NERC Research Experience Placement Scheme (1)

Project:

Imaging the coral biomineralization tool kit using a novel combination of skeletal geochemistry and immunohistology

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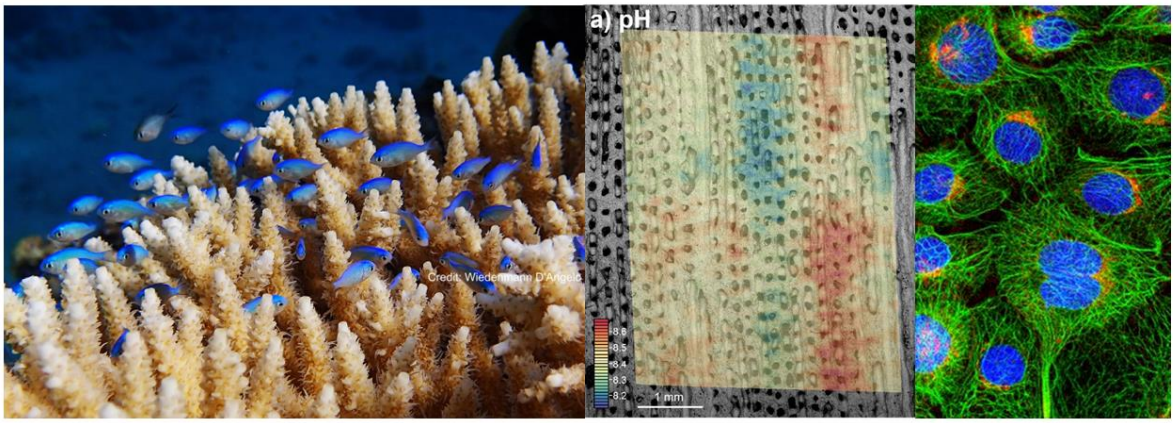

Stony coral reef, credit: Wiedenmann and D'Angelo (left), map of the variation in calcifying fluid pH in stony coral skeleton from Chalk et al. (2021; middle), Triple immunohistology labelling experiment, credit: BIU Southampton.

Introduction:

Tropical coral reefs are the ocean's most biodiverse ecosystem, home to over a million species and providing more than US$9.8 trillion each year worldwide in ecosystem services such as coastal protection, marine biodiversity, fisheries, and tourism. All these ecosystem services are dependent upon the three-dimensional framework of the reef that is constructed by stony corals.

Anthropogenic global climate change poses a number of multifaceted poses a number of multifaceted threats to stony corals, such as, ocean warming, heatwaves and ocean acidification, which are occurring concomitantly in many coral reefs with local pressures from pollution and overfishing.

Accurate prediction of the future impacts of these anthropogenic threats and their effective mitigation requires a better understanding of the toolkit corals use to construct their aragonite skeleton (a process known as biomineralization) and a knowledge of how sensitive it is to environmental change. Here, using a unique mix of cutting-edge imaging tools, you will provide powerful constraints on that toolkit and identify which particular aspects are most important.

Methodology:

Stony corals use a complex mixture of enzymatic processes to facilitate skeleton construction (reviewed in Gilbert et al. 2022). These include, but are not limited to, pumping protons (H+) out of the calcifying space to increase the pH of the calcifying fluid to aid aragonite precipitation, secreting the enzyme carbonic anhydrase to convert CO_2 and H_2O to the key ingredient HCO_3^- and producing organic acids to promote nucleation. Previous work has shown that these processes leave tell-tale fingerprints both on the chemical composition of the skeleton (Guo, 2019) and the proteins involved in biomineralization which are trapped in the growing skeleton (Mass et al. 2014).

Recent advances in laser ablation inductively coupled plasma mass spectrometry (LA-ICPMS) have provided spatial information about the biomineralization processes (Chalk et al. 2021), whereas immunohistology allows the distribution of skeletal proteins to be visualized (Mass et al. 2014).

Individually these approaches have provided useful insights into the mechanics of biomineralization, but when applied alone ambiguities remain. For instance, the LA-ICPMS approach reveals variations in the degree of calcification fluid pH increase across the skeleton, but cannot reveal what processes are responsible (Chalk et al. 2021).

On the other hand, immunohistology can reveal variations in the distribution of carbonic anhydrase, for example, but this doesn't tell us anything about how such variations impact skeleton formation.

Together these two imaging tools have the means to document how the coral changes the chemistry of its calcification fluid to facilitate calcification *and* potentially provide valuable insights into the processes responsible.

This project will combine these two imaging tools to achieve this for the first time.

This work is part of a multimillion Euro interdisciplinary project called Microns2Reefs (http://www.thefosterlab.org/microns2reefs) involving >10 researchers from across the University of Southampton and from other countries around the world.

As a team member you will be able to take part in Microns2Reefs group meetings and those of the Gavin's personal research group (www.thefosterlab.org) and the wider Geochemistry Research Group (https://www.southampton.ac.uk/research/groups/geochemistry) that Gavin leads.

References:

Chalk, T. B., Standish, C. D., D'Angelo, C., Castillo, K. D., Milton, J. A., and Foster, G. L., 2021, Mapping coral calcification strategies from in situ boron isotope and trace element measurements of the tropical coral Siderastrea siderea: Scientific Reports, v. 11, no. 1, p. 472.

Gilbert, P., Bergmann, K. D., Boekelheide, N., Tambutté, S., Mass, T., Marin, F., Adkins, J. F., Erez, J., Gilbert, B., Knutson, V., Cantine, M., Hernández, J. O., and Knoll, A. H., 2022, Biomineralization: Integrating mechanism and evolutionary history: Sci Adv, v. 8, no. 10, p. eabl9653.

Guo, W., 2019, Seawater temperature and buffering capacity modulate coral calcifying pH: Scientific Reports, v. 9, no. 1, p. 1189.

Mass, T., Drake, J. L., Peters, E. C., Jiang, W., and Falkowski, P. G., 2014, Immunolocalization of skeletal matrix proteins in tissue and mineral of the coral *Stylophora pistillata*: Proceedings of the National Academy of Sciences, v. 111, no. 35, p. 12728-12733.