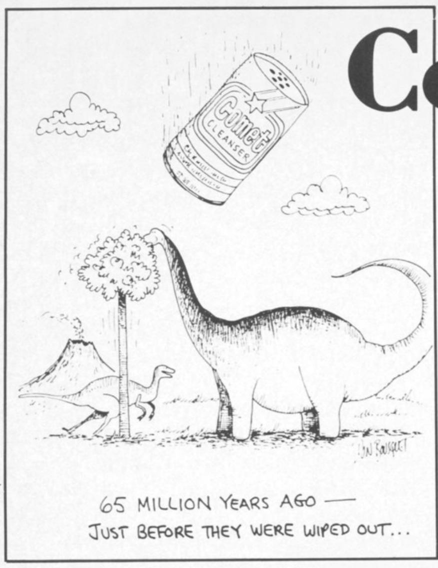


Don Bousquet

Counting the DEAD

Did the dinosaurs and their contemporaries die out with a bang or a whimper?

Second in a two-part series

By RICHARD MONASTERSKY

For some macabre reason, people find fascination in death and destruction. Take the evening news, with its proclivity for reporting on murders, fires and other tragedies of the day. Or consider the way a car crash seduces the gaze of each passing motorist.

Given this taste for the terrible, it's not surprising that the idea of a killer meteorite captured the attention of scientists and the general public alike when a team of researchers proposed this theory in 1979. What a spectacular scenario: A piece of rock roughly the size of Manhattan wallops Earth at the end of the Cretaceous period, 65 million years ago, wiping out the dinosaurs and many other life forms that dominated this time in Earth's history.

With evidence accumulating over the last decade, increasing numbers of geologists and geophysicists have come to accept the controversial idea that a bolide — a comet or meteorite — did indeed slam into Earth at the end of the Cretaceous. In fact, some scientists now believe they have found a "smoking gun" from this event: a crater left by the crash in Mexico's Yucatán region (SN: 1/25/92, p.56).

But even as debate has dwindled over whether an impact occurred, another contentious question has erupted. Researchers who study the fossil record are seeking to determine whether the impact really did decimate life on this planet. Or, to put it another way: What good is finding a smoking gun if you can't locate any corpses with bullet holes?

"I believe impacts are a fact of life. They have happened throughout Earth's history," says Gerta Keller, a paleontologist at Princeton University. "The question for us is: What effect do they really have on life? What effect did they have on evolution?"

Paleobiologists have long recognized that the time of the assumed impact — the boundary between the Cretaceous (K) and Tertiary (T) periods — marks a major turning point in the history of life. For 150 million years prior to that time, the dinosaurs and other reptiles ruled the land. Then, for some reason, most of those dominant species disappeared, leaving an ecological niche soon filled by mammals, some of which eventually spawned our own species. At the K-T boundary, land vegetation also apparently went through a major trauma, as did life in the oceans.

When scientists from the University of California, Berkeley, began formulating the impact hypothesis back in the 1970s, they viewed the bolide strike as an event that would explain the well-known K-T extinctions. According to their theory, the crash pulverized enough rock to enshroud the entire Earth in a sunlight-blocking dust cloud that cooled the planet and halted plant photosynthesis. The climatic calamity decimated flora and fauna, setting the stage for a new act in the evolutionary pageant.

Just how many died because of the crash? Many scientists who support the impact theory have estimated that half of all life on Earth went belly up in abrupt extinctions at the K-T boundary.

Over the past few years, however, extinction experts have attacked this extraordinary body count. Paleobiologists have started conducting systematic studies of life at the end of the Cretaceous to determine just how many different organisms died out and how quickly they vanished from the scene. If major extinctions dragged out over a long stretch of time or began before the impact, then factors unrelated to a bolide may have driven some of the die-offs.

Death to the dinosaurs

Of all the animals that disappeared at the end of the Cretaceous, the dinosaurs have captured the most public attention. To examine their extinctions, Peter Dodson, a vertebrate paleontologist at the University of Pennsylvania in Philadelphia, has compiled a data base of all articulated dinosaur skeletons — ones for which at least two or three bones were found lying together. His analysis leaves out isolated bones and teeth because paleontologists cannot always identify an animal from a single skeletal fragment.

Dodson's data show that dinosaurs flourished during the Maastrichtian stage, the last 8 million years of the Cretaceous period. More genera of dinosaur fossils are known from that time period than any other. But the good times did not roll on right to the end. While 73 dinosaur genera existed at some point during the Maastrichtian, Dodson finds only 18 genera present during the last 2 million years.

What's more, the dinosaur fossils from that final portion of the Maastrichtian appear almost exclusively on one continent: North America. Of the 26 known sites around the world that contain late Maastrichtian dinosaurs, 20 are in North America. This suggests that dinosaurs declined long before the impact, with only North America retaining anything resembling a diverse community, Dodson reported last October at a meeting of the Geological Society of America.

What about that North American enclave? Did species there also dwindle before the K-T boundary? To examine that question, Peter M. Sheehan of the Milwaukee Public Museum and his colleagues focused on the dinosaur community living in a small region of North America, along the border between present-day North Dakota and Montana. In this area, a rock deposit called the Hell Creek Formation holds the best known record of the last dinosaurs (SN: 11/9/91, p.293).

Sheehan and his co-workers divided the Hell Creek into three time periods of roughly 700,000 years each. Scouring the ground in search-party style, they counted the number and types of dinosaur bones from each time period. Contrary to what some other researchers had reported, Sheehan's group found no evidence that the Hell Creek dinosaur community gradually weakened at the end of the Cretaceous.

"The findings are in agreement with an abrupt extinction event such as one caused by an asteroid impact," the researchers reported in the Nov. 8 SCIENCE.

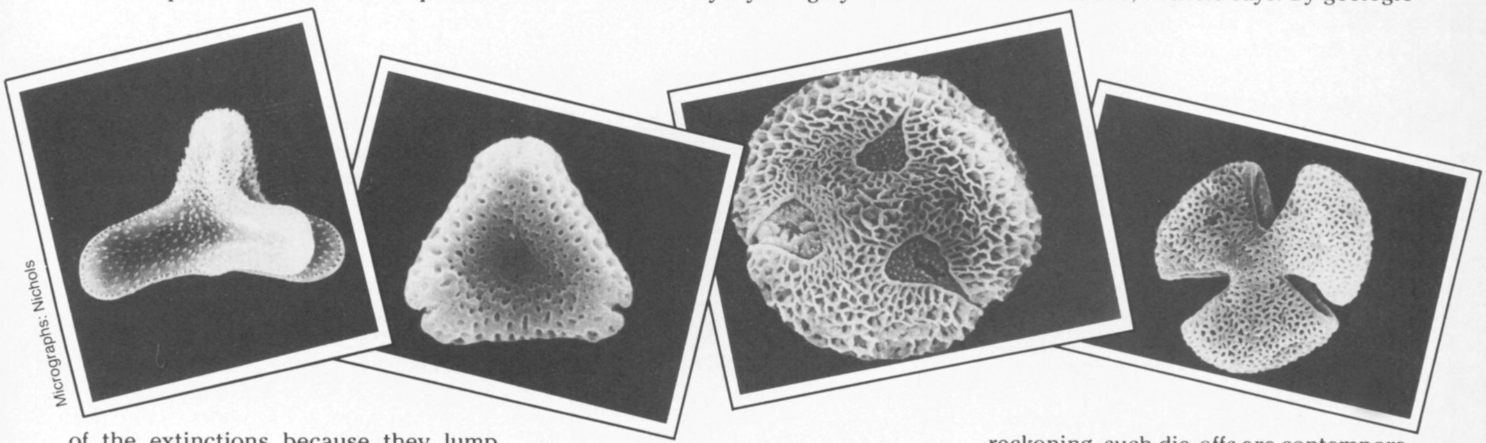
David Archibald, a paleontologist at San Diego State University, says people place too much emphasis on the dinosaurs' demise at the end of the Cretaceous. When he and a colleague looked at a broader spectrum of the vertebrate community, they found that most species fared quite well at the K-T boundary. The researchers traced the fate of 111 species of sharks, bony fishes, amphibians, lizards, crocodilians, turtles, dinosaurs and mammals. Their findings suggest that 53 to 65 percent of the Cretaceous species survived into the Tertiary period.

"Is this a mass extinction? I don't think so in terms of numbers," Archibald says.

According to Archibald, the animals that didn't survive are an evolutionary and ecologically mixed bag. The dinosaurs, sharks, lizards, snakes and marsupials that disappeared lived in a variety of environments and had a variety of weaknesses. Such diversity in the death toll suggests to Archibald that no single mechanism – such as an impact – can explain the extinction potpourri. He believes climate changes lie closer to the truth.

Sheehan counters that Archibald's numbers present a rose-colored picture of the extinctions because they lump together land and aquatic animals. Although two-thirds of the total may have survived, only a small fraction of the species on land actually made it through into the Tertiary period, he says. What's more, those species that did die out represented the largest animals in the ecosystem; their disappearance caused a major reshuffling in the animal community.

"It really was a drastic change; there were no large carnivores and no large herbivores left," Sheehan says.



A gallery of goners: Four North American pollen types that went extinct at the K-T boundary.

Rooting for plant remains

In a spoof of the impact theory, cartoonist Don Bousquet of Narragansett, R.I., pictures a large dinosaur browsing on a tree, oblivious that it will soon be crushed by a giant can of Comet cleanser falling from the sky.

In reality, though, scientists will never know which dinosaurs witnessed the actual impact and how quickly they died out. The rarity of dinosaur bones makes it impossible to tell precisely what year a particular species disappeared from the fossil record. When vertebrate paleontologists talk about abrupt extinctions, they mean something that occurred during a geologically short time – an interval that could be up to a million years long. "It's a myth that we can show that dinosaurs literally went extinct overnight," Archibald says.

Those who study fossilized plants stand a much better chance of deciphering the speed of extinctions. Because pollen grains and fungal spores are so small and plentiful in certain sedimentary rocks, paleobotanists can trace the precise points at which different plants vanish from the fossil record. In North America, where scientists have found the best continental record of the late Cretaceous, the plant extinctions at the K-T boundary occur over an extremely short span at the same time as the impact, says Kirk R. Johnson of the Denver Museum of Natural History.

Paleontologists can resolve this timing because of a particular mark left in the sedimentary record. The K-T boundary in rocks around the world appears in the form of a thin clay layer highly enriched in iridium – an element rare in Earth's crust but concentrated in meteorites. For that reason, many scientists believe the iridium layer represents the fallout from the impact dust cloud that enveloped the Earth.

In the central part of North America, scientists find the iridium layer at the precise spot where the plant community goes through a profound change, with the dominant forms of trees and shrubs exiting the scene. "One thing that can't be overemphasized in the K-T boundary study is the abruptness of the event. We're looking at something that's happening in most places over the span of a few millimeters of stratigraphic section. Anyway you cut that, it's got to be a pretty short time geologically," Johnson says.

When vertebrate paleontologists argue that animal extinctions at the K-T boundary occurred gradually, they often attribute the slow die-off to a drying up of an intracontinental sea that covered the middle of North America during the Cretaceous period. According to this theory, the sea's disappearance altered the climate in the continental interior, placing stress on animals living there.

But Johnson and many others who study the K-T sections in the United States see no evidence of major plant extinctions within the last 300,000 years of the Cretaceous. At the October geology meeting, Douglas J. Nichols of the U.S. Geological Survey in Denver reported that studies in four distinct regions of western North America show abrupt extinctions, with 20 to 30 percent of the pollen types vanishing in the top meter of the Cretaceous section.

Again, because of the limitations of the fossil record, paleobiologists cannot say whether the extinctions occurred at the same time as the impact. But 1 meter of sediment in these locations corresponds roughly to 17,000 years – an exceedingly short time for such a significant number of extinctions, Nichols says. By geologic reckoning, such die-offs are contemporaneous with the impact.

The North American pollen record also shows a dramatic aftermath to the die-offs. Rocks from New Mexico to Saskatchewan suggest that for a short time following the extinctions, ferns spread over the landscape, almost to the exclusion of other plants. In this thin layer, measuring only a few centimeters deep in most places, fern spores make up some 70 to 100 percent of the pollen population.

This suggests that ferns colonized the land surface following massive plant death at the end of the Cretaceous, says Nichols. In each location, a single fern species appears to have dominated the plant community. A visitor to western North America at that time would look out over an expanse of ferns stretching as far as the eye could see. Soon thereafter, other plants came back into the scene.

Although pollen can help scientists track the speed of floral changes, they don't provide a good sense of how many species died out because many separate tree species produce apparently identical pollen, Nichols says. Therefore, if 40 species produce similar pollen and 30 go extinct, the remaining 10 will continue to produce the same pollen, making it look as if no die-offs had occurred.

To understand the severity of extinctions, paleobotanists look at fossilized leaves, which have much more distinctive forms, Johnson says. On the basis of work in the Hell Creek Formation and a few other deposits in North America, Johnson concludes that 80 percent of the late Cretaceous leaf types disappeared at the K-T boundary.

"You really do see a fundamental change in the flora, especially in the flowering plants. In North Dakota, essentially every flowering plant species in the late Cretaceous is replaced by something different," he says.

Plants in other parts of the world seem to have fared much better. At the October meeting, Johnson presented new research results showing that a far smaller percentage of species went extinct in New Zealand. "It does not look like a very dramatic event in New Zealand," he told Science News. Other scientists who have examined fossil beds in South America and Antarctica have reported that these sites also suffered minimal extinctions.

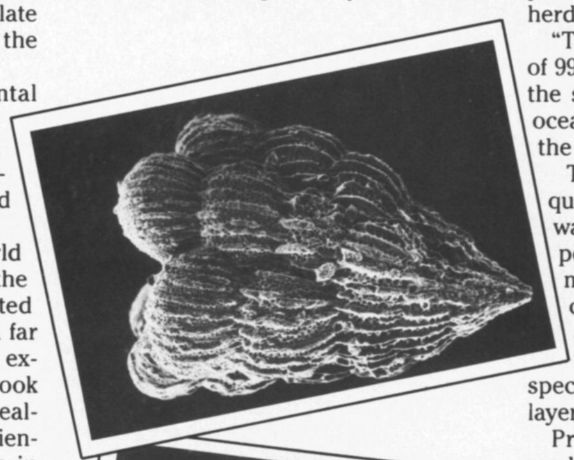
Such a distribution of die-offs is precisely the pattern one might expect to see if the bolide struck near North America, as some impact advocates have suspected. Indeed, recent evidence indicates that the impact occurred in the Caribbean-Gulf of Mexico region.

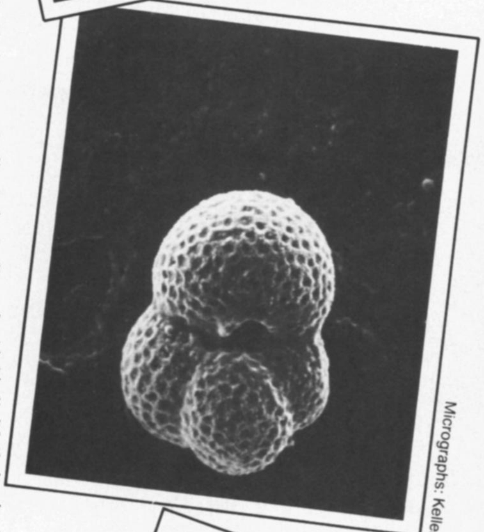
Perhaps because of the evidence they find on their home turf, many prominent U.S. paleobotanists support the idea that an impact drove the extinctions at the end of the Cretaceous. But that feeling fades north of the Canadian border. Says Arthur R. Sweet of the Geological Survey of Canada in Calgary: "I'm not an impactor at heart. Our data have never supported that as the only explanation."

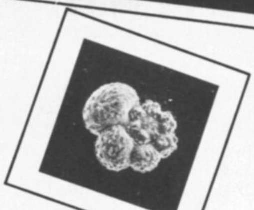
In their studies of western Canadian sites, Sweet and his colleagues see only modest extinctions – something on the order of 10 percent of the existing pollen types – occurring right at the K-T boundary. More important, they find gradual changes in the plant community leading up to the boundary. Many plants, while not necessarily going extinct, become less common in the fossil record, indicating that they suffered from some sort of environmental stress in the last few hundred thousand years before the boundary. Sweet believes some calamitous event – an impact or massive volcanic eruptions – served as the last straw for species already weakened by a climate change or some other gradual factor.

At face value, Sweet's conclusions run counter to those put forward by U.S. researchers such as Nichols, who see no sign of a floral decline before the boundary. But Nichols says the discrepancy need not mean that one interpretation is flawed. Plants in the north could have been more susceptible to changing conditions, especially if the formerly mild climate cooled to a point where temperatures in Canada dropped below freezing.

"The situation may be that the climate was changing gradually and things up in the north were feeling that [change] more and were declining," he says.







Micrographs: Keller

Gerta Keller finds that large foraminifera (top) went extinct before the K-T boundary, whereas medium-sized ones (middle) died off at the boundary. Small species (bottom) evolved after the boundary.

Trouble in the seas

Despite the notoriety of the dinosaur die-off, the ocean provides a far more stunning example of the K-T catastrophe. Deep-sea sediments deposited at the boundary reveal that plant growth almost completely ceased in surface waters – a unique biological event called the "Strangelove Ocean," after the 1963 movie about nuclear war. The oceans did not recover from the K-T crisis for a half-million years.

Tiny but abundant aquatic animals called foraminifera also suffered severely: Most species of Cretaceous foraminifera living in the upper ocean disappeared, making way for an entirely new herd of Tertiary foraminifera.

"There was a major crash in the oceans of 99.9 percent of all living organisms in the surface. It was really a very sterile ocean," says Jan Smit, a paleontologist at the Free University in Amsterdam.

The critical question is: Just how quickly did this wave of extinctions wash across the seas? From Smit's perspective, it could hardly have been more abrupt. Out of roughly 65 species of planktonic (floating) foraminifera living in the late Cretaceous seas, Smit finds at least 60 species going extinct right at the iridium layer that marks the K-T boundary.

Princeton's Gerta Keller, however, reads a very different tale from the fossil record. At sites in Spain and Tunisia, she finds about one-third of the Cretaceous planktonic foraminifera going extinct soon before the boundary, followed by a third at the boundary and a third soon after the boundary. To Keller, this stepwise extinction does not fit with a geologically instantaneous event such as a bolide impact. Rather, she believes a more gradual, down-to-earth factor, such as changing climate, initiated the extinctions some 100,000 to 300,000 years before the strict boundary.

Keller says an impact may well have occurred, but she argues that it could not have caused most of the K-T extinctions because they appear to have started before the crash. "I am only critical of the hypothesized disastrous effects of the K-T impact. I think that has been vastly overrated and still is. It is a fairy tale that over 90 percent of the microfauna go out due to the impact," she says.

Smit counters that in his examinations of the Tunisian rock section, called El Kef, he finds no early extinctions. The same species that Keller reports went out before the boundary, Smit sees living right up to the boundary.

Smit and Keller will face off in April, when they plan to meet in Tunisia along with other paleontologists. The assembled researchers will collect samples of the El Kef formation and then swap the rocks to conduct "blind" analyses, without knowing whose samples they have received. Smit and Keller had scheduled the Tunisia trip for last spring, but had decided not to travel in the Arab world during the Gulf war.

Scientists involved in the K-T debate eagerly await the Tunisia showdown, but few believe it will answer all questions. With their antithetical views, Keller and Smit may still read different tales while looking at the same rocks.

Although the plankton story remains unsettled, evidence from larger marine creatures indicates that some major extinctions did indeed occur before the boundary

Paleontologists led by Peter D. Ward of the University of Washington in Seattle report in the December GEOLOGY that studies in the Biscay region of northern Spain and southwestern France show that a ubiquitous set of huge bivalves called inoceramids gradually went extinct some 2.5 million years before the boundary. Remains of these animals in deep-sea cores indicate that inoceramid extinctions occurred all around the globe, Ward says.

The bivalve die-off came at about the same time as coral reefs were disappearing, notes Ward, who suspects that global climate change played a role in these early deaths. "The Earth had certainly been under enormous stress prior to the impact," he says.

That doesn't belittle the bolide strike, however. In their paper, Ward and his coauthors report that the widespread, nautilus-like ammonites disappeared abruptly at the K-T boundary. Eight species of ammonites died off right at the same time that planktonic organisms suffered severe extinctions, says Ward.

That find represents a turnabout for Ward, who had earlier reported evidence from a single Spanish site suggesting the ammonites died out long before the end of the Cretaceous. Over the last few years, as he studied other sites in Spain and France, Ward realized his error.

"I originally was the one who yelled to the world that the ammonites went out before the boundary, but now I'm convinced they go out *at* the boundary," he says.

K-T conspiracy?

Like the assassination of John F. Kennedy, the K-T deaths have inspired a deluge of ideas from people seeking to explain the mystery. Cartoonist Sidney Harris has lampooned the scientific squabbling by depicting a solitary man who scratches his head as he contemplates a dinosaur in a museum. The caption reads: "T. Radfield Burke, chemist, is the only person in all of science who does not have a theory about the extinction of the dinosaurs."

The story will grow clearer as more data allow scientists to select from mutually exclusive theories. For instance, with enough sampling and analysis, paleontologists should be able to resolve whether or not Cretaceous foraminifera died out before the boundary.

Likewise, the geographic distribution of extinctions – why some regions suffered more than others – has begun to make sense with new geologic evidence that the impact occurred in the Caribbean-Gulf of Mexico region. That may explain why the die-offs afflicted plants and animals in the western United States much more than in New Zealand, Antarctica or even parts of Canada.

But other issues may not gel so easily. Because major groups such as the inoceramids went extinct before the boundary, scientists must consider a "conspiracy" theory involving a gradual killing mechanism followed by an abrupt impact. The early extinctions may have resulted from some type of climate change, perhaps a rearrangement of ocean currents, suggests Ward. Many researchers have also proposed that an extremely massive set of volcanic eruptions in India, known as the Deccan Traps, may have sparked extinctions at K-T time. Perhaps these eruptions – among the largest in geologic history – could have caused die-offs prior to an impact.

If several factors conspired to cause the K-T extinction epidemic, it may be impossible to sort out the detailed story. "I don't know how anybody can portion out blame. We're in no position to be able to say that the impact caused 60 percent of the extinctions while the other stuff did this [percent]," Ward says.

If an impact could explain all the extinctions known from 65 million years ago, the K-T saga would boil down to a succinct tale. But nature apparently abhors a simple story. □