

# Importance of Calcareous Shells in Aggregate Formation and Particle Decomposition for the Coccolithophore *Emiliana huxleyi*

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## I. Motivation:

Reports showing a close relationship between the deep export of organic carbon and minerals indicate that organisms with mineral shells such as coccolithophorids are of special importance for carbon export in the ocean. Several hypotheses about the mechanism behind this coupling of mineral and organic fluxes have been raised, such as the ballast hypothesis and the mineral protection hypothesis. We examined aggregate formation and sinking as well as organic matter decomposition of calcareous and non-calcareous *Emiliana huxleyi* cells in an experiment that allowed aggregation and settling of the cells similar to what might occur in the water column.

## II. Material & Methods:

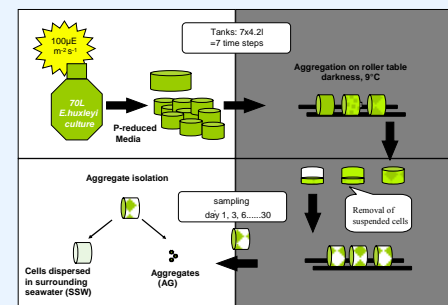


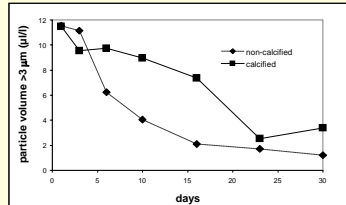
Fig. 1: Set-up of the decomposition experiment.

Calcifying (C) and non-calcifying (NCal) *Emiliana huxleyi* cells were grown in batch culture under the following conditions: 15°C, f/4 media, psu=35.1, 100 μmol photons m<sup>-2</sup> s<sup>-1</sup> (16h: 8h light: dark cycle). At late exponential growth phase, each culture was transferred to 9 4.5-L tanks and 1 10-L tank and kept in the dark at 9°C. To promote aggregation of cells, all tanks were placed on roller tables at 0.66 rpm. After an initial period of 5 days to allow aggregation, the particle concentration was lowered (to simulate sinking of aggregates into the deeper and more dilute water column) and sampling began. Each experiment lasted for 30 days with 7 sampling points (days 0, 3, 6, 10, 16, 23, 30), during each of which one tank was harvested and turned on its side for 20 min. to let aggregates settle. Aggregates and suspended particles in surrounding water were analyzed separately (Fig. 1).

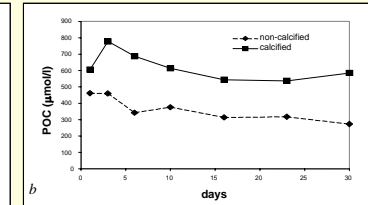
## IIIa Results: Decomposition of biogenic matter

Decomposition of particles was described by a first-order rate constant of decrease ( $k$ , d<sup>-1</sup>) of each component, calculated assuming first-order exponential decay:  $C(t) = C(0)e^{-kt}$

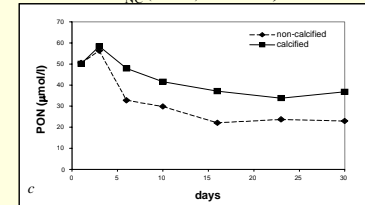
Particulate:  $k_C$  (d1-d30) = -0.027,  $r^2 = 0.91$   
 volume  $k_{NC}$  (d1-d30) = -0.068,  $r^2 = 0.98$



POC:  $k_C$  (d3-d30) = -0.011,  $r^2 = 0.77$   
 $k_{NC}$  (d1-d30) = -0.017,  $r^2 = 0.90$



PON:  $k_C$  (d3-d30) = -0.017,  $r^2 = 0.85$   
 $k_{NC}$  (d3-d30) = -0.030,  $r^2 = 0.85$



TEP:  $k_C$  (d3-d30) = -0.038,  $r^2 = 0.95$   
 $k_{NC}$  (d1-d30) = -0.048,  $r^2 = 0.86$

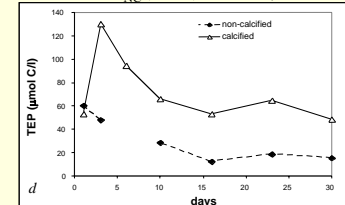


Fig. 2a-d: Decrease of organic matter components during the roller-table incubation experiments. C: calcified cells, NC: non-calcified cells,  $r^2$ : correlation coefficient, brackets indicate the time period considered for the data fit.

## IIIb. Results: Aggregation and sinking of biogenic matter

The final amount of POC in AGG was about 42% of the initial concentration for both experiments (Fig.4). Increase of POC in AGG followed a logistic growth function, indicating a limitation of the aggregation process after day 10.

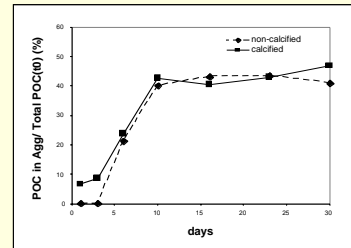


Fig. 4: Relative amount of POC contained in AGG.

Aggregates that formed during the NCal incubations covered a bigger size range and reached a larger final size than Cal aggregates (Fig. 5).

Despite this, *maximum* settling velocities were comparable for both incubations, and *average* settling velocities were actually higher for the Cal aggregates (since all Cal aggregates had sinking velocities of about 1.25-2.5 cm/s, whereas NCal sinking velocities ranged from about 0-2.25). Because Cal aggregates were more abundant and reached higher average settling velocities, sinking of Cal aggregates would be an efficient way for biogenic matter to be exported out of the surface ocean.

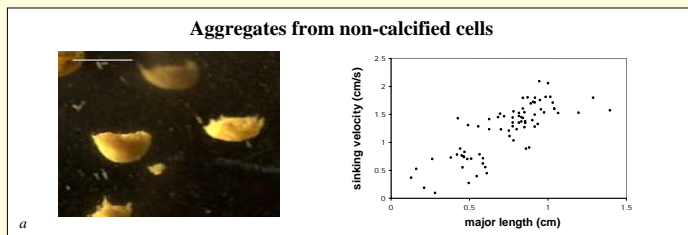


Fig. 5a,b: Left: Pictures of NCal-AGG (a) and Cal-AGG (b) within the roller tanks at day 15 of each experiment. Right: Settling velocities of AGG determined during the roller table incubations after Engel & Schartau, 1999, MEPS 182:69-76.

Amino acid and pigment compositions of all samples were compared by principle components analysis (Fig. 3). On principal component 1, calcified samples clustered near chlorophyll *a* (Chl *a*), indicating that they were comparatively fresh, and non-calcified samples clustered near the decomposition indicators pheophytin (Pptn), pheophorbide (Ppb), and β-alanine (BALA), indicating that they were comparatively degraded. Initial time points of both cultures clustered together, indicating they started with comparable freshness. Aggregates and suspended particles of both cell types were separated on principal component 2, suggesting they had compositional differences resulting from processes other than decomposition.

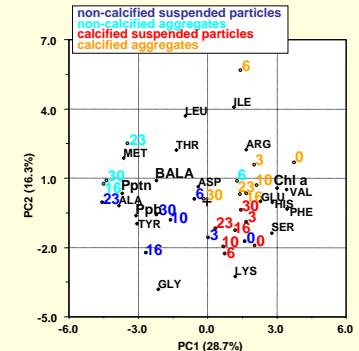
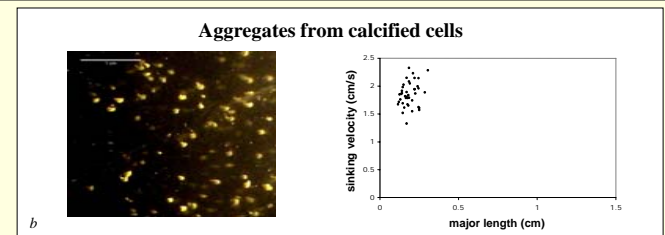






Fig. 3: Principal components analysis. Numbers represent sampling days. Axes are principal components 1 and 2, which explained 28.7% and 16.3% of variance in the data, respectively, and are scaled to sample site scores. Variable loadings are scaled up 10x to fit axes.



## IV Conclusions: Preservation & Ballast

-  *E. huxleyi* cells without a mineral shell were more subject to decomposition than calcified cells.
-  The association of minerals and organic matter reduces OM decomposition rates, either by protection of the cell in a coccosphere or by sorptive preservation of DOM.
-  Aggregates of calcareous cells reached higher average settling velocities and were more abundant than aggregates formed by naked cells.
-  OM associated with calcareous cells would be exported much faster and reach greater depths in a better state of preservation.

Acknowledgements: This work was supported by NSF grants OCE 01-36370 and 04-24845 (MedFlux) and by the Max Kade Foundation of New York.