

Quantifying the intensity of post-hydration heating of CM carbonaceous chondrites using carbonates [#1540]

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Introduction: A proportion of the CM carbonaceous chondrites were heated after aqueous alteration, leading to dehydroxylation and recrystallization of their phyllosilicates [1,2].

Carbonates are a minor constituent of the CMs but are potentially powerful tools for understanding the intensity and duration of heating because their relatively coarse crystal size (10s-100s μm) makes them suitable for characterisation by microbeam techniques. Recent work on the Sutter's Mill carbonaceous chondrite has shown that parent body heating of its calcite produced oldhamite (CaS) and portlandite (Ca(OH)₂) [3].

Here we have sought to calibrate CM carbonates as a palaeothermometer for primitive asteroids by experimentally heating the Murray CM carbonaceous chondrite and documenting temperature-related changes to the microstructure and mineralogy of its calcite.

Experimental: Five 20-30 mg chips of Murray were used. One was left untreated, and the other four were heated under vacuum ($\sim 1 \times 10^{-2}$ mbar) to different temperatures (200, 400, 600, 800 °C) at which they were held for ~ 1 hour. The quantity of H₂O liberated was measured at each step (detection limit 0.01 wt% H₂O). Resin-impregnated chips were polished without water then characterised by backscattered electron imaging, X-ray microanalysis and electron backscatter diffraction (EBSD).

Impact of heating on bulk properties: The most obvious impact of heating is dehydroxylation of serpentine, which comprises 74 vol. % of Murray [4]. Dehydroxylation starts at between 400 and 600 °C, as demonstrated by an increase in matrix analytical totals (Fig. 1a) and liberation of H₂O from the bulk sample (Fig. 1b). Other effects of heating are a progressive increase in Na concentrations of the matrix, and an increase followed by a decrease in S (Fig. 1c). Shrinkage cracks have also formed in the matrix (Fig. 1d).

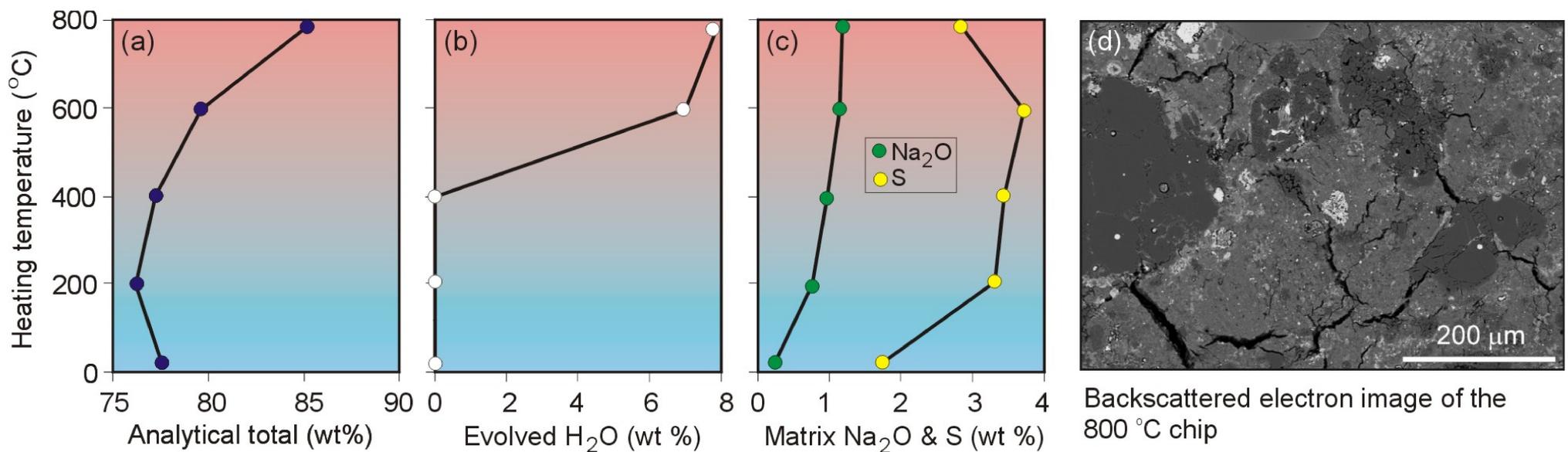


Fig. 1: Impact of laboratory heating on the bulk composition and texture of Murray.

Effects of heating on calcite: Heating to 400 °C produces no discernible changes (Fig. 2). Grains in the 600 °C chip are still calcite, as determined by EBSD, but contain micropores or subgrains (Fig. 2). These textural changes may reflect the incipient decomposition of calcite (CaCO₃) to lime (CaO) with concomitant loss of CO₂. Calcite is absent from the 800 °C chip. In its place are grains of oldhamite (CaS) rimmed by troilite (Fig. 2); the oldhamite was identified by quantitative X-ray microanalysis and EBSD.

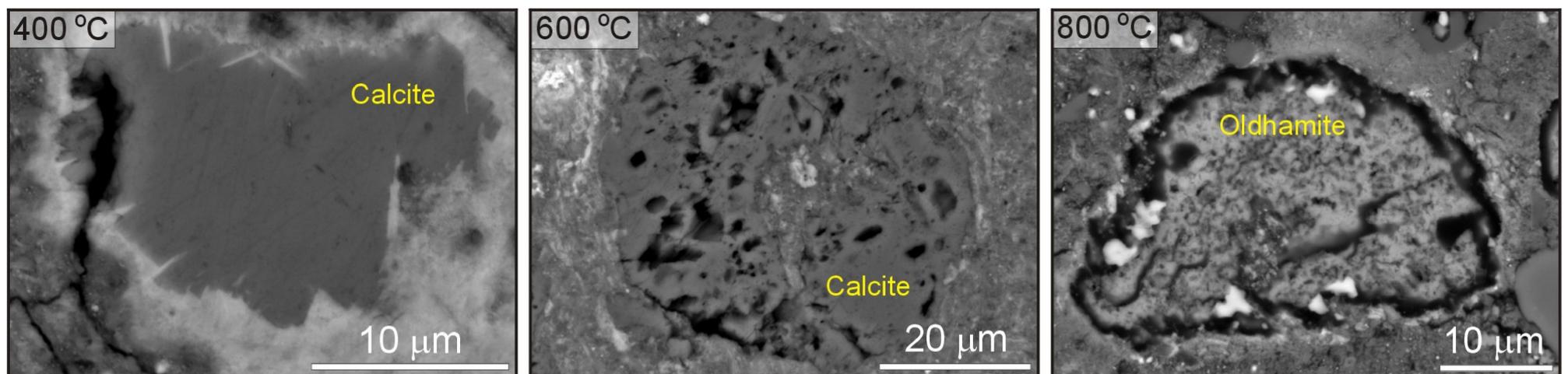


Fig. 2: Thermal evolution of Murray calcite: No change at 400 °C; micropores & subgrains in calcite at 600 °C; replacement by oldhamite at 800 °C.

Summary: Under the laboratory conditions used, the calcite-oldhamite transition is at between 600 °C and 800 °C. The fall in S content of the matrix above 600 °C (Fig. 1c) is interpreted to be due to scavenging by oldhamite. Further experiments at intermediate temperatures will be undertaken to more precisely constrain the thermal threshold and mechanism of oldhamite formation.

References: [1] Akai J. (1988) GCA, 52, 1593–1599. [2] Tonui E. et al. (2014) GCA, 126, 284–306. [3] Haberle C. W. and Garvie L. (2017) Am Min, 102, 2415–2421. [4] Howard K. T. et al. (2009) GCA, 73, 4576–4589.

Acknowledgements: We thank the UK STFC for funding.