



years ago, an asteroid slammed into Mexico's Yucatan Peninsula, causing severe but selective extinction. While that is widely accepted, it has remained unclear exactly what the mechanisms were that caused extinction of ocean-dwelling organisms. Proposed explanations include global darkness due to blocking of sunlight with resulting interruption of photosynthesis at the base of the food chain, deadly radiation due to ozone destruction, global cooling or warming, and ocean acidification). Various widely-accepted hypotheses focus on a collapse of the primary and export productivity in the oceans – such as the so-called *Strangelove Ocean* or *Living Ocean* hypotheses, respectively – but do not account for the finding that deep-sea floor dwelling phytoplankton-dependent benthic foraminifera did not undergo significant extinction. Recently, however, research conducted at Universidad Zaragoza in Spain compared benthic foraminiferal records with benthic and bulk stable carbon isotope records. The scientists concluded that decreased productivity was moderate, regional, and insufficient to explain marine mass extinction, suggesting instead that a temporary period of increased surface ocean acidity may have been the primary cause of extinction of calcifying plankton and ammonites, with recovery of primary productivity possibly being as fast in the oceans as on land.

Researchers Laia Alegret at Universidad Zaragoza, Ellen Thomas at Yale University, and Kyger C Lohmann at the University of Michigan faced a range of issues in comparing benthic foraminiferal records with benthic and bulk stable carbon isotope records. “One of the main challenges is always to obtain sufficient benthic foraminiferal specimens for a statistically valid analysis,” says Thomas. “In the deep sea, there is no light, and so no photosynthesis. Therefore, almost all food must come from photosynthesis in the surface waters kilometers above – and only a very small percentage of the primary material, produced by unicellular algae, ever reaches the sea bottom.”

Put simply, deep-sea benthic foraminifera and other deep-sea organisms<sup>1</sup>

live in a world where the limiting factor of life is food – because there is extremely little of it.<sup>2</sup> This implies that in samples from the deep-sea floor, microscopic shells of the organisms the team studied – foraminifera, a group of unicellular eukaryotes – are dramatically outnumbered by the shells of their relatives that live floating in the sunlit surface waters, and whose shells also fall to the sea floor. “We need to collect at least 300 specimens of the deep-sea dwellers per sample, which takes a lot of time sitting behind the microscope and hand-picking the bottom dwellers from the much more abundant surface dwellers,” Thomas explains to *PhysOrg.com*. “Then the very highly diverse assemblages need to be sorted out, and all specimens assigned to species.” Thomas also emphasizes that this is complicated by the fact that there is not true international agreement on the taxonomy of these species.

The team addressed these issues in a number of ways. “First,” agrees Alegret, “the consistency of our data set is unprecedented: The same authors used the same procedures and the same taxonomic concepts for all sites. Another challenge,” Alegret adds, “was finding microfossils in sediment that is not strongly affected by *diagenesis* – the high pressure and temperatures that take place during the formation of hard rocks from initially soft clay and ooze, which may strongly affect isotopic results. Material in sediment from scientific ocean drilling sites,” she continues, “is commonly less affected by diagenesis than samples obtained from rocks in quarries and outcrops on land. This gave us good preservation of the calcium carbonate, ensuring accuracy of our isotope results.”

Thomas notes that the team argues that a collapse of primary productivity by the unicellular algae in the surface waters as proposed in the Strangelove Ocean hypothesis, or continued productivity by such algae but a lack of transport of these algae into the deep bottom waters (also called a collapse of the *biological pump*) as proposed by the Living

Ocean model, would both have resulted in an interruption of food supply to the bottom dwellers for hundreds of thousands of years. “Such an interruption of food supply should have had a serious influence on the bottom dwellers, which in the present oceans react even to changes in the seasonality of food supply. However, we didn’t see that. Rather, the bottom dwellers did not go extinct, indicating that they must have had access to food.”

In fact, Alegret notes, in some regions – for example, the Pacific Ocean – there they found an *increase* in the food supplied to the sea floor – which, she points out, “is incompatible with both the Strangelove Ocean and Living Ocean hypotheses.”

The scientists point out that their findings may impact other areas of research, from paleobiology to evaluating the effects of increasing atmospheric levels of carbon dioxide. “In many fields of paleontology it has been accepted that the main cause of such extinction was the collapse of primary productivity,” Thomas notes. “If that is not the case, one needs to look at other factors. If we’re correct in our speculation that a rapid pulse of oceanic acidification can have very severe effects on ocean life, then we need to take that into account when evaluating the potential effects of the very rapid anthropogenic ocean acidification, caused by a different type of acid – specifically, due to high carbon dioxide levels – on ocean life in the near future.”

The team is already looking forward to extending their research. However, Thomas cautions, what they’d like to do and what they’ll be able to do depends at least in part on funding. “We’re rather far along with a high resolution analysis of foraminifera and stable isotopes from a site close to one of our studied sites, but in shallower waters.” Once they have these data collected, they can better compare what happened at different depths in the water column in an expansion of their work at different geographic locations.

“It would be very exciting,” Thomas envisions, “to test whether we can indeed find direct and quantitative evidence, rather than evidence from extinction patterns of calcifying organisms, for the pH values of the surface waters of the oceans – for example, by trying to apply proxies for oceanic pH and carbonate saturation, such as measuring boron isotopes and/or boron/calcium values in the shells of planktic, or surface-dwelling, and benthic foraminifera across the extinction interval. This is not easy to do,” she points out, “because the planktic – also termed planktonic – foraminifera were so severely affected by the extinction – but it may be possible with the modern possibility to analyze very small amounts of calcite.”

“If we want to predict the future effects of the present acidification of the oceans,” Alegret concludes, “we should investigate and understand past acidification events by, for example, comparing the very rapid acidification event triggered by the end-Cretaceous impact [65 million years](#) ago with the much slower acidification during the extreme warming event which occurred 55 million years ago at the end of the Paleocene and caused severe extinction of benthic foraminifera.”

**More information:** *End-Cretaceous marine mass extinction not caused by productivity collapse*. Published online before print December 29, 2011, [doi: 10.1073/pnas.1110601109](https://doi.org/10.1073/pnas.1110601109)

<sup>1</sup> *Deep, diverse and definitely different: unique attributes of the world's largest ecosystem*. *Biogeosciences*, 7, 2851-2899, 2010, [doi:10.5194/bg-7-2851-2010](https://doi.org/10.5194/bg-7-2851-2010)

<sup>2</sup> *Phytoplankton: below the salt at the global table*. [Journal of Paleontology](#), May 1986, v. 60, p. 545-554

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