SSD

SCIENCE FOR A SUSTAINABLE DEVELOPMENT

" ROLE OF PELAGIC CALCIFICATION AND EXPORT OF CARBONATE PRODUCTION IN CLIMATE CHANGE"

«PEACE»

L. CHOU, J. HARLAY, C. DE BODT, N. ROEVROS, J.-P. VANDERBORGNT, A.V. BORGES, K. SUYKENS, B. DELILLE, P. JOASSIN, S. SOLLBERGER, M. GRÉGOIRE, K. SABBE, N. VAN OOSTENDE, A. ENGEL, J. PIONTEK, N. HÄNDEL, C. BORCHARD, S. KOCH, A. BIERMANN AND M. LUNAU

ENERGY

TRANSPORT AND MOBILITY

AGRO-FOOD

HEALTH AND ENVIRONMENT

CLIMATE

BIODIVERSITY

ATMOSPHERE AND TERRESTRIAL AND MARINE ECOSYSTEMS

TRANSVERSAL ACTIONS

.be

SCIENCE FOR A SUSTAINABLE DEVELOPMENT
(SSD)

FINAL REPORT - Fase 1

ROLE OF PELAGIC CALCIFICATION AND EXPORT OF CARBONATE PRODUCTION IN CLIMATE CHANGE
"PEACE"

SD/CS/03

Promotors
Lei Chou
Université Libre de Bruxelles (ULB)
Laboratoire d'Océanographie Chimique et Géochimie des Eaux
Campus Plaine – CP 208, Boulevard du Triomphe, B-1050 Brussels

Alberto V. Borges
Université de Liège (ULg)
Unité d'Océanographie Chimique, B5
Allée du 6 Août 17, B-4000 Liège

Koen Sabbe
Universiteit Gent (UGent)
Protistologie & Aquatische Ecologie
Krijgslaan 281 S8, B-9000 Gent

Anja Engel
Alfred Wegener Institute for Polar and Marine Research (AWI)
'Global change and the future marine Carbon cycle' Group
Am Handelshafen 12, D-27515 Bremerhaven

Authors
L. Chou, J. Harlay, C. De Bodt, N. Roevros, J.-P. Vanderborght (ULB)
A.V. Borges, K. Suykens, B. Delille, P. Joassin, S. Sollberger, M. Grégoire (ULg)
K. Sabbe, N. Van Oostende (UGent)
A. Engel, J. Piontek, N. Händel, C. Borchard, S. Koch, A. Biermann,
M. Lunau (AWI)

Avenue Louise 231
Louizalaan 231
B-1050 Brussels
Belgium
Tel: +32 (0)2 238 34 11 – Fax: +32 (0)2 230 59 12
http://www.belspo.be

Contact person: Martine Vanderstraeten
+32 (0)2 238 36 10

L. Chou, J. Harlay, C. De Bodt, N. Roevros, J.-P. Vanderborght, A.V. Borges, K. Suykens, B. Delille, P. Joassin, S. Sollberger, M. Grégoire, K. Sabbe, N. Van Oostende, A. Engel, J. Piontek, N. Händel, C. Borchard, S. Koch, A. Biermann and M. Lunau. ***Role of pelagic calcification and export of carbonate production in climate change « PEACE » (SD/CS/03).*** Final Report. Brussels Belgian Science Policy 2009 – 121 p. (Research Programme Science for a Sustainable Development)

1. SUMMARY

In order to provide an accurate prediction of ocean organic and inorganic carbon storage, it is essential to understand the physical, chemical and biological controls governing the present and future marine ecosystem and ocean carbon dynamics. These also include biogeochemical responses to and feedbacks on climate change. One of the emerging and alarming issues concerns the ocean acidification, due to increasing atmospheric CO_2 concentration, and its impacts on marine ecosystems. The important role of calcification in the global carbon cycle has been increasingly recognized. A better understanding of the effects of changing pH and carbon system parameters on marine biogeochemical cycles and organisms is urgently needed to allow the evaluation of different scenarios of CO_2 increase and mitigation strategies. Redressing this concern should be of high priority within research agendas. This was especially important in the context of the preparation of the 2007 IPCC assessment report and will contribute to the scientific basis of the drafting of the second Kyoto Protocol (2012). As pointed out in a document prepared by a group of global change scientists on ocean acidification (The Royal Society of London, 2005), this issue also needs to be kept under review by international scientific bodies such as IOC, SCOR and IGBP. Furthermore, a bill was introduced recently to the US senate to establish an interagency committee to develop an ocean acidification research and monitoring plan and to establish an ocean acidification program within NOAA. The present research contributes to the core projects of the IGBP: AIMES, GLOBEC, IMBER, LOICZ and SOLAS.

The overall objective of the PEACE project is to evaluate the role in climate regulation of calcification, primary production and export processes during coccolithophorid blooms. We use a transdisciplinary approach that combines process-oriented field investigations with laboratory experiments and modelling tools. Specific objectives are:

1) to study the net ecosystem dynamics during coccolithophorid blooms,
2) to unravel the link between the bacterial community, grazing, transparent exopolymer particles (TEP) dynamics, carbon export and dimethylsulfide (DMS) cycling during coccolithophorid blooms,
3) to assess the effects of ocean acidification on coccolithophorid metabolism and TEP production, and
4) to model coccolithophorid dynamics and their impact on ocean dissolved inorganic carbon (DIC) chemistry.

The objectives of the project were met and major conclusions can be summarized hereafter.

In the period 2006-2008, intense phytoplankton blooms were observed and sampled along the shelf break of the Northern Bay of Biscay. These blooms were either

dominated by diatoms or coccolithophores (mainly *E. huxleyi*), with prasinophytes, dinoflagellates and cryptophytes as codominants, and were characterized by high spatial and (short-term and interannual) temporal variability in composition and biomass, as different phases of the spring bloom were sampled during the cruises. In general, the degree of water column stratification appeared to be a good predictor of bloom stage, with especially coccolithophores declining as stratification increased. Spatial and temporal patterns in bacterial community composition were complex and appeared to be highly station-specific; there was however little change with depth (0-80 m). While they roughly corresponded (directly or indirectly) to bloom composition, other factors (e.g. nutrients) also appeared to affect these communities.

Results from biogeochemical investigations showed that our study area acted as a sink for atmospheric CO_2. Hence, the balance of organic carbon fixation to inorganic carbon production during coccolithophorid blooms does not lead to a significant accumulation of CO_2 that would reverse the direction of the air-sea CO_2 flux (i.e. from a sink to a source of atmospheric CO_2). The impact of calcification on reducing the CO_2 sink in the study area is variable, but on average it is relatively small, ~12%. This implies that the potential feedback on atmospheric CO_2 of the projected decrease of pelagic calcification, due to the "production" of CO_2 from biogenic precipitation of $CaCO_3$, would probably be minor.

Our data also showed that benthic $CaCO_3$ dissolution rates over the continental shelf represent ~1% of the pelagic calcification rates. This suggests a decoupling of calcification by coccolithophores and the dissolution of $CaCO_3$ in the sediments. Particulate inorganic carbon (PIC) produced by coccolithophores is either stored in the sediments or exported out of the system, but does not seem to be significantly dissolved in the sediments.

Field investigations showed that the northern Biscay area is a zone of high calcite production as witnessed by reflectance images and ^{14}C incorporation measurements. Biogenic calcium carbonate may act as "ballast" and increases the transfer efficiency of particulate organic carbon (POC) from the surface ocean to the deep waters (Armstrong et al., 2002; Klaas and Archer, 2002). In addition, TEP production during coccolithophorid blooms has also been shown to enhance organic matter export (De la Rocha and Passow, 2007). During our cruises, the contribution of TEP-C to POC has been shown to be important. Thus, the ballast effect and the production of TEP could be responsible for a high export of particulate matter in the northern Bay of Biscay. The contribution of TEP in coccolithophore aggregates to the vertical export was not quantified in this study. Nevertheless, a large deposit of gelatinous matter was observed in late August 1995 along the slope of the N.W. European continental margin (de Wilde et al., 1998). Pigment analyses revealed that prymnesiophytes (coccolithophores, mainly *E. huxleyi*) were the major contributor to this mucus-rich aggregates layer, which was confirmed by SEM examination (de Wilde et al., 1998). The production of TEP could thus constitute the first step within the process of coccolithophore aggregation, sedimentation and seafloor deposition in the Bay of Biscay.

Our field data showed that high lysis rates co-occurred with a high microplankton grazing rates, together forming key sources of phytoplankton mortality. Both processes tended to intensify with increasing water column stratification, suggesting an indirect bottom-up control on phytoplankton loss. These results can be paralleled with increasing community pelagic respiration, bacterial production, and an evolution towards net heterotrophy with increasing stratification. In addition to grazing and cell lysis, viral cell lysis was identified as an additional loss term that could be significant (in accodance with previous mesocosm experiements) yet poorly investigated and quantified in the field.

Finally, our biogeochmical investigations allowed a better understanding of the TEP dynamics under naturally occurring bloom conditions:

- Dissolved acidic sugars are an important source for TEP production during coccolithophorid blooms in the Bay of Biscay
- Analysis of size spectrum of particles suggests assembly of lager particles from smaller ones by aggregation.
- Important concentrations of TEP were observed at the sediment-water interface (up to 10% of the pelagic TEP stock), which suggests that sediment deposition and diagenetic degradation could be a major fate of pelagic TEP.

Our laboratory experiments yielded new results, which contribute to a better understanding of the future response of C cycling in pelagic calcifying communities to ocean acidification and other global change factors (e.g. temperature):

- Calcification per cell decreased by 34% in the culture at present pCO_2 and by 7% in the one at future pCO_2 with a temperature increase of 5°C
- Changes in polysaccharide composition indicate that the surplus of free glucose generated by higher glucosidase rates was efficiently metabolized by bacterioplankton and that the bacterial substrate supply was improved under simulated future-ocean pH
- Lowering of pH potentially changed the equilibrium between TEP-precursors and TEP for the benefit of TEP formation. Further investigations are needed to explore the underlying mechanisms of increased TEP formation in response to increasing pCO_2
- Net production of particulate organic matter (POM), such as POC and TEP, decreased significantly with increasing pCO_2 in contrast to previous studies. This is due to the increase in bacterial biomass production under nutrient deplete

conditions with increasing pCO_2, suggesting that the response to ocean acidification may depend on the ecosystem status, i.e. on the balance between autotrophic and heterotrophic communities.

- Rising pCO_2 induced a decrease in the PIC:POC ratio and reduced the sinking velocity of aggregates of *Emiliania huxleyi*. Our findings therefore suggest a reduced deep-export of organic matter in the ocean, if pCO_2 in seawater further increases.

Overall, the results obtained during PEACE reveal that our understanding of the effects of ocean acidification on marine biogeochemistry, carbon cycling and potential feedbacks on increasing atmospheric CO_2 is still in its infancy. Further research is required to reduce uncertainties and to improve our knowledge before a robust and credible implementation in mathematical models can be achieved, allowing the projection of a plausible future evolution of carbon biogeochemistry under global change. Such future research will necessitate a multitude of approaches, such as a combination of laboratory experiments, field measurements and modelling as carried out in the framework of the PEACE project.

Key words: marine carbon cycle, ocean acidification, pelagic calcification, biogenic calcium carbonate, carbon dioxide uptake by the oceans, air-sea fluxes