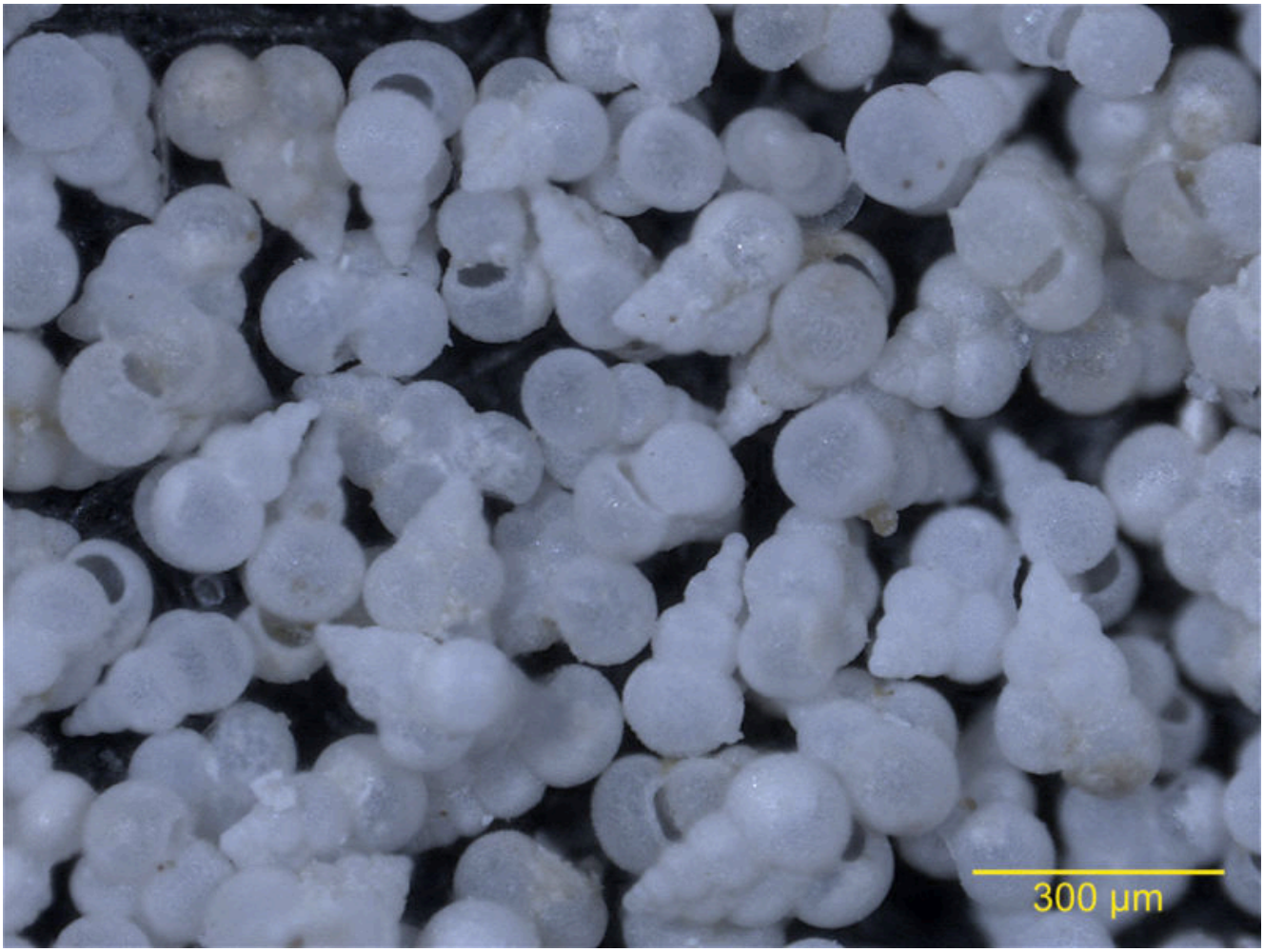
End-Cretaceous mass extinction saw big swings in ocean pH



Enlarge / Forams collected from the time of the Chicxulub asteroid impact that (at least in part) drove a mass extinction.

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As nasty as the asteroid impact at the end of the Cretaceous sounds, you wouldn’t think scientists would be spending much time asking, “Yeah, but how did things *actually die*?”

It’s not just a macabre fascination. With so many awful things going on at once—including a remarkable stretch of volcanic eruptions in what is now India—there are a handful of kill mechanisms to choose from. And when you closely examine the patterns of which species in which environments went extinct, the picture gets complicated.

One major question has been the extinctions in the oceans. On land, there were several years of freezing temperatures and sunless skies, not to mention the tsunamis and worldwide wildfires. The oceans have a tremendous thermal mass, however, that would have moderated the global chill. In the deep ocean, the loss of sunlight wouldn’t be felt as immediately.

After the skies cleared, potent global warming set in for the long haul due to the CO_2 produced when the impactor evaporated bedrock to make the impact crater. The ongoing volcanic eruptions in India were also emitting CO_2, and there’s even evidence that seafloor volcanism picked up due to the impact.

Dropping (due to) acid

Just like today, that increase in atmospheric CO_2 would be associated with acidification of the oceans. That’s what a team of researchers led by Michael Henehan at GFZ Potsdam focused on in a new study.

From a handful of seafloor sediment cores, the team measured isotopes of boron in the tiny calcium carbonate shells of single-celled organisms called forams. Some forams are plankton, floating near the surface, while others live on the seafloor—meaning they can show you what was happening in both environments. And the boron isotopes they incorporate into their shells will shift along with the pH of seawater.

The first thing to look at is actually what was happening *before* the asteroid impact. Despite the intense volcanic

eruptions in that period, ocean pH seems to have been steady for quite some time. But right after the impact event, that changes.

The reconstructed surface ocean pH shows a sharp drop from 7.8 to about 7.5. As the pH scale is logarithmic, that's a huge swing. For context, our CO_2 emissions since the Industrial Revolution have, so far, decreased ocean pH from about 8.2 to about 8.1—a 30% increase in acidity.

A pH change of that scale would signify an increase of atmospheric CO_2 from about 900 parts per million to 1,600 parts per million. (For context, again, today's concentration is about 410 parts per million. The Cretaceous was a warm period in Earth's climate history.)

On the rebound

But after the steep drop in pH, it rose all the way to about 8.0 over the next 40,000 years, exceeding the initial pH. After about 80,000 years, it settled in at around 7.8 again. So why the pendulum swings? They're likely a result of all the extinctions.

The researchers also measured isotopes of carbon that can tell you about what life was doing. Because photosynthesis only occurs in the shallow, sunlit ocean, there is a downward "carbon pump" driven by sinking organic material. This helps to maintain a difference in carbon isotopes and pH between the shallow and deep ocean. But over the 40,000 years after the impact event, that difference disappeared. This change to the usual carbon isotope pattern actually lingered for *over a million years*.

This pattern had been noticed in the carbon isotopes before, with several possible explanations proposed. The colorfully named "Strangelove Ocean" hypothesis, for example, calls for a total loss of photosynthetic activity. The "Living Ocean"

hypothesis, on the other hand, explains things with a weakening of the downward carbon pump instead of reduced photosynthesis.

The researchers used their new data to evaluate these hypotheses in model simulation experiments. To fit the data, they needed a sort of in-between scenario where photosynthesis is cut in half after the impact, with a longer-term weakening of the carbon pump even after photosynthesis recovers.

The idea here is that many photosynthetic plankton with calcium-carbonate shells went extinct. This threw off not only the chemistry of the entire ocean (pH is linked to CO_2 and calcium carbonate) but also deprived it of the dense bits of carbon-rich stuff that drive the carbon pump by sinking.

Even as new species of plankton appeared to fill in the gaps in the tens of thousands of years after the impact, this carbon pump function seems to have taken a very long time to be restored. That wasn’t because ocean pH remained uncomfortably low for a million years—it actually rose relatively quickly. “Rather,” the researchers write, “there may be intrinsic constraints on the time required to recover normal marine ecosystem function after such severe global perturbations, despite the short generation times that should make marine plankton ideally suited to rapid evolutionary radiation.”

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