EARTH SCIENCE

# Deadly combination

**New evidence suggests that seismic waves from the Chicxulub meteorite impact doubled the eruption rate of lavas on the opposite side of the planet — a combination that led to the mass extinction at the end of the Cretaceous period.**

ROBERT DUNCAN

The events surrounding the termination of the Cretaceous period 66 million years ago make one of the most captivating stories in our planet's history. Evidence for both a devastating meteorite impact at Chicxulub (Yucatan, Mexico) and massive volcanic eruptions in western India at this time is compelling, and each has been blamed for the abrupt demise of the dinosaurs, along with the majority of all species living at that time. A lively debate has raged for several decades about the predominance of one catastrophe or the other in the rapid and sustained environmental destruction that led to mass extinction. And now the story just gets better, with Renne and colleagues' report[1] in *Science* of evidence that the impact and the eruptions may be linked.

The Deccan Traps (Fig. 1) are an enormous, solidified accumulation of lava flows more than $10^6$ cubic kilometres in volume[2]. They formed when melting of the mantle produced magmas that erupted through the continental lithosphere in western India. This volcanic activity is the most recent of several similarly large magmatic provinces whose occurrence coincides with mass extinctions through the geological record[2]. A limiting factor in understanding how such catastrophic volcanic activity leads to mass extinctions has been the uncertainty associated with determining the age of the resulting rocks.

Previous ideas about the cause (or causes) of the terminal-Cretaceous mass extinction stemmed from the idea that species decline occurred gradually over several million years — which could be explained by a variety of factors, such as climate change, falling sea level and the advent of mammals that ate dinosaur eggs. Studies of high-resolution sedimentary records of the mass extinction[3], however, have revealed that it was much more abrupt, leaving meteorite impact and massive volcanic eruptions as the only two viable mechanisms. Because Deccan volcanic activity started well before the Chicxulub impact[4], fragments of the meteorite could not have initiated those eruptions, and so the impact and volcanism have been considered to be independent, coincidental events.

Renne *et al*. report high-resolution age determinations from the main section of Deccan lava flows (the Western Ghats), and so establish that the Chicxulub impact occurred within approximately 50,000 years of a dramatic change in eruption rate and magma composition. The researchers therefore assert that energy from the impact was propagated by means of seismic waves through and around Earth's surface, altering the Deccan magma 'plumbing system' to accelerate the eruption rate. This in turn contributed to environmental decline through the release of gases such as carbon dioxide and sulfur dioxide to the atmosphere.

The current findings follow on from recent related work by Richards *et al.*[5], who estimated that the Chicxulub impact produced kinetic energy equivalent to a mega-earthquake of magnitude 9 to 11. They also reported that the seismic-wave energy arriving in the Deccan area, more than 14,000 km away from the impact, was sufficient to trigger volcanic eruptions by increasing the permeability of the crust and magma flow, and by causing the disruption or coalescence of crustal magma chambers[6].

In the geological record, the Chicxulub impact is marked by high concentrations of the rare metal iridium and shocked quartz in marine sediments; shocked quartz forms when the normal form of the mineral is deformed under intense pressure but at low temperature at impact sites. The temporal coincidence of the impact with the mass extinctions at the end of the Cretaceous — known more formally as the Cretaceous–Palaeogene boundary (KPB) — is well accepted on the basis of those markers[3], but the new data place the KPB much more precisely within the period of the Deccan lava flows.

The Chicxulub impact alone may have produced sufficiently severe and abrupt environmental deterioration to have caused mass extinction. By contrast, none of the other major mass extinctions shows evidence of meteorite impacts, but all coincide with the occurrence of large volcanic provinces[2]. It therefore seems reasonable to accept that both the impact and the volcanism, on nearly opposite sides of the planet, contributed to abrupt species decline and extinction at the KPB.

Richards *et al.*[5] also reported that eruption volume, frequency and magma composition during the Deccan lava-flow sequence changed substantially at about the time of the Chicxulub impact and the KPB. More than 70% of the total volume of magma erupted


**Figure 1 | The Deccan Traps.** Massive lava flows in western India occurred at the end of the Cretaceous period, and produced the accumulation of rock known as the Deccan Traps. Renne *et al.*[1] suggest that the impact of the Chicxulub meteorite caused an acceleration in eruption rate during that volcanic activity, and that a combination of this increase and the effects of the impact may have caused the mass extinction that marked the end of the Cretaceous.


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after this change, in the form of huge (up to 10,000 $km^3$) lava flows during roughly the next 500,000 years[7], although these flows occurred less frequently than before. But could this transition simply reflect thinning of the continental lithosphere, as documented for other large volcanic provinces[8]? Richards and colleagues note that the orientation of dikes — vertical, planar cracks in rock that allowed magma to rise to the surface — changed from orientations determined by the direction of lithospheric extension to randomly directed orientations across the transition, whereas trace-element indicators of depth of melting show no change. Both of these factors indicate that the increased magma production was not due to lithospheric extension and thinning.

Renne and colleagues' improved correlation of the Chicxulub impact with documented changes in eruption dynamics in the Deccan province supports a plausible mechanism for linking the former to the latter. This link does not fully explain the extended regime of larger but less-frequent eruptions following the impact, but the authors speculate that changes in magma-chamber size and distribution could be controlling factors. Ultimately, the KPB records a complex environmental response to two forcings — meteorite impact and volcanic eruptions — that are now firmly linked. Further details of the timescale for post-impact Deccan eruptions may emerge from the study of high-resolution marine sedimentary records of volcanic input and biotic recovery. ■

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CLIMATE CHANGE

# A rewired food web

**Climate change is causing large fish species to move into arctic marine environments. A network analysis finds that these fishes, with their generalist diets, add links to the existing food web that may alter biodiversity and web stability.**

JULIA L. BLANCHARD

Climate change is driving species shifts both on land and in the sea. For species that inhabit extreme environments, such as the poles or highest altitudes, there may soon be nowhere left to go. The consequences of species redistributions for whole ecosystems are often discussed but poorly understood. This is due in part to the amount of information that is required to understand the complex networks of ecological interactions between organisms and their changing habitats. Writing in *Proceedings of the Royal Society B*, Kortsch *et al.*[1] combine network analysis with large-scale species-distribution data and detailed knowledge of food-web interactions — who eats whom — in the Barents Sea, which lies north of Norway and Russia. The authors use this information to show how changes in the distributions of the fastest-shifting fish species can substantially alter the structure of an arctic marine food web.

Warming waters mean that, in the Northern Hemisphere, some southerly fish species are moving northward and forging new interactions along the way. Will these changes push some species towards faster extinction and others towards domination? Although we do not yet have an answer, knowing the nature of the animals' interactions and how they are likely to change can provide clues to help guide the mitigation of biodiversity loss before it is too late.

The study of complex networks has helped us to understand how quickly diseases can spread, how information moves on the Internet, and how traffic, trade and even biochemical signals work[2]. Food webs are complex networks of predator–prey interactions that have fascinated scientists for more than a century. The structure of a food web — how the links between species are configured — can influence the web's stability. A variety of metrics describe network connections. These include the number of links to and from each species; the strength and density of the links; whether subsets of the web are clustered in modules; and whether there are loops within networks. Such metrics have been studied for their influence on multiple ecosystem features[3], such as whether simulated species extinctions lead to cascades of other species going extinct, or how fast disturbances spread through the network.

Kortsch and colleagues' network analysis of marine arctic food webs shows that they contain relatively few connections and are quite modular — two features that have been linked to greater stability and resilience to the spread of perturbations. These food webs function in regions that are covered by sea ice for a large proportion of the year. Here, the most abundant life forms are benthic organisms, which live on or beneath the sea floor, and the food they eat comes from dead or dying tiny algae (phytoplankton) that are normally locked in the sea ice. This benthic energy flow has been described as a slow pathway, one that is relatively resilient to sudden or abrupt changes[4,5].

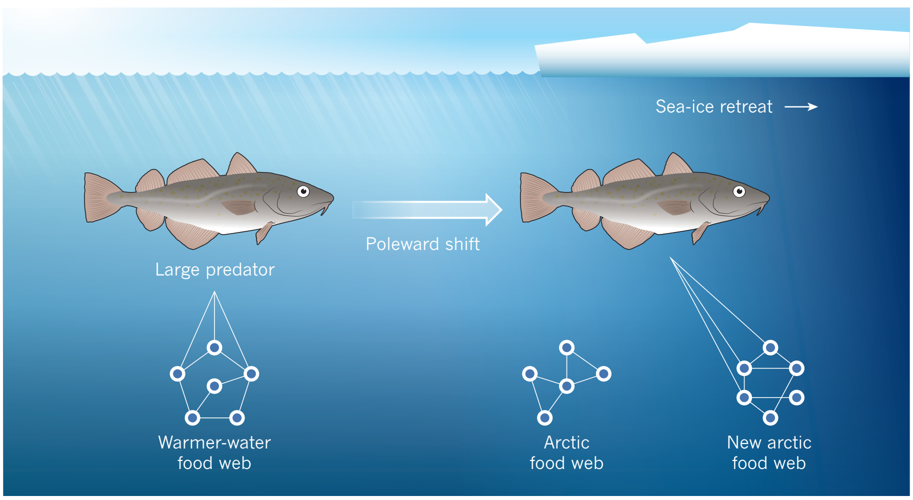


**Figure 1 | Shifting structure.** The marine arctic food webs studied by Kortsch *et al.*[1] contained fewer links than those farther south. This is partly because the warmer waters are home to large, wide-roaming fish species that consume organisms of a range of sizes and in various habitats. However, these large fishes are starting to move poleward as climate change causes warming and sea-ice retreat. The authors document that the increasing presence of large fishes in marine arctic environments is changing the structure of the food web, introducing new links and decreasing its modularity.


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