Isotopic response of Pleistocene coccoliths to an ambient \( p\text{CO}_2 \) change: a calibration experiment

Camille Godbillot
Institut des Sciences de la Terre de Paris (UMR 7193 ISTeP), CNRS/Sorbonne Université – Paris, France.
Aix Marseille Univ, CNRS, IRD, INRAE, CEREGE – Aix-en-Provence, France. godbillot@cerege.fr

Fabrice Minoletti
Institut des Sciences de la Terre de Paris (UMR 7193 ISTeP), CNRS/Sorbonne Université – Paris, France

Franck Bassinot
Laboratoire des Sciences du Climat et de l’Environnement (UMR 8212 LSCE), CNRS/CEA/Université Versailles Saint Quentin – Gif sur Yvette, France

Michaël Hermoso
Laboratoire d’Océanologie et de Géosciences (UMR 8187 LOG), CNRS/Université du Littoral Côte d’Opale/Université de Lille/IRD – Wimereux, France

For geological periods where direct measurements of \( p\text{CO}_2 \) performed on ice cores are not possible, the reconstruction of this key paleoclimatic parameter can only be achieved through proxy data. Results from both \textit{in vivo} cultures and cell modelling biogeochemical studies have demonstrated a link between the biological fractionation of coccoliths and the \( \text{CO}_2 \) concentration of the living environment of their producers, the coccolithophores. Changes in the \( \text{CO}_2 \) levels of the surface ocean also drive, on a geological timescale, the isotopic composition (vital effect) of Cenozoic coccoliths. These results have encouraged the use of coccolith vital effects as proxies for seawater \( \text{CO}_2 \) concentrations. However, a number of potential biases may hinder the application of the empirical calibrations from culture experiments to wild coccolith populations. This work formalizes a transfer function linking the vital effects of fossil coccoliths to the constrained values of Pleistocene [\( \text{CO}_2_{\text{aq}} \)], with a view to develop a new tool to reconstruct older \( p\text{CO}_2 \) levels.

The calibration relies on the carbon and oxygen isotopic analyses of purified fractions of coccoliths from the North Atlantic core MD95-2037 across Termination II (ca. 140-130 ka). Using the alkenone-based sea-surface temperature (SST) record available at the site and atmospheric \( \text{CO}_2 \) concentrations from the Antarctic ice cores, we derived values for surface ocean \( \text{CO}_2 \) concentrations across the deglaciation. We quantified the changing magnitude of the vital effect of the coccoliths to the presumed forcing by \( \text{CO}_2 \) and formulated a transfer function between the two parameters. We evidence a control of \( \text{CO}_2 \) concentrations on the isotopic difference (\( \Delta^{18}\text{O}, \Delta^{13}\text{C} \)) between coccoliths of different sizes produced across the penultimate glacial-interglacial transition. We discuss the factors complicating the obtained relationship, including the effect of growth rate changes and/or air-sea disequilibrium. As a perspective to this work, we discuss the possible application of this calibration to more ancient periods in the Cenozoic, where direct measurements of \( p\text{CO}_2 \) are not available.