Session 2: Climate Change and Biodiversity

Ocean Acidification – A Biogeological Perspective

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When CO_2 is absorbed from the atmosphere into the ocean, it forms carbonic acid and lowers pH. This process is commonly referred to as ocean acidification (OA). On geologic timescales, the CO_2 concentration in the atmosphere and the carbonate chemistry of the oceans are constantly changing and adjusting to forcing through tectonics, volcanism, weathering, biology and currently, the human race.

Relationships between the elemental and isotope composition of fossil remains and environmental parameters, so called proxy relationships or "proxies" for short, allow to reconstruct climates of the past. Proxy evidence suggest that atmospheric CO_2 concentrations have been much higher than today during long warm intervals in Earth's history and that those conditions were not harmful to e.g. calcifying organisms. In fact, the name Cretaceous with its high atmospheric pCO_2 was coined because of its massive limestone deposits from e.g coccolithophores that build the cliffs of Dover in the UK. Hence, it is a common misconception that high atmospheric pCO_2, per sé, goes hand in hand with reduced biocalcification. In fact, for most calcifying organisms the saturation state of the ocean with respect to calcium carbonate is more important than its pH.

If a carbon perturbation is slow enough, surface waters will remain supersaturated because dissolution of deep sea sediments and weathering of rock on the continent, can keep pace with the perturbation and the saturation state of the ocean with respect to calciumcarbonate is well regulated. As a consequence, calcifying organisms continue to form their skeletons in a well buffered ocean even when pH is low. On the other hand, organisms that actively regulate their acid-base balance will still be under pressure at a lower pH even though the saturation state of the ocean remains high, simply because they have to spend more metabolic energy on their pH regulation at the expense of other processes.

There have been periods in Earth's history where we have indications that the ocean has been acidified, in terms of a lower pH than today. For instance, at the end of the Permian, ca. 251 Myr ago or at the Paleocene-Eocene Thermal Maximum (PETM), 55 Myr ago. These acidification events were also triggered by a carbon perturbation but had a different origin (volcanism and methane clathrates, respectively) than today. Nevertheless, all are characterized by catastrophic extinctions and biodiversity loss. Importantly, it should be noted that OA (lowering of pH) is only one consequence of a carbon perturbation. These events are usually accompanied by global warming, stronger stratification of the ocean and a decrease of the oxygenation of the deep sea (so called "Ocean Anoxic Events" or OAE's). As such, it is difficult to de-convolve the consequence of decreased pH from the plethora of associated impacts.

It is important to keep in mind that the climatic conditions prior to the above mentioned geologic events were vastly different from today. The atmospheric pCO_2 was high to start with, the oceans were warmer and had a different chemistry, which, by itself, had a considerable impact on the saturation state with respect to calciumcarbonate. However, the most important difference between all previous geological events compared to today is the rate at which the human induced carbon perturbation proceeds.

Hence, even though we do not seem to have a perfect analog to the present day carbon perturbation, we can only expect that the consequences of manmade OA are worse than those recorded in the geological records, simply because the rate of change is unprecedented in the Earth's history and the marine ecosystem as we know it today has mainly evolved in a time where atmospheric CO_2 has been low and oceans were well buffered. The detailed PETM record, which is probably the best analog, teaches us, that it might take about 100kyr for a full chemical recovery of the ocean and that biological recovery takes millions of years.

Ocean acidification is occurring today and will continue to intensify, closely tracking global CO_2 emissions. Given the potential threat to marine ecosystems and biodiversity and, its ensuing impact on human society and economy, especially as it acts in conjunction with ocean warming, there is an urgent need for immediate action. This "double trouble" is probably the most critical environmental issue that humans will have to face in their immediate future and it might become the major socio-economic challenge of this century.

The impacts of ocean acidification are global in scope and yet some of the least understood of all climate change phenomena. Given that its effects are already measurable and that biological impacts may become dramatic within only decades, we must now accept the challenge to better coordinate and stimulate research on ocean acidification if we are to fully understand the consequences of and eventually help mitigate ocean acidification.

Understanding the risks and consequences of OA and recognising that both OA and global warming are caused by anthropogenic CO_2 emissions will hopefully help to set in motion a stringent climate policy worldwide. The only solution to neutralize OA and global warming is a long-term mitigation strategy to limit future release of CO_2 to the atmosphere and/or enhance removal of excess CO_2 from the atmosphere.

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