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Carbonate Dissolution Due to Ocean Acidification and the Rate of Recovery of Benthic Foraminifera

Introduction (957 characters)

The objective of this study is to test the influence of ocean acidification on carbonate sedimentation and preservation. Quantifying the impact of acidification on carbonate sedimentation is relevant in investigating post-extinction recovery of foraminifera. Time intervals over which planktonic foraminiferal populations rebounded after ocean acidification events have likely been underestimated due to carbonate dissolution. Evaluating changes in carbonate preservation in acidic conditions will improve estimations of the duration of carbon system re-equilibration after a massive input event.

The rapid rate of modern global carbon emissions makes understanding the biotic response to ocean acidification and massive carbon system perturbations urgent.

I hypothesize that increased dissolution of carbonate sediments created an illusion of rapid recoveries of benthic foraminifera after extinction events synchronous with periods of ocean acidification.

Justification (2,465 characters)

Understanding repercussions of carbon cycle perturbations, like ocean acidification, is relevant in the wake of rapid, modern anthropogenic carbon emissions. Ocean acidification caused by a massive ^{12}C input is thought to have occurred during the Paleocene-Eocene Thermal Maximum (PETM). Sediment cores from the Ocean Drilling Project site at Walvis Ridge reveal a switch from calcareous ooze to red pelagic clay at the Paleocene-Eocene boundary, followed by a gradual recovery back to carbonate ooze (Zachos, 2005). The negative $\delta^{13}C$ excursion, signifying a massive carbon input into the ocean, is concurrent with a rapid drop in wt% of $CaCO_3$ (Zachos, 2005). Reduced carbonate preservation in this interval is indicative of ocean acidification, and shoaling of the carbonate compensation depth (CCD), causing carbonate dissolution.

Lower estimates of the PETM carbon release of ~1Pg per year are similar to anthropogenic carbon emissions in the last fifty years (Zeebe, 2009). Over the past two centuries, oceans have absorbed roughly 40% of anthropogenic CO_2 (Zeebe, 2008). Ocean surface pH has decreased by about 0.1 in the last 100 years due to oceanic CO_2 uptake (IPCC, 2014).

Atmospheric CO_2 levels may increase to 880 ppm by the end of the century (Freely, 2009). This is predicted to increase ocean acidity from a pre-industrial level of 8.2 to 7.8 pH (Freely, 2009). It is therefore important to thoroughly study the PETM as an ancient analog of ocean acidification.

Elevated CO_2 in seawater reduces carbonate ion concentrations due to dissolution. A decrease in just 0.2 to 0.3 pH inhibits biocalcification of marine organisms like corals, plankton, and foraminifera (Zeebe, 2008). This is supported by the appearance of thin-shelled planktonic morphotypes *M. allisonensis* and *A. sibaiyaensis* exclusively during the PETM ocean acidification (Kelly, 1996). Biocalcification impedance due to ocean acidification likely played into the major benthic foram extinction (BFE) at the Paleocene-Eocene boundary. Understanding biotic responses to ocean acidification is critical in developing bioconservation strategies. Accurately assessing the duration of the acidification event and the isotope excursion is also important for estimating future impacts of anthropogenic carbon emissions. Evaluating the timing of the carbon system and biotic post-extinction recovery requires further investigation of the impact of ocean acidification on carbonate preservation.

Research Plan (2498 characters)

This research plan uses actualistic experimentation to quantify the rate and amount of carbonate dissolution in differing levels of acidity. This data can be applied to past ocean acidification events, such as the PETM, to evaluate the time-richness of carbonate layers. This will improve estimations of the duration of post-BFE rebound of benthic foraminifera, and the duration of recovery from the massive carbon perturbation.

In this study, ten seawater samples of identical temperature and chemical conditions will be set to various pH levels in identically-sized tanks. Modern carbonate microfossils, including coccoliths and foraminifera, will be required. Calcitic and aragonitic carbonate sediment samples will be collected, and tested separately to account for their differences in stability in acidic environments. This is essential in relating experimental results with different time periods and localities. An initial point count of whole shells versus fragments for the calcitic and aragonitic sediments must be taken.

Equal masses of carbonate sediment will be submerged in the seawater samples. Calcitic and aragonitic compositions will be separated. Using a CO_2 syringe, two seawater samples will be adjusted to pH levels of 6, 6.5, 7, 7.5, and 8. The pH level of each tank must be tested using a pH probe meter. Each respective pH sample will be tested with calcite and aragonite, making ten samples total.

After submerging the carbonate microfossils, the magnitude of carbonate dissolution will be measured over regular time intervals. Every two hours, the vertical thickness of the carbonate layer will be recorded, pH will be measured, and sample of about 250 shells from each tank will be analyzed microscopically with a point count.-These measurements will be taken on two hour intervals for 240 hours. Then, the three measures of carbonate dissolution over time, including layer thickness reduction, pH increase, and point count data will be compared and correlated.

Experimental results will be plotted as temporal graphs reflecting the amount of carbonate dissolved over time. This will be represented using three graphs: carbonate layer thickness over time, pH level over time, and shell fragment to whole shell ratio over time. These graphs will reveal the rate of carbonate sediment dissolution in conditions of varying acidity, which can provide more accurate inferences about the timing of the PETM carbon isotope excursion and benthic foram extinction recovery.

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