Proposition de sujet de thèse 2024

(A remplir par les équipes d'accueil et à retourner à Isabelle HAMMAD : hammad@cerege.fr
**à renseigner obligatoirement pour la validation du sujet, (1) : A remplir lors de la campagne d'attribution des allocations, à l'issue de la session de juin des Masters*

Sujet de doctorat proposé *: Response of main calcifying plankton groups to environmental crises

Encadrant(s), *nom, prénom, adresse mail *: Thibault de Garidel-Thoron (HDR) et Olivier Sulpis*

Laboratoire *: CEREGE

Tableau récapitulatif du sujet

Candidat(e)(1)	
Nom - Prénom :	
Date de naissance :	
Licence (origine, années, mention) :	
Mention et classement au Master 1 année (Xème sur Y)	
Mention et classement au S3 du Master 2 (Xème sur Y)	
Mention et classement au S4 du Master 2 (Xème sur Y)	
Mention et classement au M2 (année) (Xème sur Y)	
MASTER (nom, université)	
Sujet de doctorat proposé*	
Encadrants (2 max, indiquer si HDR ou pas)*	Thibault de Garidel-Thoron (HDR) & Olivier Sulpis
Laboratoire*	CEREGE
Programme finançant la recherche (indiqué si obtenu ou envisagé) (1)	LEFE SENSEXPLOR (2024-2026) obtenu ; CARBONARA 2024 (FRB CESAB) obtenu ; DYNAMITE (FRB CESAB, 2024-2026) obtenu ; ASPERGE (NWO, 2022-2025) obtenu ; Deep-C (ERC StG, 2025-2030) envisagé

Sujet de doctorat proposé*

Intitulé* : **Response of main calcifying plankton groups to environmental crises**

Descriptif *:

The ocean mitigates climate change by taking up a quarter of the annual CO_2 emissions (Friedlingstein et al., 2023). Part of this carbon is stored in seawater in its dissolved form, and part of it is transformed into particulate matter that eventually leaves the surface ocean and reaches the seafloor. Planktonic organisms secreting a calcium carbonate ($CaCO_3$) shell occupy a key, ambivalent role in this scheme. First, the precipitation of their shell generates CO_2, thereby reducing the ocean CO_2 sink, while the sinking of their shell constitutes a direct export of C to the deep ocean. Meanwhile, the dissolution of their shells generates alkalinity, which in turn boosts the capacity of seawater to take up more CO_2 from the atmosphere. Thus, any environmental perturbation that affects calcifying planktonic organisms, either through migrations or changes in abundance, will necessarily affect how much CO_2 is taken up from the atmosphere and stored into the ocean. It is urgent to predict how calcifiers will respond to the current climate change in the next decades and centuries, but also important to understand how they responded in the past, in the many environmental crises across Earth history.

$CaCO_3$ is present in the ocean under two main mineral forms: calcite (the most stable form) and aragonite (the least stable form). The distribution, abundance and diversity of oceanic calcite producers (mostly foraminifera and coccolithophores) is relatively well understood and quantified, thanks to recently published global datasets such as *CASCADE* (De Vries, 2022) and *FORCIS* ((Chaabane et al., 2023), PI T. de Garidel-Thoron), and a similar effort is under way for aragonite producers (mostly pteropods), with the *DYNAMITE* project (FRB CESAB project, PI O. Sulpis). This abundance of data enables, for the first time, to train ecological niche models that, when coupled with environmental data (seawater temperature, acidity, chlorophyll concentration), are able to predict the abundance of a certain species or group, at a given location and time, in the future or in the past.

During the Cenozoic (66 million years ago until today), the Earth experienced different environmental crises, with the last few decades standing out as the most extreme. First, **during the Paleocene-Eocene Thermal Maximum, the release of carbon within the ocean-atmosphere system warmed the Earth by ~5°C over a roughly 100 ka period** (McInerney and Wing, 2011), disrupting the marine carbonate system through massive ocean acidification (Haynes and Hönisch, 2020). More recently, **the deglaciation from the Last Glacial Maximum (LGM), the coldest and most glaciated interval during the Cenozoic, has led to a warming of a similar magnitude but over a shorter timespan (~5°C over 10 ka)**. The LGM climate transition is very well documented (e.g. (Geoscience and 2009, 2009; Strack et al., 2022), yet, the commonalities of the response of planktonic communities' calcification have never been studied. **Since the end of the preindustrial era, human activities have released large quantities of CO_2 into the atmosphere which may cause, in most pessimistic scenarios, a warming of ~5°C over the 21st century**. Because these three environmental crises are associated with warming of similar magnitudes, but over very different paces, the response of the biosphere is expected to be very different. This leads to the following questions: **how do different calcifying planktonic groups respond to environmental crises? How does the pace of environmental changes constrain the ability of plankton communities to adapt? How do plankton migrations and community changes affect the surface-ocean CO_2 sink in return?**

To address the overarching questions, several hypotheses can be formulated and tested, aiming to elucidate the relationships between environmental variables and the abundance, distribution, and behavior of calcifying planktonic organisms, as well as the consequent effects on CO_2 sequestration processes:

H1 : The creation of more niches through the Cenozoic long term stratification of the global ocean, is synchronous with an increase in functional diversity of planktonic foraminifera, which colonized deeper waters in the water column(Boscolo-Galazzo et al., 2021, 2022). The colonization increased the resilience of ecosystems to environmental crises over time, influencing the adaptive responses of coccolithophorids and pteropods;

H2 : The current environmental crisis has an exceptionally rapid pace, which will drive most calcifying planktonic species to extinction, whereas past crises across the Cenozoic allowed more time for planktonic communities to adapt through migrations;

H3 : Calcification drops caused by environmental crises constitute a short-term CO_2 sink, mitigating climate change. Aragonite producers play a disproportionately important role in this feedback mechanism.

To test these hypotheses, a combination of approaches will be deployed by the PhD student :

- **Data synthesis:** collect and analyze data on the current distribution and abundance of calcifying planktonic organisms from existing global datasets, e.g., *CASCADE*, *FORCIS*, *DYNAMITE* in the modern ocean ; *Paleobiology Database* for extinct species, *Triton* for planktonic foraminifera (Fenton et al., 2021), *CLIMAP* and *MARGO* for the LGM. Incorporate associated environmental parameters (temperature, pH, chlorophyll concentration).
- **Ecological niche modeling:** train ecological niche models (e.g., *GRNN*, *ESM*) using the gathered ecological and environmental data, and predict the distribution and abundance of calcifying planktonic organisms for the three identified environmental crises events (PETM, LGM, 21st century). For each event, corresponding environmental conditions will be extracted from Earth System model simulation outputs, from the *DeepMIP*, *PMIP* and *CMIP* model ensembles.

- **Carbonate system calculations:** from the predicted calcification changes and from modeled seawater chemistry fields (pH, alkalinity), compute the feedback on seawater CO_2 content and, by extension, on the CO_2 fluxes between the surface ocean and the atmosphere.

The student needs to be comfortable in coding with Matlab and handling large datasets, and should have basic knowledge in ecology and environmental chemistry. The main project supervisors will be Thibault de Garidel and Olivier Sulpis (CEREGE), in strong collaboration with modellers of ecological niche (Gregory Beaugrand, Université de Lille; Sonia Chaabane, CEREGE) and Earth system (Yannick Donnadieu and Pierre Maffre, CEREGE).

References:

Boscolo-Galazzo F, Crichton KA, Ridgwell A, et al. (2021) Temperature controls carbon cycling and biological evolution in the ocean twilight zone. *Science* 371(6534): 1148–1152.
Boscolo-Galazzo F, Jones A, Dunkley Jones T, et al. (2022) Late Neogene evolution of modern deep-dwelling plankton. *Biogeosciences* 19(3). Copernicus GmbH: 743–762.
Chaabane S, de Garidel-Thoron T, Giraud X, et al. (2023) The FORCIS database: A global census of planktonic Foraminifera from ocean waters. *Scientific data* 10(1): 354.
De Vries JC (2022) *Coccolithophore ecology with a special focus on their life cycle and standing stocks*. Monteiro F (ed.). PhD. University of Bristol.
Fenton IS, Woodhouse A, Aze T, et al. (2021) Triton, a new species-level database of Cenozoic planktonic foraminiferal occurrences. *Scientific data* 8(1): 160.
FRB CESAB (2024). DYNAMics of the production and export of aragonITE shells. Retrieved from <https://www.fondationbiodiversite.fr/en/the-frb-in-action/programs-and-projects/le-cesab/dynamite/>
MARGO Project Members. 2009. "Constraints on the Magnitude and Patterns of Ocean Cooling at the Last Glacial Maximum." *Nature Geoscience* 2 (2): 127–32. https://doi.org/10.1038/ngeo411.
Haynes LL and Hönisch B (2020) The seawater carbon inventory at the Paleocene-Eocene Thermal Maximum. *Proceedings of the National Academy of Sciences of the United States of America* 117(39): 24088–24095.
McInerney FA and Wing SL (2011) The Paleocene-Eocene Thermal Maximum: A Perturbation of Carbon Cycle, Climate, and Biosphere with Implications for the Future. *Annual review of earth and planetary sciences* 39(Volume 39, 2011). Annual Reviews: 489–516.
Strack T, Jonkers L, C Rillo M, et al. (2022) Plankton response to global warming is characterized by non-uniform shifts in assemblage composition since the last ice age. *Nature ecology & evolution* 6(12): 1871–1880.

Détail des Programmes finançant la recherche* : LEFE SENSEXPLOR (2024-2026) ; CARBONARA (FRB CESAB - 2024) ; DYNAMITE (FRB CESAB); ASPERGE (NWO, 2022-2025)

Directeur(s) de thèse proposé(s)*

(limiter au plus à deux personnes principales, dont au moins une titulaire de l'HDR)

Directeur HDR proposé*

Nom - Prénom : de Garidel-Thoron, Thibault
Corps : DR CNRS
Laboratoire (i.e. formation contractualisée de rattachement, éventuellement équipe au sein de cette formation) :
Adresse mail : garidel@cerege.fr

Choix de cinq publications récentes (souligner éventuellement les étudiants dirigés co-signataires) :

Adebayo, Michael B., Clara T. Bolton, Ross Marchant, Franck Bassinot, Sandrine Conrod, and **Thibault de Garidel-Thoron**. 2023. "Environmental Controls of Size Distribution of Modern Planktonic Foraminifera in the Tropical Indian Ocean." *Geochemistry, Geophysics, Geosystems* 24 (4). https://doi.org/10.1029/2022gc010586.

Bourel, B., R. Marchant, **T. de Garidel-Thoron**, M. Tetard, L. Beaufort, Y. Gally, and Barboni D. 2020. "Automated Recognition by Multiple Convolutional Neural Networks of Modern, Fossil, Intact and Damaged Pollen Grains." *Computers & Geosciences*. https://doi.org/10.1016/j.cageo.2020.104498.

Chaabane, S., **T. de Garidel-Thoron**, X. Giraud, R. Schiebel, G. Beaugrand, G.-J. Brummer, N. Casajus, et al. 2023. “The FORCIS Database: A Global Census of Planktonic Foraminifera from Ocean Waters.” *Scientific Data* 10 (1): 354. https://doi.org/10.1038/s41597-023-02264-2.

Marchant, R., M. Tetard, A. Pratiwi, M. Adebayo, and **T. de Garidel-Thoron**. 2020. “Automated Analysis of Foraminifera Fossil Records by Image Classification Using a Convolutional Neural Network.” *Journal of Micropalaeontology* 39 (2): 183–202. https://doi.org/10.5194/jm-39-183-2020

Suárez-Ibarra, J. Y., Tiago M. Freire, C. F. Frozza, Tainã M. L. Pinho, S. M. Petró, Bruna B. Dias, T. Chalk, et al. 2023. “Surface Fertilisation and Organic Matter Delivery Enhanced Carbonate Dissolution in the Western South Atlantic.” *Frontiers in Ecology and Evolution*. https://doi.org/10.3389/fevo.2023.1238334.

Thèses encadrées ou co-encadrées au cours des quatre dernières années*
Nom : **Jaime Yesid Suarez-Ibarra**
Intitulé : Morphometric response of planktonic foraminifera (Neogene and Quaternary) to environmental parameters
Type d'allocation : ERASMUS-+ Univ. Prague, Tchéquie
Date de début de l'allocation de doctorat : 1er décembre 2020
Date de soutenance (si la thèse est soutenue) : soutenance prévue en octobre 2024
Programme finançant la recherche : ERASMUS-+ Univ. Prague; Johanna M. Resig Foraminiferal Fellowship from the Cushman Foundation.
Situation actuelle du docteur (si la thèse est soutenue) : N/A
Pourcentage de participation du directeur à l'encadrement en cas de co-direction : 50 % depuis sept. 2023 (changement de direction de thèse).

Nom : **Michael Adebayo**
Intitulé : Dynamique de l'océan équatorial pendant les périodes chaudes Plio-Pléistocène par analyse automatisée des foraminifères planctoniques
Type d'allocation : Allocation Ecole Doctorale 251 (bourse “président”)
Date de début de l'allocation de doctorat : 1er octobre 2019
Date de soutenance (si la thèse est soutenue) : 16 octobre 2023
Programme finançant la recherche : Projet LEFE IndSo
Situation actuelle du docteur (si la thèse est soutenue) : recherche emploi (reconversion professionnelle industrie)
Pourcentage de participation du directeur à l'encadrement en cas de co-direction : 50%

Autre directeur proposé (*éventuellement*)*

Nom - Prénom : Sulpis Olivier
Corps : CR CNRS
Adresse mail : sulpis@cerege.fr
Laboratoire (i.e. formation contractualisée de rattachement, éventuellement équipe au sein de cette formation) : CEREGE
Choix de cinq publications récentes (souligner éventuellement les étudiants dirigés co-signataires) :

van de Mortel, H., Delaigue, L., Humphreys, M. P., Middelburg, J. J., Ossebaar, S., Bakker, K., Trabucho Alexandre, J. P., van Leeuwen-Tolboom, A. W. E., Wolthers, M., & **Sulpis, O.** (2024). Laboratory Observation of the Buffering Effect of Aragonite Dissolution at the Seafloor. *Journal of Geophysical Research: Biogeosciences*, 129, e2023JG007581.
Sulpis, O., Jeansson, E., Dinauer, A., Lauvset, S.K. and Middelburg, J.J. (2021) Calcium carbonate dissolution patterns in the ocean. *Nature Geoscience*, 14: 423-428.
Sulpis, O., Boudreau, B.P., Mucci, A., Jenkins, C.J., Trossman, D.S., Arbic, B.K. and Key, R.M. (2018) Current $CaCO_3$ dissolution at the seafloor caused by anthropogenic CO_2. *Proceedings of the National Academy of Sciences* 115: 11700-11705.
Sulpis, O., Trossman, D.S., Holzer, M., Jeansson, E., Lauvset, S.K. and Middelburg, J.J. (2023) Respiration patterns in the dark ocean. *Global Biogeochemical Cycles*, 37(8).

Sulpis, O., Agrawal, P., Wolthers, M., Munhoven, G., Walker, M. and Middelburg, J.J. (2022) Aragonite dissolution protects calcite at the seafloor. *Nature Communications*, 13: 1104.

Thèses encadrées ou co-encadrées au cours des quatre dernières années*
Nom : **Hinne van der Zant (basé à l'université de La Rochelle)**
Intitulé : Modélisation des flux de matière et de gaz à effet de serre à l'interface sédiment/air/eau d'une vasière intertidale tempérée
Type d'allocation : Financement du département des Charentes Maritimes
Date de début de l'allocation de doctorat : Septembre 2023
Date de soutenance (si la thèse est soutenue) :
Programme finançant la recherche : La Rochelle Territoire Zéro Carbone
Situation actuelle du docteur (si la thèse est soutenue) :
Pourcentage de participation du directeur à l'encadrement en cas de co-direction : 50%

Nom : **Ben Cala (basé au NIOZ, Texel, Pays-Bas)**
Intitulé : BEYΩND the known drivers of marine carbonate mineral dissolution: closing the gap in the alkalinity budget
Type d'allocation : Financement de l'université d'Utrecht (Pays Bas)
Date de début de l'allocation de doctorat : Février 2022
Date de soutenance (si la thèse est soutenue) :
Programme finançant la recherche : Université d'Utrecht (Pays Bas)
Situation actuelle du docteur (si la thèse est soutenue) :
Pourcentage de participation du directeur à l'encadrement en cas de co-direction : 33%