Foraminifers as proxy of the marine carbon cycle and ocean acidification

R. Schiebel, C. Barras, H. Howa, F. Jorissen, A. André, J. Meilland, A. Movellan, S. Terrien

La pompe organique de carbone est responsable de l'exportation de carbone de la surface vers l'océan profond, et affecte ainsi la concentration en CO_2 dans l'atmosphère et l'océan, et par conséquent le climat. L'effet de la production de foraminifères à coquilles calcaires sur le rapport C_{inorg} / C_{org} a jusqu'à présent été considéré comme négligeable en raison du paradoxe des carbonates. Nous avons développé une nouvelle méthode pour quantifier le C_{inorg} et le C_{org} de différents foraminifères, et présentons une première évaluation de la biomasse globale des foraminifères planctoniques dans les océans actuels. Les rapports C_{inorg} / C_{org}, étant affectés par le pH de l'eau de mer et la rétroaction des organismes calcifiants sur l'acidification de l'océan (OA), doivent être inclus dans les scénarios actuels de climat. De plus, ces rapports peuvent être utilisés dans les reconstitutions paléo-océanographiques comme proxy des budgets de carbone planctoniques et benthiques, des couplages pelagos-benthos, et ajoutent une information essentielle sur les transferts de CO_2 entre la basse atmosphère et l'océan profond affectant le climat global.

Method development

Foraminifers provide ideal proxies in paleoceanography, because they are ubiquitous, and their immediate effect on the environment is negligible. We have developed a new nano-photo-spectrometrical method for protein-biomass quantification in a single foraminifer test as proxy of rain-ratio (C_{inorg} / C_{org}) and biological carbon pump (**Fig. 1**; PhD thesis A. Movellan, Angers Univ., 2009-2013, and **[3]**).
Morphometric data (test size and weight), biomass, and shell-carbon data allow reconstruction of the paleo-production and sedimentation of foraminifers. In addition, size-normalized test weight is proxy of the carbonate ion concentration $[CO_3^{=}]$, *p*H, and $[CO_2]$ of the past seawater and surface sediment **[2]**. The new method was developed on the modern benthic foraminifer *Ammonia tepida* (**Fig. 1**), and applied to live planktic foraminifers (PF) sampled from the water column.

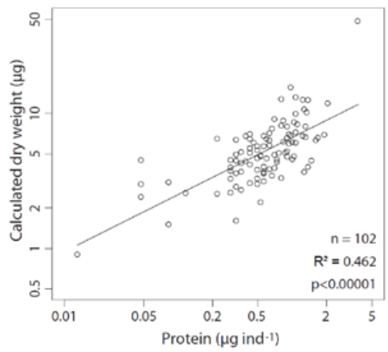

Fig. 1. Protein-to-test weight relation of the benthic foraminifer *A. tepida* (residual standard error of 0.387 **[2]**).

First biomass budgets

Modern planktic foraminifer (PF) biomass includes regional and basin-scale differences of four orders of magnitude (**Fig. 2**). A first 'global' PF biomass budget **[1]** is currently extended to the southern hemisphere ocean (ongoing PhD thesis J.Meilland).

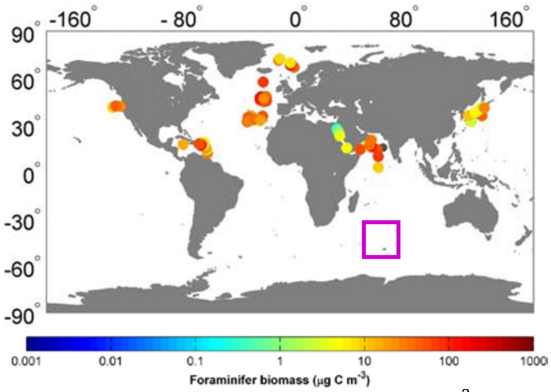

Fig. 2. Average PF biomass (Log_{10} μgC m^{-3}) at 0-25 m water depth, binned on a 3°×3° grid **[4]**. Data from the Southern Ocean (purple rectangle, PhD thesis J. Meilland) range the same scale as in N hemisphere.

Most importantly, water-depth related budgets show significant flux of C_{org} to subsurface waters, i.e. an active modern PF carbon pump. In turn, the global PF biomass is of negligible quantity, in comparison to other plankton groups like diatoms, and hence perfect indicator of the plankton biomass, and biological C-pump **[1]**. In addition, the global distribution of planktic foraminifers is sufficiently homogenous **[1]**, possibly not species-specific, and independent of water depth for any individual (PhD thesis A. Movellan, 2013).

Foraminifers and Ocean Acidification

PF test calcite mass is negatively affected by Ocean Acidification (Moy et al., 2009, Nature Geosc.). OA would hence be counterbalanced by reduced PF test calcification ($CaCO_3$ paradox). The effects of OA on PFs are possibly strongest in the Southern Ocean, where CO_2 uptake by the modern ocean is highest. We analyse modern and late Quaternary PF (sediment core MD04-2718, Kerguelen Plateau) for changes in faunal composition, size, biomass, and test calcite mass, for both the feedback of PFs to OA, and the consequent changes on the biological carbon pump. Direct effects of OA on the production and preservation of foraminifer $CaCO_3$ are analyzed in cultivated benthic foraminifers, i.e. *Ammonia aomoriensis* and *Elphidium incertum* **[2]**. First results indicate interspecific differences in the effect of AO on test production and preservation, as well as effects on the test chemistry (e.g., Mg/Ca ratio **[2]**). The effect of OA on the stable isotope (e.g., $\delta^{18}O$, $\delta^{11}B$, $\delta^{7}Li$), and trace metal composition (Me/Ca) will further be assessed on foraminifers from natural environments (project INSU-INTERRVIE), and foraminifers grown under controlled conditions (project LEFE-CYBER).

Collaborations

C.LoMonaco, LOCEAN, Paris VI
A.Mazaud, E.Michel, LSCE, Gif s/Yvette
S.Schmidt, EPOC, Bordeaux I
A.Gooday, M.Zubkov, NOC, UK
J.Schönfeld, GEOMAR, Germany
J.-P.Gattuso, N.Vigier, LOV, Villefranche-sur-Mer

Associated publications

[1] Buitenhuis, E.T., et al. incl. **Schiebel, R.**, 2013. MAREDAT: Towards a World Ocean Atlas of MARine Ecosystem DATa. Earth System Science Data 5, 227–239, doi:10.5194/essd-5-227-2013.

[2] Haynert, K., Schönfeld, J., **Schiebel, R.**, et al., 2014. Response of benthic foraminifera to ocean acidification in their natural sediment environment: a long-term culturing experiment. Biogeosciences, in print.

[3] **Movellan, A.**, 2013. La biomasse des foraminifères planctoniques actuels et son impact sur la pompe biologique de carbone. Thèse de doctorat, Univ. d'Angers.

[4] **Schiebel, R.**, **Movellan, A.**, 2012. First-order estimate of the planktic foraminifer biomass in the modern ocean. Earth System Science Data 4, 75–89, doi:10.5194/essd-4-75-2012.