selected due to its availability and frequent reference within the literature to the presence of calcite [3,5]. Backscattered electron (BSE) SEM imaging and chemical analysis by Energy Dispersive X-ray Spectroscopy (EDS) were undertaken using a Zeiss Sigma SEM and FEI Quanta SEM at the University of Glasgow. Following the location and imaging of a selection of calcite grains within both sections, the exposed surface of each section was covered by 5 mL of deionized water for a total period of six hours. During this soaking period sample P19258 was kept at 5 °C to simulate conditions where liquid water might exist around Antarctic meteorite finds [6-7], whilst section P19261 was kept at ~20 °C. Every two hours the water was drained, collected for future analysis and the calcite grains re-imaged to track the progress of any dissolution. The 5 mL of deionized water was then replenished and soaking resumed.

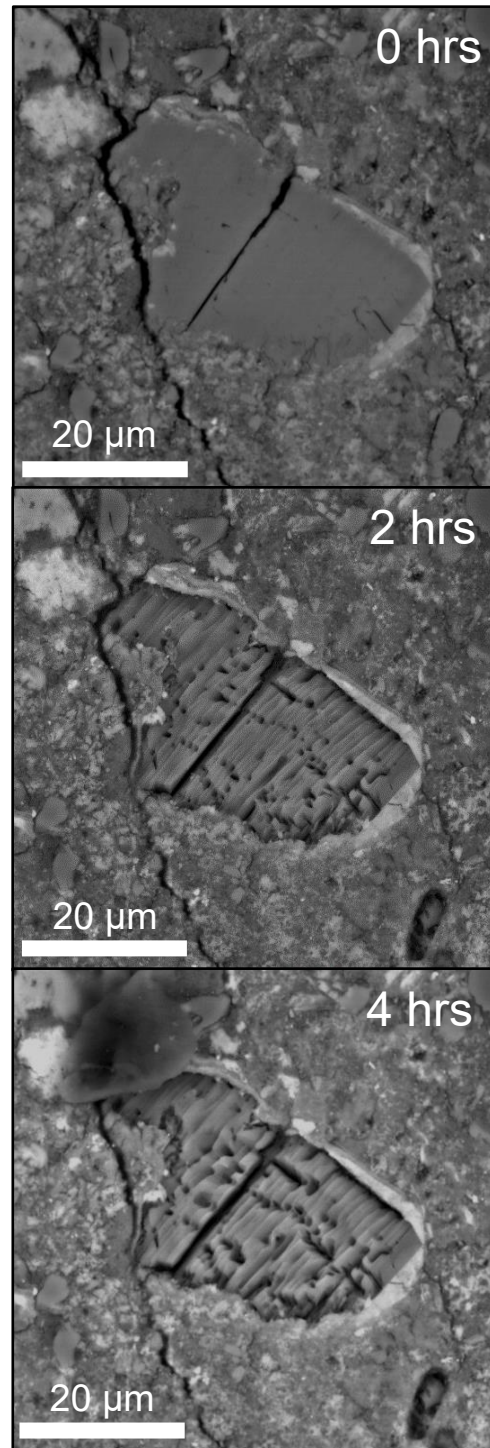


Figure 1. BSE images of a calcite grain in section P19258 after soaking for 0, 2 and 4 hours, at 5°C in 5 mL of deionized water.

**Results:** The calcite grains examined in this study were examples of type 1b calcite grains being subhedral or anhedral, less than  $\sim 70 \mu\text{m}$  and lacking obvious serpentine/tochilinite rims [4].

**5 °C soaking:** Section P19258 was soaked at 5 °C and saw significant dissolution of all the calcite grains imaged over the six-hour soaking period (Fig. 1). The majority of grains developed a pitted appearance (Fig. 1). It is thought this texture represents etch pits, resulting from the intersection of dislocations with the crystal surface [8]. Significant areas of dissolution were also seen around all pre-existing fractures and surface defects.

**20 °C soaking:** Section P19261 was soaked at 20 °C and all the calcite grains imaged also experienced significant dissolution with similar etch pits developed. There appears to be no significant difference in the rate of calcite dissolution between the two temperatures investigated. In addition to the dissolution of the calcite grains, after four hours of soaking sample P19261 developed a coating of a white, Mg-sulphate efflorescence (potentially epsomite [9]). This efflorescence coated the edge of the sample and was clearly visible by the naked eye. It was dissolved during the following two hours of soaking.

**Discussion:** The results of this study show that, provided liquid water is present, carbonates may be no better preserved in Antarctica compared to warmer environments. The significant dissolution experienced by all the calcite grains imaged, at both  $\sim 5 \text{ °C}$  and  $\sim 20 \text{ °C}$ , over such a short time period also highlights how surprising calcite's presence in CM chondrites is. It is especially so considering that terrestrial residence times for some Antarctic CM chondrites finds can be in excess of 5 Ma [10], and some CM chondrite falls are from humid tropical climates. It is therefore suggested that some factor is limiting the extent of calcite dissolution.

One possible control of calcite abundances within CM chondrites is the extent of parent body aqueous alteration. However, [11] ruled that no close correlation existed between petrological subtype and calcite abundance. This is because calcite forms in the early stages of parent body processing [2] and any correlation with petrologic subtype would require the precipitation of calcite throughout the duration of aqueous alteration. Despite this, the brecciated nature of the CM chondrites results in significant variability in reported calcite abundances within the literature, making testing any relationship difficult.

The rapid development of a Mg-sulphate on the surface of sample P19261 is believed to be the fastest recorded development of efflorescence on a carbonaceous chondrite. Previously [9] observed the

development of sulphate grains on the surface of a CI chondrite sample (Ivuna) within 6 years of section preparation. This work highlights that the presence of even small amounts of liquid water can dramatically reduce the time required for efflorescence development and the leaching of soluble elements.

The significance of these findings and the need for greater understanding of the evolution of carbonates within CM chondrites was recently highlighted by the detection of meter-sized carbonate veins on asteroid Bennu by the OSIRIS-REx spacecraft [12]. The presence of these large veins suggests extensive water flow on the CM parent body [12]. However, the results presented suggest that carbonaceous material is extremely impermeable.

**Conclusions:** This study has shown that the rate of calcite dissolution within CM chondrites can be extremely rapid in both warm and cold environments and with only a small amount of water present. This study also records the development of a Mg-sulphate, believed to be epsomite, on the surface of a CM chondrite after just 4 hours of soaking. These results suggest that the Antarctic environment may produce more significant alteration than previously realised and that further study is needed to fully understand the implications of terrestrial weathering of CM chondrite carbonates.

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