NEWS FROM THE DEEP: MULTISCALE TISSUE MECHANICS OF COLD-WATER CORALS IN A CHANGING OCEAN

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Background

Ocean acidification is a threat to cold-water corals (CWCs) and could lead to dramatic and rapid loss of the reef framework habitat they build [1]. Weakening of structurally critical parts of the coral reef framework can lead to physical habitat collapse on an ecosystem scale [1,2], reducing the potential for biodiversity support. The mechanisms underpinning crumbling and collapse of CWCs can be described via a combination of laboratory-scale experiments and mathematical and computational models which I will illustrate in this talk.

Recent Advances

We sampled the main habitat forming CWC, *Lophelia pertusa,* from the Southern California Bight (SCB), a habitat representative of a future ocean. These CWCs are facing an aragonite concentration (Ω_{arag}) ranging between 0.67-1.86; the lowest Ω_{arag} condition that these corals have been recorded at to date [1]. We also sampled *L. pertusa,* from Scottish waters that are representative of a current ocean with Ω_{arag} between 1.67-2.62 [3].

We obtained data from electron back-scatter diffraction and Raman spectroscopy (n=60), synchrotron radiation micro-computed tomography (SRµCT, n=75), nanoindentation (n=45), XRD (n=15), micropillar testing (n=144) (Figure 1) [3], and TEM (n=18). We developed a micromechanical model, supplemented by molecular dynamics simulations [3], to integrate our experimental data and to predict failure of CWC structures under climate change impacts.

Increasing porosity and dissolution from exposure to corrosive waters and bioerosion but on the structural length-scale are the main drivers for crumbling and collapse of reef habitat. Interestingly, CWC skeletal material reaches 462 MPa compressive strength and 45-67 GPa stiffness. This is 10 times stronger than concrete, twice as strong as ultrahigh performance fibre reinforced concrete, or nacre [4,5]. Contrary to what would be expected, CWCs retain the strength of their skeletal material but seem to adapt its stiffness to address a lack of calcium carbonate when grown under future oceanic conditions. As this happens on the material length-scale, it is independent of increasing porosity and dissolution.

Future directions

Our results show how risk of crumbling of coral habitat can be assessed through evaluating increasing porosity and dissolution. We are currently generating a digital representation of the CWC material from crystal level to whole colonies (Figure 1). This will allow us to conduct data-driven analyses of habitat crumbling for entire reef systems. We complement our experiments and models with a database of >500 digitised CWCs from 1-30 cm (1 to >1000 branches). This information could help to determine tipping points of net reef habitat loss but also to develop assessment tools to quantify habitat provision of CWCs in present and projected future oceans [2].

Our results also point to mechanisms that allow CWCs to address some climate change impacts by adapting their skeletal building material. They grow a strong and tuneable biomaterial which is interesting for a range of applications from novel adaptive materials to implants. The digital material is key to facilitate translation and data-driven material processing in these developments.

Uwe is Assistant Professor in Mechanical Engineering at the School of Engineering and Physical Sciences, Heriot-Watt University. He was a postdoc at Bern University until 2015 and he obtained his PhD in 2011 at Ulm University focusing on multiscale mechanical properties of bone tissue. His present research concentrates on architectured mineralised tissues. He (co-)authored over 55 publications in peer-reviewed journals such as Nature Materials, Nature Climate Change, Acta Biomaterialia, Scientific Reports, and Bone as well as over 110 contributions to (inter)national conferences including 20 invited talks.

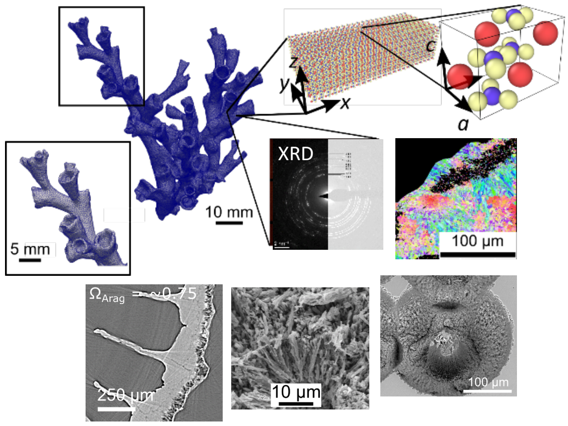

Figure 1: Visualisation of a digital CWC material integrating computational and experimental entities in an entity relationship model.

References

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