Dinosaurs and Friends Snuffed Out?

A new sort of paleontological field study is showing that, contrary to earlier claims, the dinosaurs and some other species were still thriving just before the asteroid hit

IN THE 10 YEARS SINCE NOBEL LAUREATE Luis Alvarez, his son Walter Alvarez, and their colleagues made the controversial suggestion that an asteroid impact wiped out the dinosaurs and a host of other species 66 million years ago, their hypothesis has won many adherents. Most geologists now agree, for example, that an asteroid or a comet did indeed strike at the right time. But one important group of scientists held back: the paleontologists.

Early on, the keepers of the fossil record protested that such a biological catastrophe was nonsense. Even if there was a gigantic impact, they said, it didn't have anything to do with the demise of the dinosaurs. The fossil record clearly showed that the plants and animals that had dominated Earth for tens to hundreds of millions of years before the asteroid struck died out gradually, species by species, over millions of years, not suddenly as the impact hypothesis predicted.

Now, more and more paleontologists are coming around to the idea of a catastrophic impact. As paleontologist Peter Ward of the University of Washington puts it, "The old saw was that [species] went out gradually, but as specialists begin to look more closely, they're finding otherwise." What's convinced them are new, intensive field studies. Not that the new records can be used to prove that a given species went out during "one bad weekend," as the impact advocates would have it. But what had appeared in some cases to be a gradual depletion of species turns out to be an artifact of the way paleontology has usually been done. "About 100 years too late, people are looking at what [the fossil record] really means," adds paleontologist David Raup of the University of Chicago. "This is a marvelous time. People are asking new questions and using new tools."

The primary new tool in studying mass extinctions is the sort of exhaustive field work the Alvarezes and their supporters had advocated for years. The fossil record had been read traditionally from specimens returned from the field for a variety of studies, none of them being the detection of sudden extinctions. The Alvarezes and others argued that this was simply too imperfect a means of telling whether a particular group of animals had petered out before the impact struck or was getting along just fine, thank you, until the moment of destruction.

Most paleontologists dismissed these arguments. Neither Luis Alvarez nor his son was a fossil expert; Luis, who died in 1988, was a physicist, and Walter is a geologist. And the elder Alvarez had a way of antagonizing paleontologists with deprecations of their field as he drove home his scientific arguments.

In particular, Luis Alvarez found fault with claims that the dinosaurs had already died out—gradually, of course—shortly before the asteroid impact 66 million years ago. That impact left its mark in the form of a thin layer of iridium-rich debris. And in the dinosaur caches of Montana, Wyoming, and the Dakotas, that layer was 3 meters above the closest bona fide dinosaur fossil deposit found by paleontologists. As far as the paleontologists could tell, the ranks of the dinosaurs thinned over a period of at least 10 million years, and the last known dinosaur bones appeared to have been laid down on the (very rough) order of a hundred thousand years before the impact.

Alvarez and others maintained, however, that paleontologists saw a gradual decline and the 3-meter gap because their searches had neglected a lot of fossils. One of the paleontologists who took this argument seriously was Peter Sheehan of the Milwaukee Public Museum. Although not a dinosaur specialist—his interests are in fossil brachiopods, small shelled marine animals that survive to the present day—Sheehan persuaded his museum to sponsor an unprecedented search for new dinosaur fossils in the badland terrain of North Dakota and Montana.

During the summers of 1987, '88, and '89, the museum deployed search crews of 20 volunteers drawn from the public—each volunteer paying $800 for the opportunity to plod systematically over miles of sun-scorched terrain searching for dinosaur fossils. Once a specimen was located, experts came in to make an identification. When the project was over, the volunteers had put in more than 15,000 man-hours and had found 2500 dinosaur fossils in the area searched, which is called the Hell Creek Formation. According to Sheehan, the fossils found by this effort show no indication of a gradual decline toward extinction: "We find the number of individuals as sorted out by family is staying the same [through the last 3 million years before the impact]," he says. "We reject the idea that the dinosaurs died out gradually through the Hell Creek."

The Milwaukee Public Museum search also shrank the 3-meter gap to 60 centimeters, a considerable achievement considering that an enormously greater effort would likely be required to eliminate it.

Why had paleontologists missed so many dinosaur fossils? Sheehan says simply that "most of the bones of the Hell Creek have been ignored." Paleontologists focused on either the rare species, which would help understand ancient flora and fauna, or the most exquisitely preserved skeletons, which would add to a museum's exhibits. "That's why a data base like ours had not been put together before," he says.

P. Sheehan/Milwaukee Public Museum

Neglected evidence. *A fossil gets a close look during an intense search for clues to the dinosaurs' demise.*

Although Sheehan's search is among the

first to reveal the flaws of traditional readings of the fossil record, paleontologists had been warned long before by two of their own that passing over so many fossils could lead to trouble. In 1982 paleontologists Philip Signor of the University of California at Davis and Jere Lipps of UC, Berkeley, published a study based on the numerical manipulation of hypothetical fossil collections. In it they warned that the time at which a species appears to go extinct depends on the abundance of the fossils it left behind. In the case of the dinosaurs, for example, the rarer ones would disappear from the record before the more abundant ones, even if they all went extinct at the same geologic instant. And the fewer fossils collected the more gradual the march to extinction would appear.

This so-called Signor-Lipps effect in the distribution of fossils can be compared to what happens when someone sprinkles pebbles evenly across a hillside, the top of which marks a sudden "mass extinction of pebbles." It's unlikely a pebble will fall right at the top of the hill to mark the moment of extinction if only a handful of pebbles is scattered. But use a truckload of them, and a collector will be able to follow the pebbles right up to the mass extinction with no apparent decline in pebble abundance.

The significance of the Signor-Lipps effect has been slow to sink in, but even paleontology-as-usual gradually began to provide examples of the effect's workings while simultaneously producing further support for a biological catastrophe at the impact. In the early 1980s, Ward and his colleagues went to the Spanish Atlantic coast near the French border, where the exposed cliffs provide easy access to 200 vertical meters of sediments that were laid down during the last couple of million years before the impact. The researchers were looking for ammonite fossils, the centimeter- to meter-size remains of coil-shelled cephalopods that survived for 330 million years until they disappeared after the impact.

In a 1986 paper, Ward reported that at this site, at least, the ammonites seemed to have died off gradually over a couple of million years without making it to the time of the impact. Try as they might, Ward and his colleagues could not find an ammonite within 10 meters of the impact layer.

That report provided solace for those who favored a gradual decline of species, but it did not hold up long. Ward's subsequent searches at four other sites along the Spanish coast, where ammonite fossils turned out to be more abundant, found at least nine species within 1 meter of the impact layer; the closest was just 14 centimeters away. Ward's latest compilation of worldwide data shows at

More Death by Impact?

The mass extinction 66 million years ago that included the dinosaurs wasn't Earth's only convulsion. Another wave of death swept the planet a little more than 200 million years ago, for example, and now a group of researchers has found evidence that this mass extinction was also linked to the catastrophic impact of an asteroid or comet.

Signs of the older impact turned up in the north of Italy, the by-product of a geological mapping survey that David Bice conducted in Tuscany as part of his doctoral dissertation for Walter Alvarez of the University of California, Berkeley. Alvarez is one of the originators of the once highly controversial, but increasingly accepted, hypothesis that an impact wiped out the dinosaurs (see main story). While Bice, who is now at Carleton College in Northfield, Minnesota, was doing the mapping, he noted a rock outcrop that looked as if it might contain the boundary between sediments laid down in the Triassic Period, which ended 205 million years ago, and those of the subsequent Jurassic Period. The Triassic-Jurassic (T-J) boundary marked an era of widespread extinctions among amphibians, reptiles, and other species. So Bice reasoned if the rock outcrop contained the boundary it would be a good place to look for signs of any impact that might be responsible for those extinctions.

After finishing his dissertation, Bice returned to Italy for samples of a shale layer laid down immediately above the presumed boundary. Bice found what appeared to be the classic indicator of a large impact—grains of quartz riddled by distinctive banding, or lamellae. Most of these quartz grains carry only one set of parallel lamellae, but about 10% have two intersecting sets and rare grains have three. Only truly shocked grains are known to have such multiple sets of lamellae.

Glen Izett of the U.S. Geological Survey in Denver is a veteran in the shocked quartz business. He says that photographs Bice took of the grains "look like textbook examples of shock in quartz grains." Although Izett was impressed by the photographs, he and other experts will have to examine the grains directly before they can conclude that they provide proof of another large impact. Impact discoveries have been claimed before that did not hold up on close inspection.

Experts also want to pinpoint the time of the putative impact to see if it struck at the T-J boundary. Paleontologist Cathryn Newton of Syracuse University, who has been working with Bice, thinks she has strong evidence that it did. She looked for the fossils of a group of clams and snails that was prevalent late in the Triassic Period. She found they were abundant in a layer of limestone immediately below the shale layer where Bice found the shocked quartz grains. None of the fossils appeared in the shale itself, and only above the shale did typical Jurassic fauna appear. Thus, the T-J boundary would seem to fall at the geologic instant between the top of the limestone and the bottom of the shale, which would leave a record of a deceptively abrupt extinction.

Although the extinctions seen by Newton appear to have been abrupt, and therefore possibly caused by a coincident impact, evidence from a single site is not sufficient to rule out a gradual decline in species. Sediments recording such a gradual extinction might have been erased by erosion, for example.

But Sarah Fowell of Columbia University's Lamont-Doherty Geological Observatory in Palisades, New York, has also found evidence for abrupt T-J extinctions and at a far distant site—in lake sediments deposited in New Jersey. In these lakes the record is more complete than the one laid down in the ocean. Using as a clock the regular beat of climate change induced by Earth's orbital variations, Fowell pinned down T-J vertebrate and plant extinctions to an interval of 21,000 years. That is a blink of an eye to paleontologists, who tend to think in terms of millions of years. And at least one aspect of this mass extinction looks particularly catastrophic. A sharp pulse in the abundance of fern spores at the T-J boundary is reminiscent of the fern spike at the mass extinction 66 million years ago in the western United States, where impact debris clearly coincides with extinctions.

If further work confirms that an abrupt, impact-related mass extinction did occur at the T-J boundary, as it now appears, the development would be welcomed with open arms by researchers studying the later mass extinction. They've had a tough time trying to decipher a one-of-a-kind event in Earth's history. ■ R.A.K.

ast 22 species within a meter of the impact deposit. Ammonites, like dinosaurs, seem to have been getting along well enough as they approached the time of the impact.

Why hadn't earlier workers found ammonites up to the time of the mass extinction? "The level of work just had not been good enough," says Ward. "They were asking other questions. They just weren't interested in the extinction question."

Ward is not alone in finding that massive collecting of fossils is required to minimize the Signor-Lipps effect. Back in the early 1980s, paleobotanist Leo Hickey of Yale University couldn't see any clear signs of a catastrophe in 1000 or so leaf fossils that he had collected from the same areas of the United States that are mined for dinosaur fossils. But that perspective changed once he and his student Kirk Johnson, who is now at the University of Adelaide, had collected and analyzed 25,000 specimens.

P. Ward

Fossil heaven. *Fossils from Spanish sea cliffs support an ammonite catastrophe.*

"I became a believer," says Hickey. "This evidence is incontrovertible; there was a catastrophe. We really hadn't been looking at the record in enough detail to pick this extinction up, and we weren't disposed to look at it as a catastrophe. I think maybe that mind set persisted a little too long."

Another massive collection effort is swaying the mind of graduate student Paul Morris of Harvard University. He collected 3000 freshwater mollusk fossils, mostly clams, from the Hell Creek formation, and he could see no indication of a gradual decline. Sheehan's and his own results make Morris a bit uncomfortable. "Until recently, I've been in the camp favoring somewhat more gradual extinctions," he says, but both studies "seem supportive of a very sudden cause for the non-marine extinctions."

All this does not mean that every extinction that occurred near the time of the impact was caused by it. Looking back from that time in his paleobotanical record, Hickey sees plenty of species dying out during the million years leading up to the impact, although the changes are far less intense than those associated with the impact. And Kenneth MacLeod of the University of Washington and Ward have found that the inoceramids—clams that littered the sea floor with myriad bits of debris—gradually died out at least a million years before the impact.

In light of such results, even the most ardent impact advocate would allow some role in extinction for forces other than an impact, such as the sea level fall that immediately preceded the impact or even the voluminous volcanic outpourings at about the same time in India. But in this view, the impact would have tipped the scales toward extinction for many species that would otherwise have endured the other strains.

Non-catastrophists can also argue that even the new, intensively collected records allow relatively sudden but environmentally controlled extinctions. In the dinosaur record and even in the ammonite record, the Signor-Lipps effect still cloaks the final years before the impact in uncertainty. Perhaps, it could be argued, the dinosaurs resisted increasing environmental strain until it was just too much and they suddenly collapsed a few hundred thousand years before the impact.

But for an increasing number of paleontologists, the evidence now seems clear that an impact did cause many of the extinctions that occurred 66 million years ago. "I don't think you'll have to wait for the old guys to die off," Hickey says, before paleontologists accept the idea of a catastrophe.

■ RICHARD A. KERR

The Fine Details of Extinction

Although evidence is accumulating that an asteroid or comet impact caused catastrophic extinctions 66 million years ago (see main story), researchers still have only a fuzzy view of exactly what happened at the time of impact. Because the only way to sharpen their view is to collect more fossils, they are handicapped by the rarity of the larger fossils, such as those of the dinosaurs. The dinosaur record is so sparse that it can only be meaningfully sliced into million-year increments.

Enter the micropaleontologists, who can hold millions of specimens in the palms of their hands. Tracing specimens through the thinnest slivers of time should be no problem to them. For example, micropaleontologists sifting for pollen in the sedimentary rock deposited 66 million years ago in the western interior of North America read catastrophe in a few millimeters of sediment. There, in a layer built up over years rather than millennia, half the members of the major plant groups disappeared forever, only to be replaced by opportunistic ferns. And this sliver of sediment is marked by the unmistakable debris from the impact of an asteroid or comet.

Less clear-cut, though, is the world of marine micropaleontology. Its experts have for several years been locked in an inconclusive battle over just what happened around the time of the impact, in particular to the microfossils called foraminifera. The two principal combatants are Gerta Keller of Princeton University and Jan Smit of the Free University in Amsterdam. They see eye to eye on very little, as exemplified by their independent analyses of marine sediments from El Kef, Tunisia.

According to Smit, virtually all of the 30 foraminifera species he looked at went extinct at just about the time of the impact. In contrast, although Keller finds species going extinct at the time of the impact, she also finds them dying out as much as 30,000 years before, and up to thousands of years after the impact. Keller's are the most abrupt "gradual" extinctions ever reported, but her order of events isn't consistent with the idea that the impact caused most of the extinctions.

At the moment, there is no agreement about why the two researchers are finding such discordant results at El Kef. But whatever the problem or problems, they may soon be ironed out. Smit and Keller will be traveling to Tunisia in May for a symposium and field trip to El Kef. Under the watchful eye of an impartial third party, samples will be collected, processed, and distributed to Smit, Keller, and other researchers, who will be told nothing about them. This blind analysis may allow the differences between Keller and Smit to be sorted out, unless current events intervene. The hotels in Tunis where the symposium participants are likely to stay are across the street from the headquarters of the Palestine Liberation Front, says Keller. "I'm going unless there is a war in the Gulf—in which case, count me out," she says.

■ R.A.K.

ADDITIONAL READING

V. L. Sharpton and P. D. Ward, eds., *Global Catastrophes in Earth History: An interdisciplinary conference on impact, volcanism, and mass mortality.* Geol. Soc. Am. Special Paper, no. 247, (1990).