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Life's Closest Call

What caused the spectacular extinctions at the end of the Permian period?

By RICHARD MONASTERSKY

The menu of any seafood restaurant bears silent witness to one of the worst moments in the history of life on Earth.

Nearly 250 million years ago, at the close of the Permian period, waves of death washed across the planet, snuffing out almost 95 percent of the species in the seas. The crisis ended the reign of the Permian ocean communities, dominated by creatures anchored to the seafloor, and cleared the way for the emergence of much more mobile and meatier animals. The beneficiaries of this calamity eventually gave rise to favorites on the modern dinner plate, making possible such delicacies as lobster bisque, fried calamari, seared tuna, and even sea urchin sushi.

The late Permian extinctions took a terrible toll on land as well, wiping out the ruling vertebrates and opening the door to the eventual emergence of dinosaurs in the Triassic period that followed. The planetary plague felled so many trees and other forms of vegetation that, for a brief period, fungi took over as the governing land cover, consuming the abundant deadwood (SN: 3/16/96, p. 164).

"The height of the extinction is the closest life has come to complete extermination since its origin," writes paleontologist Douglas H. Erwin in *The Great Paleozoic Crisis, Life and Death in the Permian* (1993, New York: Columbia University Press).

What could have driven life so close to the edge? Geoscientists have pondered the question for over a century with little success, but the search for answers has intensified in the last year as increasing numbers of researchers have tossed new ideas into the ring and resurrected old hypotheses. Paleontologists and geologists are now scrutinizing a long lineup of possible culprits, ranging from extraterrestrial slams to toxic belches rising from Earth's hidden reaches.

In the past, scientists seeking to explain the Permian extinctions have dragged out the usual suspects—those thought to underlie the more moderate extinctions that pepper the geologic record. The cast of traditional characters includes declining sea levels, dwindling supplies of oceanic nutrients, and shifts in global climate.

Although some of these changes were indeed occurring at the end of the Permian, many paleontologists believe that guilt must lie elsewhere. "I'm not convinced that the usual suspects are capable of producing the kind of almost total ecosystem collapse that you see at the Permo-Triassic boundary. Business-as-usual hypotheses are somewhat worrisome," says paleobiologist Andrew H. Knoll of Harvard University.

Knoll is pursuing the notion that the killer was deadly soda water. According to this scenario, toxic concentrations of carbon dioxide accumulated in the deep ocean and then surged to the surface, extinguishing much of the life in the shallow seas. Knell fashioned this idea along with Richard K. Bambach of Virginia Polytechnic Institute and State University in Blacksburg, Donald E. Canfield of the Max Planck Institute for Marine Micropaleontology in Bremen, Germany, and John P. Grotzinger of the Massachusetts Institute of Technology. They proposed their hypothesis in the July 26, 1996 SCIENCE.

The carbon dioxide crisis, according to their model, stemmed ultimately from plate tectonics, which had herded all of Earth's continents together earlier in the Permian. With this arrangement of continents and the absence of polar ice caps, ocean circulation patterns would have been far different than they are now. In the modern world, cold polar temperatures cause oxygen-rich water to sink in the Antarctic and Arctic, helping to aerate the deep ocean. The Permian world lacked such strong polar currents, called thermohaline circulation.

Without the stirring action of these currents, the giant ocean gradually grew foul. The decay of animals, plants, and other organic matter used up all of the dissolved oxygen in the deep waters, replacing it with carbon dioxide and other toxic gases such as hydrogen sulfide. These poisons accumulated in the dark recesses of the sluggish seas.

The process could not continue forever, though. Plants at the surface pulled carbon dioxide from the atmosphere and, when they died, carried carbon to the bottom of the stagnant ocean. Because the carbon remained trapped there, carbon dioxide's concentration in the atmosphere fell, leading to a global cooling. The drop in temperatures at the poles triggered thermohaline circulation and flushed the deep waters to the surface. The toxic load of carbon dioxide and other gases then wreaked havoc on animals and plants filling the upper reaches of the ocean.

Knoll and his colleagues point to several lines of evidence supporting their hypothesis. One factor is the ratio of light to heavy isotopes of carbon in the seafloor sediments deposited at the end of the Permian. The swings in isotope values match the pattern expected if carbon dioxide had first accumulated in the deep ocean and then suddenly rushed to the surface. It appears that a cycle of carbon dioxide buildup and release took place at least twice over a period of several million years at the end of the Permian, say the researchers.

Further support for their scenario comes from examining the winners and losers in the Permian disaster. "Hypercapnia [carbon dioxide poisoning] is just devastating to aquatic organisms. It does all sorts of awful things. In fact, it's used in some labs to anaesthetize aquatic organisms. It was harsh for all organisms, but some would have been better able to deal with it than others," says Bambach.

The extinctions punished immobile and sluggish aquatic creatures most of all. They lost more than twice as many genera as did active animals, which had faster metabolism and better circulatory systems.

Active animals had higher odds of survival because they routinely generated more carbon dioxide than their sedentary neighbors, so they had mechanisms to cope with it. Many types of fish, arthropods, clams, and snails outpaced the grim reaper by dint of their gills and improved circulation.

The extinctions fell hardest on the less active corals, anchored echinoderms, and the extremely abundant brachiopods. The latter are two-shelled creatures that bear a superficial resemblance to clams but have a less advanced circulatory system. Brachiopods were one of the most successful invertebrates until the late Permian extinctions decimated their ranks and left them minor players in the modern oceans.

Hypercapnia may not have harmed land animals and plants directly, but the extra carbon dioxide in the air would have warmed the climate drastically by strengthening Earth's greenhouse effect. This rapid climate change may have killed off many land organisms, propose the scientists.

The idea of a deadly gas attack does not sit well with Paul B. Wignall of the University of Leeds in England. The hypothesis proposed by Knell and his colleagues requires that oxygen concentrations in the deep ocean dwindled at least twice in the later stages of the Permian, leading to different bursts of extinctions. But the record of seafloor sediments does not support low oxygen values, or anoxia, at these times, says Wignall.

Citing studies of rocks from Japan, China, Pakistan, the United States, Canada, and Spitsbergen, Norway, Wignall claims that anoxia developed only during the latest stage of the Permian, a point that Knoll and his colleagues dispute.

What's more, Wignall doesn't agree that the extinction pattern matches the hypercapnia idea. Some marine organisms with low metabolic rates, such as certain single-celled foraminifera, survived the crisis without much hardship, he notes. The carbon dioxide hypoth-

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esis, he says, "probably ranks as the most wrong of all competing end-Permian extinction scenarios."

Wignall believes that anoxia itself, not carbon dioxide poisoning, was the prime culprit. Along with Richard J. Twitchett of Leeds, Wignall has documented that anoxia developed throughout the world's oceans, from the tropics to the poles, in the final stage of the Permian (SN: 5/25/96, p. 326). Oxygen starvation reached from the depths to the shallow layers of the ocean, leading to widespread extinctions of marine creatures, suggest Wignall and Twitchett.

The two scientists remain unsure why anoxia developed at this time, but they have a suspicion that the answer lies in Siberia. At the end of the Permian, a huge series of volcanic outpourings paved over much of northern Russia with a basaltic lava. The amount of rock that erupted then would have been enough to cover the entire globe with a layer 6 meters thick. Such an immense volcanic release must also have spewed out vast amounts of carbon dioxide gas, which would have warmed the climate and stalled the currents that normally carry oxygen to the deep ocean, according to their scenario.

Wignall readily admits, however, that this plotline may have problems with timing. The starting date of the Siberian eruptions remains unclear, as does the timing of the extinctions. Lacking better data, scientists cannot tell whether the volcanic outpourings preceded the main burst of extinction.

Other scientists pursuing the cause of the Permian devastation are not content to limit their search to Earth alone. Over the past few years, several researchers have looked toward the sky, proposing that a massive comet or meteorite struck the planet at the end of the Permian and took a bite out of Earth's biology.

The idea that impacts can cause extinctions has gained popularity in the last 17 years, thanks to studies of a more recent global crisis that occurred 65 million years ago. Geologists have amassed considerable evidence that an extraterrestrial object the size of Mount Everest slammed into the Yucatan region at the close of the Cretaceous period. This crash coincided with a mass extinction that wiped out the last remaining dinosaurs and many other organisms.

Supporters of the impact theory for the Permian extinction had scant evidence of any planet-disrupting blow at that time—until Gregory J. Retallack went searching in the Southern Hemisphere. A paleobotanist at the University of Oregon in Eugene, Retallack reported finding grains of "shocked" quartz at two sites in Antarctica and one site in Australia. This type of quartz is riddled with intersecting sets of fractures and is born only during impacts.

Retallack presented his evidence at a meeting of the Geological Society of America in October 1996. But his pictures of the quartz grains have yet to win over geologists who specialize in studying impact evidence. "In a nutshell, I don't think they're shocked," says Bruce F. Bohor of the U.S. Geological Survey in Denver.

At present, Retallack and his colleagues have studied the quartz grains only under a light microscope, where it is difficult to distinguish shock features from the more prosaic deformations caused by normal tectonic stress in Earth's crust. Such tectonic cracks are relatively common in quartz, says Bohor, who suspects that Retallack's grains bear these kind of fractures. Retallack is now conducting further tests on the Australian and Antarctic samples.

Even if the quartz does turn out to be evidence of an impact, many researchers are skeptical that such a crash had much to do with the Permian extinctions. An impact capable of triggering such unparalleled losses should have strewn telltale clues around the world. Geologists have failed to find shocked quartz and other signs of an impact at the many sites examined, suggesting that any impact at the time must have been fairly small.

It may be that no one killer can shoulder the blame for the Permian catastrophe, says Erwin of the Smithsonian. He has long supported the horrible luck hypothesis—the idea that a multitude of problems popped up and combined to trigger the Permian extinctions. Erwin notes that the end of this period was marked by considerable unrest, during which sea levels were falling, climate was warming, the oceans were going anoxic, and the Siberian eruptions were releasing dangerous gases into the atmosphere. Before scientists can confidently assign blame for the Permian deaths, they have to spend more time studying the corpses, says Erwin. In order to test the various killing scenarios, paleontologists need to obtain a better idea of what groups died out and when. “We still have a while to go,” Erwin predicts.

Most other researchers would agree. “Let’s not just vote on what is right or not,” implores Knoll. “Let’s go out and do the work.” □