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Tracking the geological evolution of C-complex asteroids using carbonates

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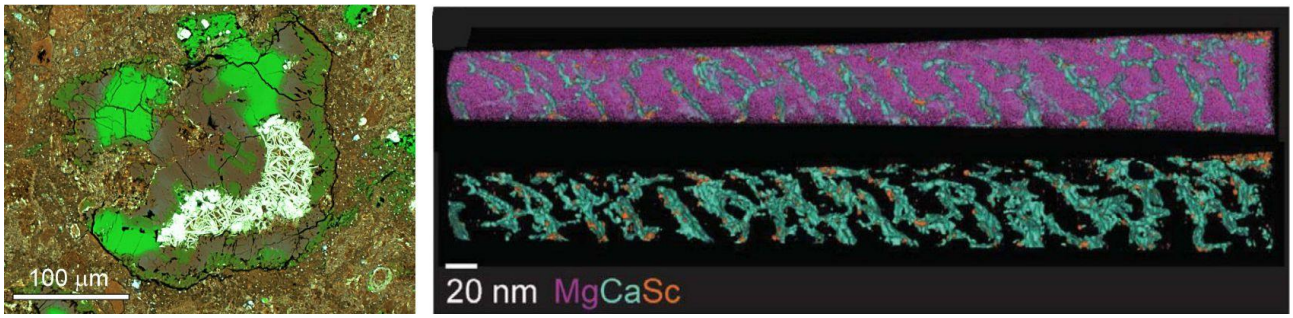
Aims: This project will use CM carbonaceous chondrite meteorites to explore the geological evolution of C-complex asteroids during the early history of the Solar System. The overarching goal of the wider research programme is to understand the role of these water- and organic matter-rich asteroids in delivering bio-essential compounds to early Earth.

Context and science questions: C-complex asteroids formed 4560 million years ago within the protoplanetary disk from mineral grains (silicates, sulphides, metal), organic matter and ices. Soon after being built, the ice was melted by internal heating and the liquid water produced reacted with mineral grains to create secondary phases including phyllosilicates (mainly serpentine) and carbonates (calcite, dolomite, aragonite). The carbonate minerals are particularly valuable because their chemical and isotopic compositions, and microstructures, are powerful tools for understanding the geological evolution of these primitive bodies. Specifically, carbonates can provide unique insights into long-standing questions about asteroid evolution including the temperature and duration of water/rock interaction, the presence or absence of fluid flow, and the nature and timing of deformation by hypervelocity impacts[1].



Left-false colour multi-element X-ray map of a polymineralic carbonate grain in the meteorite QUE 93005. Right-Atom probe tip from part of the grain showing its complex nanoscale structure[2].

This project comes at a uniquely important time in our understanding of the early Solar System and its most primitive bodies. Samples have recently returned from two C-complex asteroids: Ryugu (sampled by the Japan Aerospace Exploration Agency (JAXA) Hayabusa2 mission), and Bennu (sampled by the NASA OSIRIS-REx mission). Furthermore, a CM carbonaceous chondrite recently landed in Winchcombe, Gloucestershire, and was the first UK meteorite to be recovered in 30 years[3].

Methodology: Carbonate minerals in a variety of CM meteorite samples will be analysed using conventional microanalytical techniques (e.g., scanning electron microscopy, electron backscatter diffraction, electron probe microanalysis, Raman spectroscopy) together with the novel tool of atom probe tomography, which enables determination of the chemical and isotopic composition of a sample at the atomic scale[2,4].

Dissemination and skills: This research area is inherently international in scope. The student will collaborate with partners in Europe, the USA and Australia, and share results at international conferences including the annual Meteoritical Society and Lunar and Planetary Sciences meetings. Upon completion the student will be equipped with skills that could lead to employment in areas such as space exploration, materials technology, or environmental management.

Application details: The entry requirement is a 2.1 Honours degree or equivalent in geology, Earth science, planetary science, materials science or a cognate discipline. The application deadline is Wednesday 31 January 2024. Interviews will be held in mid-late February 2023, and the studentship will start in October 2024.

Information on how to apply is **here**:

References

[1] Lee M. R., Lindgren P. and Sofe M. R. (2014) Aragonite, breunnerite, calcite and dolomite in the CM carbonaceous chondrites: high fidelity recorders of progressive parent body aqueous alteration. *Geochim. Cosmochim. Acta* 144, 126–156.

[2] Daly, L., Lee, M.R., Cairney, J., Eder, K., McCarroll, I. and Yang, L. (2018) Atom Probe Tomography of Nanoscale Structures in Carbonates from the Queen Elizabeth Range (QUE) 93005 CM2 Carbonaceous Chondrite: Implications for the Evolution of Parent Body Fluids. *81st Annual Meeting of the Meteoritical Society*, #6239.

[3] King A. J., Daly, L. et al. 2022. The Winchcombe meteorite, a unique and pristine witness from the outer solar system. *Science Advances* 8: eabq3925.

[4] Daly, L., Lee, M., Bagot, P.A., Halpin, J., Smith, W., McFadzean, S., O'Brien, A.C., Griffin, S. and Cohen, B.E. (2020) Exploring Mars at the nanoscale: applications of transmission electron microscopy and atom probe tomography in planetary exploration. *IOP Conference Series: Materials Science and Engineering* 891, 012008.