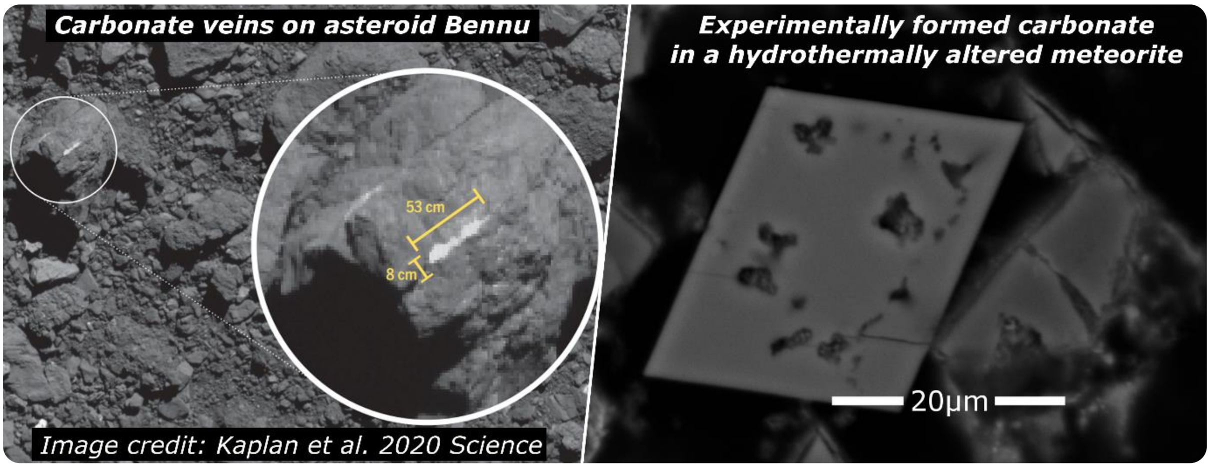
Carbonates in ungrouped carbonaceous chondrites: tools for exploring the geology of hydrated asteroids



Supervision team: Dr Martin D. Suttle, Prof Ian Franchi, Prof Monica Grady

Lead contact: Dr Martin D. Suttle

Project highlights:

- Analysis of anomalous ungrouped meteorites, including recent falls.
- Using carbonate minerals to explore past fluid activity on primitive asteroids.
- Reconstructing the isotopic composition of primordial water and carbon reservoirs.
- Constraining the formation distance, alteration temperature, and fluid composition on numerous asteroids.

Summary: This project will study carbonate minerals in ungrouped carbonaceous chondrites, using isotopic, chemical, and crystallographic data to provide new quantitative constraints on the formation conditions and geological histories of C-type asteroids. Key science questions include *at what heliocentric distances did the carbonaceous chondrite asteroids form, over what temperature range did aqueous alteration operate and how are carbonaceous chondrite asteroids related.* The findings from this work will be directly relevant to the study of carbonate minerals returned from asteroid Bennu in 2023. This position is fully funded by the UK's Science and Technology Facilities Council (STFC) and is based at the Open University's (OU) School of Physical Sciences.

Background: Recently, NASA's OSIRIS-Rex spacecraft reported metre-long carbonate veins on asteroid Bennu [1]. Smaller carbonate minerals are common in carbonaceous chondrite meteorites. Oxygen isotope analysis of these minerals can reveal at what temperatures they precipitated and therefore the thermal regimes on asteroids [2] as well as the isotopic composition of asteroidal water and how these fluids changed over time [3]. In turn, these data provide insights into the origin of water in the outer solar system and whether asteroids provided the early Earth with water. In addition, studying carbon isotopes in carbonates allows us to explore whether ices or organic matter were the main source of carbon. Knowledge of the carbon budget has been used to infer where in the solar system asteroids formed, specifically how far from the proto-Sun [4].

Carbonates are therefore an essential tool for studying the early solar system, capable of answering a diverse array of high-priority science questions. However, their application in a planetary science context is a relatively new and emerging field. Major developments have occurred in the last ten years with research focusing on the established chondrite groups (the CMs, CIs and CRs). This has left the ungrouped meteorites relatively unstudied. Exploiting this knowledge gap, this project will focus on new and anomalous meteorites.

Workplan: This project will analyse ungrouped chondrites (Bells, Essebi, Adelaide, Tagish Lake, Tarda, Flensburg, MIL 090292 & MIL 07687) with the possibility of including material from asteroid Bennu. Each sample is the only known representative of its parent asteroid, meaning that the project will explore the geological histories on numerous water-rich asteroids. Analysis of the new UK fall (Winchcombe) will act as a CM chondrite reference sample. This broad approach ensures that the relationships between carbonaceous chondrite groups can be investigated, greatly expand our understanding of the aqueous alteration process from individual cases to a general model. This project capitalizes on the OU's research history and expertise studying ungrouped chondrites.

Polished meteorite sections will be studied under SEM to identify carbonate minerals. These will then be analysed chemically (EMPA) and crystallographically (TEM) before being destructively sampled for isotopic analysis (nanoSIMS). Supporting bulk analyses (XRD & Finesse Mass Spectrometer) on meteorite powders will provide context.

Career development: The successful candidate will develop an extensive knowledge base in planetary science, whilst also gaining transferable skills in stable isotope geochemistry, mineralogy, and crystallography. The student will learn how to independently operate all microanalysis instruments, reduce data, draw interpretations, and publish their findings in high-impact peer-reviewed journals. This project provides exciting opportunities to work with state-of-the-art equipment, attend international conferences, communicate science to the media and work with data from space missions. A STEM PhD is a good stepping stone for a career in academia, industrial research, science communication, government policy, publishing, or the UK space sector.

References

1. Kaplan et al. 2020. Bright carbonate veins on asteroid (101955) Bennu: Implications for aqueous alteration history. *Science*, 370:6517.
2. Vacher et al. 2019. Thermal evolution of hydrated asteroids inferred from oxygen isotopes. *APJ*, 882:L20.
3. Fujiya et al. 2020. Carbon isotopic evolution of aqueous fluids in CM chondrites: Clues from in-situ isotope analyses within calcite grains in Yamato-791198. *GCA*, 274:246-260.
4. Fujiya et al. 2019. Migration of D-type asteroids from the outer Solar System inferred from carbonate in meteorites. *Nat. Astron.*, 3:910-915.

Qualifications required:

A minimum of 2:1 BSc or a MSc in physics or a related discipline, e.g. geology, earth sciences, chemistry, geochemistry, natural sciences.