A (palaeo)ecological view on reconstructing high CO_2 worlds

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Modifications in carbonate chemistry of the ocean have a profound impact on marine calcifiers. Past events of proposed rapid changes in ocean pH are associated with extinctions, rapid changes in the composition of marine plankton and benthos, and impacts on calcification. Here, we present new data on the consequences of these ecological impacts on a wide range of our classical proxy carriers, including benthic foraminifers, coralline algae, deep sea corals and bivalves. Our data is derived from culture experiments, comparisons between historical samples and recently collected material and deep-time geological examples. Using Synchrotron X-Ray Tomography, Raman spectroscopy, Atomic Force Microscopy, Nano-indentation, Electron microprobe and (Nano)SIMS, we examine for changes in carbonate growth, elemental composition and material properties. By combining time scales and methodologies, we are highlighting the astonishing versatility of marine calcifiers to reallocate energy and thereby sustain calcification.

We show that ocean acidification can lead to both decreases and increases in carbonate produced by benthic calcifiers. Additionally, highly different taxa were found to sustain their growth even in undersaturated conditions. Importantly for temperature reconstructions, we found evidence that the elemental uptake is impacted leading to lower Mg concentrations under high CO_2 conditions in coralline algae. The lowering of the Mg concentrations at stable temperature conditions leads to an underestimation of the environmental temperature of 3.5° at 589 µatm compared to control. We speculate that the cause of this change might either be a physiological loss of control on elemental uptake or a strengthening of the skeleton by altering the material properties. A reduction in Mg affects the hardness/brittleness of the carbonate and hence the structural stability of the skeleton. In combination with strong biological control on the pH in the calcifying fluid, all of our results emphasise the complexity of the response to ocean acidification and the as yet unquantified impact on reconstructing past temperatures and pH.