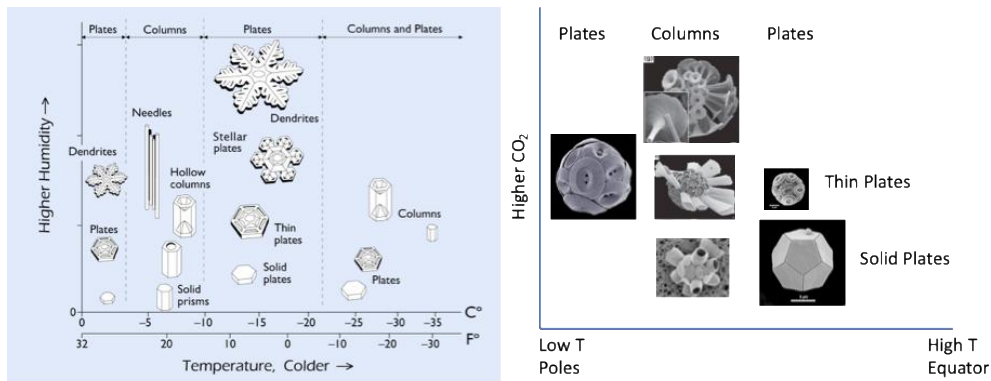


Coccolithophore calcification: a metabolic waste product and geological carbon sink

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Key words:	Coccolithophores, biomineralization, glacial-interglacial cycles, long term carbon cycle
Research theme(s):	• Oceanography, Climate and Palaeoenvironment • Palaeobiology and Evolution
Eligible courses for this project:	• DPhil in Earth Sciences (3-4 years) • Interdisciplinary Life and Environmental Science Landscape Award (ILES�A)

Overview

We currently have no knowledge about how the environment limits the biological production rates of calcium carbonate in the modern and future ocean, nor how it has changed in the past. The long term geological sink of carbon dioxide, weathering, only works if ultimately, the CO₂ that is transported to the ocean, is transformed to biogenic carbonate or organic carbon and removed to sediments. The carbonate sink accounts for on average 80% of the geological sink of carbon. The majority of computer models formulate the production of calcium carbonate in proportion to the saturation state of the ocean, akin to inorganic carbonate. New work from our group suggests that, despite the intricate apparent biotic control over crystal morphology, calcification of coccolithophores is primarily a process developed to remove excess calcium from the cells. Due to the fundamental link between cell size and growth rate, small cells with a low PIC/POC are transport limited compared to larger, slower growing but high PIC/POC species which are reaction limited. It is this which dictates, at least in part, the space filling or dendritic crystal morphologies that emerge across species, akin to the process of snowflake formation (see Figure).



Consequently, the production rate of calcium carbonate by coccolithophores is instead controlled by an interplay between the diffusive supply rate of $\text{CO}_2(\text{aq})$ across the membrane, versus the amount of phosphate and/or temperature which controls the division and metabolic rate of the cells. Such a context, alters the idea of how carbonate compensation works on timescales > 10 kyrs and changes perception of how coccolithophore calcification will act as a feedback on the shorter and longer term carbon sink. Furthermore, the growth rate of different species of coccolithophore has implications for their oxygen evolution rate, and evolutionary turn-over and this will be validated against the geological record.

This project has a number of dimensions assessing the time-dependent strength of the biological carbonate sink and its physiological basis. The project has at its centre, modern cultures to isotopes and morphology in sedimentary records, and could extend more towards biological understanding of the cellular processes or towards modelling of the past and future carbonate carbon sink depending on student motivation/background skills. The primary aim is to ground-truth emerging hypotheses about calcification rates across the different species. This will be achieved by growing different strains of coccolithophore of contrasting morphological features under conditions of altered nutrient, temperature, calcium and carbon availabilities together with isotopic analysis- designed to match boundary conditions of the more recent geological past (glacial-interglacial cycles) and more distant geological past (Cenozoic). Traditionally, much focus has been placed on the physics and chemistry of ocean processes for the sequestration of CO_2 during glacial periods, but this emerging view of a dynamic biologically controlled carbon sink to sediments reinvigorates debate that the longer term sedimentary sink may also play a major role in CO_2 sequestration even on glacial timescales (Adloff et al., 2025). The student will generate records of cell size and metabolic/growth rate from sedimentary records over multiple glacial cycles to resolve whether changes in nutrient availability or decreasing temperature drive slower or faster metabolic rates during glacial periods, and assess the impacts on the atmospheric composition.

Methodology

Laboratory batch culture of different species of coccolithophores in a matrix of conditions with varying $\text{CO}_2(\text{aq})$, Ca, P and temperature to assess both the cellular, and community production rates of calcite via alkalinity drift. The cells will be assessed for growth rate, size, isotopic composition and importantly we will also measure the oxygen production efficiency of differently sized cells (or the photosynthetic quotient) under these changing conditions.

Establish methodologies using the Coulter Counter for measuring the carbonate particle size spectrum of sediments by establishing the degree of filtering and size-separation that is

needed. Develop a record of coccolithophore size changes through the last 1 Million years and create size-separated fractions for isotopic and trace metal analysis. Generate physiological signatures of changing carbonate production rates, at high and low latitude sites and assess how those physiological controls on production rates affect carbonate burial rates.

Timeline

Year 1: Initial dilute batch experiments resolving the appropriate matrix of conditions and selection of species. Set up of O₂ electrode assays. Harvesting of cell material for “omics” analysis and isotopes. Selection of cores for analysis and sending in of request for core material.

Years 2 and 3: Establishment of Coulter Counter methods for sedimentary interrogation and derivation of evolutionary turn over. Size separation of sediments for isotopic analysis. Depending on interest: interrogation of omics data for cultures, or setting up of computer modelling methodology.

Year 4: Data integration, thesis completion, papers for international journals/conference presentation.

Training & Skills

The student will be trained in laboratory culture of marine algae, the derivation and analysis of omics datasets, and the analysis and interrogation of stable isotope fractionation data. The student will work in an interdisciplinary way with both the Earth Science Department and the Biological Science Department. Through group meetings, the student will be training in oral presentation skills and over the course of the PhD will also acquire writing skills.

References & Further Reading

List of relevant texts formatted as follows:

N Chauhan, REM Rickaby, [Size-dependent dynamics of the internal carbon pool drive isotopic vital effects in calcifying phytoplankton](#), *Geochimica et Cosmochimica Acta* 373, 35-51

The coccolithophore section of:

<https://www.sciencedirect.com/science/article/abs/pii/B9780323997621001285?via%3Dihub>

Adloff et al., 2025; <https://egusphere.copernicus.org/preprints/2024/egusphere-2024-1754/>

Further Information

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