Carbonate Mud Formation in Lac d'Ilay: A Microbially Driven Sedimentary Carbon Sink

Emmanuelle Vennin*[1], Pierre Boussagol[2], Sébastien Motreuil[2], Aline Bonnotte , Aline Bonnotte[3], and Pieter Visscher[4]

[1]UMR CNRS 6282 Biogéosciences – CNRS : UMR6282, Université de Bourgogne – Université de Bourgogne, 6 boulevard Gabriel, 21000 Dijon, France
[2]UMR CNRS 6282 Biogéosciences – CNRS : UMR6282, Université de Bourgogne – France
[3]Plateforme DImaCell, UMR 1347 Agroécologie, INRAE – INRAE – France
[4]Departments of Marine Sciences Earth Sciences, University of Connecticut, Storrs, CT 06269, USA. – États-Unis

Résumé

Carbonate mud plays a critical role in the global carbon cycle, serving both as a long-term sink for atmospheric CO and as a key archive for reconstructing past climates. Despite its importance, the mechanisms underlying carbonate mud (micrite) formation remain debated. Here, we present an integrated model for micrite formation based on a combination of novel bio-physicochemical analyses applied to deep sediments from Lac d'Ilay, a Jurassian lake in France. Our study reveals that active carbonate precipitation occurs down to at least 1.2 meters within the sediment, and micrite mineralization continues through the entire core depth dated to approximately 2,000 years. This process is tightly linked to the production and subsequent degradation of exopolymeric substances (EPS), primarily derived from recurring pelagic phytoplankton blooms and supplemented by benthic microbial communities. In the water column, high concentrations of EPS (1.8–3.0 mg·L^{1}) were measured, yet only minor carbonate crystallization ($<$ 5 μm) was observed due to undersaturation with respect to calcite and aragonite. Upon settling, EPS accumulates in the sediment, where its concentration declines progressively with depth-from _˜50 μg·g^{1} dry sediment at the surface to _˜1.5 μg·g^{1} at the bottom of the core. This vertical gradient is accompanied by a loss of EPS functional properties (acidity, protein, and sugar content), suggesting microbial degradation.

Cryo-SEM imaging reveals that micrite nucleation occurs at the nodes of degraded EPS, with progressive crystallization correlating with EPS decomposition and calcium release. Our results demonstrate that microbial degradation-via both aerobic and anaerobic heterotrophic processes-reduces the calcium-binding capacity of EPS, releasing calcium ions that subsequently precipitate as micrite.
This study challenges the classical view that carbonate mud forms primarily in the water column or via purely abiotic pathways. Instead, it highlights the sediment column as a dynamic site of carbonate precipitation, driven by organic matter transformation. The production of micrite through microbial degradation of EPS underscores the sediment's role not only as a passive carbon sink but as an active generator of biogenic carbonate. These findings have significant implications for interpreting fossil micrite deposits and for understanding biogeochemical feedbacks in carbon cycling over geological timescales.

*Intervenant

Mots-Clés: mud, carbonate, microbes, lac Ilay, Jura