Extinction Potpourri: Killers and Victims

The meeting of the Geological Society of America, held late each October, is also the principal gathering of paleontologists in this country. This year's meeting in San Diego featured news about two major biological extinctions—one that did in the dinosaurs and another that paved the way for modern mammals.

Where to Run From a Mass Extinction?

Say you're a member of an ancient genus of bivalves—an oyster, maybe—living some 65 million years ago. You learn that the world as you know it is about to end: The mass extinction that marked the end of the Cretaceous period is just around the corner. Only about half of all the bivalve genera will make it into the Tertiary period. What should you do to better your chances of survival? Become tolerant to wide swings of temperature, in case climate change will drive the extinction? Move out of the tropics in case they get hit the hardest? Change your diet so you don't starve when your usual food disappears?

There wasn't much a hapless bivalve could do to beat the odds, paleontologist David Jablonski of the University of Chicago told his audience at the Geological Society of America (GSA) meeting. In the hope of finding some clue to the mechanism that drove the mass extinction at the boundary between the Cretaceous (abbreviated K to avoid confusion with other "C" periods) and Tertiary periods, researchers have been looking hard for some common factors explaining the resilience of some genera and the vulnerability of others. But they've had limited success, suggesting that a pervasive, indiscriminate force was at work—a notion Jablonski's work reinforces. From a systematic survey of the bivalve fossil record before and after the extinction, he concludes that whatever triggered the KT extinctions—whether it was the blast of an asteroid impact, a gradual change of climate, or something else—it struck down the mollusks with little regard to traits that may have helped them flourish in the past.

Jablonski did his bivalve survey by searching the literature and going through the collections of the British Museum of Natural History, examining specimens from formerly marine areas of Africa, North America, and Europe. When he compared genera living in those areas during the last 9 million years of the Cretaceous with ones surviving during the first 5 million years of the Tertiary, he found that the same extinction odds—roughly 50:50—seemed to hold regardless of the characteristics of a genus. It didn't matter whether a genus was in then tropical North Africa or temperate northern Europe. Being adapted to a wide range of temperature didn't seem to help either: Genera limited to the tropics did no better than those with species both within and outside the tropics. Even having a large number of member species didn't improve a genus's chances of surviving the KT mass extinction. That's a puzzle because large genera do seem more resistant to disappearing during the periods between mass extinctions.

Jablonski identified only three breaks from the pattern of indiscriminate extinction. Peculiar Cretaceous bivalves called rudists that built reef-like constructions and flourished in areas such as southern Europe and the Caribbean did much worse than the norm—they were completely wiped out. Immobile bivalves that lived on the sea floor and fed on matter suspended in the water suffered more than those living and feeding within the bottom mud. And genera spread over many regions—Europe, Africa, and North America, for example—fared better than those restricted to a single province.

The relatively uniform pattern of bivalve extinction leaves the field of possible KT extinction mechanisms almost as wide open as ever. Jablonski says his work does seem to rule out a severe warming of the tropics, since temperate and tropical genera were affected equally, but some sort of pattern might still be lurking in fossils from other parts of the world. To find it, he says, someone will just have to start rummaging through the shell collections again.

Plate Tectonics as a Driver of Evolution

Species come and species go, but sometimes evolution seems to lurch forward, eliminating a host of old species and spinning out a bounty of new ones. Researchers presume these upheavals are triggered by sudden environmental shifts, such as the one that may have followed the giant asteroid impact 65 million years ago. But it doesn't always take something as calamitous as an impact to reorganize the environment, as paleoceanographer David Rea of the University of Michigan reminded his audience.

The reshaping of Earth's surface by plate tectonics may also trigger abrupt environmental changes and the ensuing bursts of extinction and speciation, Rea noted. As a case in point, he presented evidence from a single deep-sea core that ties the geologically abrupt reshuffling of plates about 57 million years ago—an event marked by the opening of the North Atlantic between Greenland and Norway—to a sequence of environmental changes. One change was the warming and localized drying of the continental climate widely held responsible for the burst of evolution that replaced archaic mammals with "modern" ones; the other was a transformation in the circulation of the deep ocean that seems to have caused a mass extinction there.

Rea had already gathered scattered deep-sea records that seemed to trace a chain of environmental changes back to the reorganization of plate motions. But because individual events were recorded in different cores, there was always some uncertainty about their exact sequence. The new core, from the southern Indian Ocean, eliminates that uncertainty because it chronicles all the major events. The first event, the plate reorganization itself 57 million years ago, is imprinted on the core as a peak in manganese and iron, elements spewed in abundance from sea-floor hot springs when plates change direction and new plate boundaries form.

Then comes evidence of the climatic warming that sealed the fate of the archaic mammals. In the core, it takes the form of a change in oxygen isotope composition, a signal of an ocean warming. Rea links this warming to a global greenhouse. It was triggered, he says, when the hot springs injected additional calcium into the ocean, driving carbon dioxide out of seawater and into the atmosphere, and volcanoes at the new plate boundaries added an extra measure of the greenhouse gas.

Next the core bears evidence of other environmental changes that Rea sees as secondary effects of the tectonics-induced greenhouse. Atmospheric circulation slowed, as recorded by a decrease in the mean size of wind-blown dust in his Indian Ocean core. Because ocean currents affect the heat gradients that drive atmospheric circulation, that finding suggests to Rea that the reversal of deep-sea circulation seen at about the same time in other cores (*Science*, 10 February 1989, p. 740) had occurred, sending warm water from shallow tropical seas into the deep ocean at high latitudes.

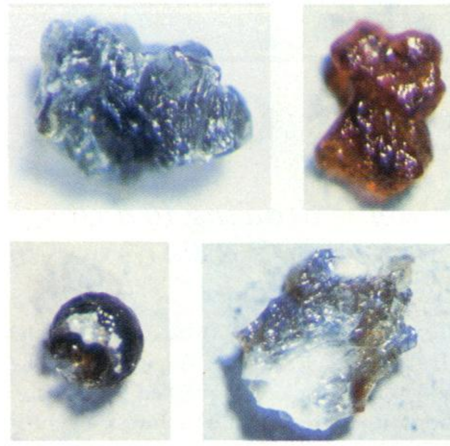
The last event in the core—presumably the result of the changed ocean circulation—is the mass extinction of bottom-dwelling, unicellular animals called foraminifers. So far, the core has not yielded any sign of the recently reported abrupt deep-sea warming that coincides with the extinction (*Science*, 20 September, p. 1359)—a warming that may have been a final catastrophic step in the slower circulation change Rea saw. More detailed sampling of the core may by required to see the warming.

But even if the core places the plate reorganization, the environmental changes, and the extinctions in a sequence suggesting cause-and-effect, it raises a new question: Why does the sequence of events unfold so slowly? The change in atmospheric circulation comes 800,000 years after the warming gets started, Rea notes, and the deep-sea extinctions follow 400,000 years after that. That runs counter to the assumption that these events—if they were causally related—should have been separated by no more than a few thousand years. "Four hundred thousand years is an awkward length of time," says Rea. "There's probably something going on that we don't understand, which is not too surprising" given the still-fuzzy picture of events 57 million years ago.

Looks Like the Yucatan Holds a Killer Crater

A year ago, researchers looking for the crater left by the great asteroid impact that marked the end of the dinosaurs' reign thought they might have glimpsed their quarry: a 180-kilometer-wide, ring-shaped structure at a site called Chicxulub on the north coast of the Yucatan Peninsula. But there were nagging doubts. Specialists could not be sure that the ring, buried beneath kilometers of sediment, actually had been formed by an impact. Nor was it clear that the crater—if that's what it was—had been formed at the crucial moment, 65 million years ago. But new evidence discussed at the meeting is dispelling doubts that Chicxulub was indeed the epicenter of the impact.

At meetings over the past year, Alan Hildebrand of the University of Arizona and his colleagues had presented two key pieces of evidence for an impact at Chicxulub. Samples of rock left over from oil-exploration wells drilled decades ago within the structure contained quartz grains shot through with striations that form only when the mineral experiences the extreme shock of an impact. Hildebrand also found that some of the samples containing shocked


STANLEY MARGOLIS

Baubles from the big splash. *These bits of colored glass (each 2 to 3 millimeters across) formed as droplets of molten rock splattered from an asteroid or comet impact, cooled, and fell onto what is now northeastern Mexico.*

quartz were mineralogically similar to the rocks formed by melting in known impact craters. Other impact specialists reserved judgment, however, largely because they had not had a chance to examine the samples for themselves (*Science*, 19 April, p. 377).

Over the past few months, though, Chicxulub rock samples and photographs of processed samples have been circulating among the specialists. And they are impressed. "It's looking good," says Richard Grieve of the Geological Survey of Canada in Ottawa. "If I was half convinced last March, I'm 75:25 now." Eugene Shoemaker of the U.S. Geological Survey in Flagstaff goes further. Last spring he was willing to give 5-to-1 odds that Chicxulub is an impact crater. Now he's 98% sure. To dispel those last few percentage points of doubt, Grieve would like to see more such samples, but that would mean spending a few million dollars to drill new holes through the overlying sediment, he says.

Meanwhile, less direct evidence that a massive impact struck the Yucatan is coming from another quarter: deposits scattered around the Caribbean and the Gulf of Mexico that contain signatures of a nearby massive impact. Two years ago on Haiti, Hildebrand recognized the first such deposit, containing abundant shocked quartz and centimeter-sized glassy spherules presumably splashed out of a nearby impact crater as molten rock (*Science*, 18 May 1990, p. 815). Now, as reported at the GSA meeting, researchers have found three more deposits obviously formed near an impact. That "makes the Yucatan an ever more attractive site for the impact," says Walter Alvarez of the University of California, Berkeley, who was an originator of the impact hypothesis.

In three talks at the meeting, a loosely confederated group organized by Alvarez, Stanley Margolis of the University of California, Davis, and Jan Smit of the Free University in Amsterdam described the three additional sites. One lies to the north of the coastal city of Tampico in northeastern Mexico. There Alvarez, Smit, and others in the Berkeley group found an outcrop bearing a layer of spherules and what looked like shocked quartz, overlaid by a thick bed of debris. The debris was enriched near its top in the element iridium, the now-classic marker of an extraterrestrial impact.

Besides bearing those three signs of an impact, the Alvarez group says, the so-called Mimbral deposit also records the action of a huge tsunami, presumably generated by the catastrophe. Despite having formed beneath at least 500 meters of water, the deposit includes ripple marks and debris, such as bits of wood, that must have been washed off the land—all of which suggests a wave that may have been a kilometer or more high. The Alvarez group has also seen much the same sequence of events in deep-sea drilling cores from a second area, one that is still under water in the Gulf of Mexico, 400 kilometers northeast of Chicxulub. And, with Mimbral as a guide, Smit found a few spherules at the base of a third deposit at Brazos near the Texas coast, one that had been identified previously as an iridium-bearing tsunami bed.

As the number of nearby impact deposits has multiplied, so has evidence linking them specifically to the Chicxulub structure. Margolis noted that the chemical similarity of spherules from Mimbral and Chicxulub's putative melt rock allows both materials to have been formed by the same impact. And geochemist Haraldur Sigurdsson of the University of Rhode Island and his colleagues reported in *Nature* the week after the GSA meeting that the glasses and shocked minerals found in Haiti could well have been formed from the geologic layer-cake found at Chicxulub—carbonate and evaporite rocks on a base of schists and volcanic rocks.

Besides strengthening the case that what formed the Chicxulub ring really was an impact, the deposits also bolster the confidence that the Yucatan impact took place 65 million years ago. The spherules from the Haiti deposit have been dated to 64.5 million years using radiogenic isotopes, and the other three deposits fall at about 65 million years ago in the stratigraphic record. But to be confident that the Chicxulub structure formed at the geologic instant of the mass extinction, geologists will need an age for the crater itself. The necessary isotopic dating of the existing Chicxulub samples is being attempted even now. ■ RICHARD A. KERR