Microbially induced calcite precipitation in caves: Implications for speleogenesis, climate reconstruction and climate change mitigation

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Speleothems are among the most important climate archives. Their formation age, texture and geochemical composition provide scientists with information on past temperature, amount of precipitation and even seasonality. Any process altering the formation and post-depositional mineralogical transformations can significantly alter the paleoclimatic application of their geochemical data and effect future climate prediction and models. The growth of speleothems through calcite precipitation has long been viewed as an abiogenic process. However, more recently, a growing body of research indicate that microorganisms can play an important role in carbonate precipitation, thereby modulating speleothem growth. A variety of biochemical activities, including the presence carbonic anhydrase(s) and ureolysis, have been shown to influence the redox conditions and facilitate the precipitation of calcium carbonate. Bacterial surfaces including cell walls and extracellular polymeric substances (EPS) have also been reported to promote the nucleation and growth of calcite. As such, the overarching aim of this research is to **(a) identify cave- or speleothem-associated microbes that are involved in biomineralization and (b) determine the impact of these microbes on the mineralogical and isotopic properties of speleothems.**

The isolation of novel microbes that naturally promote the cementation of cave structures by precipitating calcium carbonate can also be applied to the development of sustainable materials such as bioconcrete. Microbially Induced Calcite Precipitation (MICP) has shown its merits in improving the mechanical properties of materials and pose an opportunity to reduce about 8% of the world's CO_2 emissions that is caused by the production of cement each year. The sequestration of CO_2 into solid carbonates may also constitute an alternative strategy for carbon immobilisation. **Characterisation of the biomineralization potential of these novel cave microbes will pave the way towards the development of a greener, more sustainable construction industry**

This project will employ a *novel* multidisciplinary approach, bringing together mineralogy, microbiology, biochemistry and geochemistry to (a) elucidate the microbial diversity associated with different cave speleothems, (b) isolate and identify novel microbes that promote calcite precipitation from caves and speleothems, (c) determine the biochemical processes that are involved, (d) investigate the potential of cave- or speleothem-associated microbes in the formation of calcium carbonate minerals under *in vitro* conditions (Oxford Cave), (e) determine the crystal morphology and crystal phase, (f) analyse the carbon and oxygen isotope composition of cave speleothems as well as the carbonates formed *in vitro* by these bacteria, (g) characterise the biomineralization potential of these microbes for industrial applications (biogeoengineering and/or CO_2 sequestration)

Training opportunities:

The student will have access to training in microbiology, biochemistry and sequencing techniques at the University of Reading (with Dr Renee Lee). Further characterisation of the calcite precipitation potential of candidate species will be carried out in the first ever cave-analogue setup (Oxford Cave) in the Department of Earth Sciences, University of Oxford under the training and supervision of Dr Christopher Day. The department is also equipped with laboratories and instruments for measuring a wide range of isotopes and elements which the student will have access to during the project. The mineralogical profile of the crystals will be determined using powder X-ray diffraction (PXRD), Scanning Electron Microscope (SEM), cryoTEM and Raman spectroscopy at the School of Chemistry, University of Edinburgh (under the supervision and training of Dr Fabio Nudelman). The project will also involve field work in UK or international caves. Locally, the project will be carried out in close collaboration with the South Wales Caving Club and Natural Resources Wales. International field work will be organised by Dr Christopher Day who is currently working on a number of caves around the world. The student will receive training on field techniques, including microbial and speleothem sampling.

Student profile:

This project will be suitable for students with a first or upper second-class degree in biology, earth sciences or environmental science. Any previous experience in undertaking laboratory work and fieldwork is highly desirable. A good understanding of microbiology, biochemistry and geochemistry would be an advantage. Ideally the candidate should be a self-starter, adaptable and have good communication skills which is required for working in a multidisciplinary environment.

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