Growth-rate controlled trace metal uptake by modern calcifying marine algae

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This project will contribute to the development of a reliable proxy for the cellular growth rate (µ) of ancient populations of coccolithophore marine phytoplankton. Quantifying these ancient growth rates will provide important information about ancient marine ecosystems, such as upwelling intensity and dynamics, but is also a key factor in reducing uncertainty in one of the primary means of estimating ancient atmospheric carbon dioxide levels. This method, based on the carbon isotope fractionation occurring during photosynthesis by the coccolithophore algae, is determined by both CO_2 availability in the surface ocean and µ. An accurate estimate of past CO_2 thus relies on an accurate assessment of coccolithophore growth rates in ancient populations. There is substantial evidence from laboratory culture studies that strontium incorporation into the calcite scales (coccoliths) of the coccolithophore algae is also determined by the growth rate of the host cell. This project seeks to develop a fuller understanding of the controls on coccolith Sr/Ca ratios in natural populations. It will apply a new technique for trace metal analyses of single coccoliths to produce Sr/Ca population data for coccoliths sampled directly from the surface ocean, from shipboard bioassay experiments, sediment traps and core-top sediments. This will, for the first time, quantify the cause of Sr/Ca variability in natural populations, develop an understanding of the temporal averaging of this signal and, by studying different oceanographic regimes, establish the fingerprint of seasonal upwelling, persistent upwelling and oligotrophic systems in ocean sediments.

Although laboratory cultures of coccolithophore species indicate a strong growth-rate control on the incorporation of strontium into coccolith calcite [*Rickaby et al.*, 2002] and Sr/Ca data from coccolith-rich sediment fine fractions that indicate that this signal is transmitted to the marine sedimentary archive [*Fink et al.*, 2010; *Stoll and Schrag*, 2000], a clear quantitative understanding of this sedimentary record has been hampered by 1) the mixing of multiple taxa with different Sr/Ca fractionations, and 2) the time averaging of populations formed under different trophic conditions, from seasonal mixing to millennial climate variability. The proposed project will address these problems by employing a combination of Secondary Ionisation Mass Spectroscopy (SIMS) analyses of single coccolith Sr/Ca and ICP-OES analyses of size specific micro-separations of core-top sediments. This allows, for the first time, the quantification of Sr/Ca variability within a population of coccoliths of a single species and an accurate assessment of taxonomic mixing and temporal averaging by analysing the following samples:

- plankton samples collected direct from the surface ocean which are associated with full determinations of cell numbers, nutrients, temperature, salinity and carbonate chemistry;
- shipboard bioassay experiments with variable growth rates and carbonate chemistry;
- time series sediment trap and core-top sediment samples from a range of productivity regimes;

These datasets will provide a unique constraint on both the primary controls on coccolith Sr/Ca in natural populations and an understanding of how temporal variability in growth rates is reflected in the frequency distributions of coccolith Sr/Ca in sediment traps and core-top sediments. The shift from mean Sr/Ca values (bulk-carbonate) to determining coccolith frequency distributions and micro-filtered size separations has the potential to be a major advance in the extraction of information from sediment hosted coccolith assemblages. This project will make use of modern coccolith material collected during a number of recent and planned research cruises associated with the UK Ocean Acidification programme and NERC Shelf Sea Biogeochemistry Programme.

***Benefits and training*:** This studentship will provide a detailed training in modern coccolithophore taxonomy, phytoplankton ecology and fundamental geochemical analysis techniques (SIMS and ICP-OES). Co-supervision will be provided by world-leading experts in modern coccolithophore ecology (Young and Poulton), trace metal geochemistry (Anand) and the application of the Sr/Ca nutrient proxy to paleoceanographic research (Dunkley Jones).

Fink, C., et al. 2010, *Geobios-Lyon*, *43*(1), 151-164; Rickaby, R. E. M., et al. 2002, *Glob. Biogeochem. Cycle*, *16*(1), 1006; Stoll, H. M., and D. P. Schrag 2000, *Geochem. Geophys. Geosyst.*, *1*(1), doi:10.1029/1999GC000015.

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