Extinction by a One-Two Comet Punch?

As if one huge impact 65 million years ago weren't bad enough, two or more blows may have ravaged life

TEN YEARS AGO, RESEARCHERS WHO CLAIMED that a huge asteroid or comet hit Earth 65 million years ago and killed off the dinosaurs and other unfortunate species risked being regarded as fringe scientists. Now, even as that notion moves into the mainstream, some geologists are asking their colleagues to swallow even more: the possibility that not one, but two major impacts struck 65 million years ago, just a few years apart at most.

"There isn't any way to get around" two nearly simultaneous impacts, says one of the researchers, geologist Eugene Shoemaker of the U.S. Geological Survey (USGS) in Flagstaff. And once you get used to that idea, prepare yourself mentally for even more: Shoemaker thinks the most probable source of multiple impacts is a comet that broke up and then pummelled Earth with its debris year after year. "My best guess is that Earth got splattered," Shoemaker says. That might explain why this mass extinction was the most severe of the past 200 million years, and it implies that the search that has turned up two possible killer craters, in Iowa and the Yucatan (*Science*, 15 November 1991, p. 943), may uncover even more, carved out at the same geologic moment.

The impact deposits of the western United States, which are pushing the battered-Earth hypothesis into the limelight, always appear as a couplet. The lower layer consists of two or three centimeters of grayish clay containing impact spherules. Above is a second layer, less than a centimeter thick, containing iridium from an impactor and quartz grains shocked by the impact. Conventional thinking—at least for the past few years—has held that both layers were laid down by a single impact, now presumed by many researchers to be a big one in the Yucatan. The thick lower layer would be the ejecta that shot directly out of the crater to form a blanket extending for thousands of kilometers, and the upper layer would be finer-grained debris that was lofted so high that it drizzled down around the globe hours or weeks later.

Anyone pushing this single-impact explanation of the western deposits should take a closer look at them, say geologists who have made microscopic examinations of slices through the two layers. David Fastovsky of the University of Rhode Island and his colleagues were the first to suggest 2 years ago that a single impact might not explain the observed layering. Examining samples from a site in Montana, they discerned extensive alteration of the lower layer, apparently formed by prolonged exposure to the weather before a second layer was deposited. But not much came of Fastovsky's discovery. For whatever reason, his conclusion that the layers were probably formed by two separate impacts attracted little notice.

Now, Shoemaker has joined the case for a double impact, together with geologist Glen Izett of the USGS in Denver, who presented some of the findings at last month's meeting of the American Geophysical Union in San Francisco. Shoemaker and Izett have identified traces of plant roots that extended through the lower layer but could not be traced into the upper layer, as if plants had time to grow on the surface of the lower layer before the upper layer was deposited. And they found signs of extensive weathering of

GLEN IZETT

Time out between impacts? *A root (grey structure) may have grown into the lower deposit.*

A Simple Flip-Flop for Earth's Poles?

Earth's two magnetic poles have a habit of switching places as often as every 100,000 years, but researchers are mystified about what causes these flip-flops. That's not surprising, since they are hard put to explain exactly how the liquid iron of the core generates the magnetic field in the first place. They once hoped that the behavior of the field during a reversal might hold a key to both mysteries, but no such luck: Paleomagneticians came to believe that the reversing field degenerates into a hopelessly jumbled and uninformative mess during a reversal. Now, however, paleomagneticians are undergoing a bit of a reversal themselves.

According to presentations at last month's American Geophysical Union (AGU) meeting in San Francisco, in a few magnetic reversals at least, the flip-flopping field seems to retain its relatively simple structure after all. That recognition "means there's a better chance that reversals are a tractable problem," says paleomagnetician Bradford Clement of Florida International University, "and that makes me optimistic that the reversals may hold a clue about how the field is generated in the first place."

This turn of events has required some backpedaling by the researchers involved. Take paleomagnetician Kenneth Hoffman of California Polytechnic State University. During the past decade, Hoffman convinced many researchers that fields during reversals bear little resemblance to today's dominant field—the classic dipole field of a bar magnet, with a north and south pole. Instead, they combine fields having more than two poles, making the transitory field almost indecipherable in paleomagnetic records frozen into sediments or lava flows.

Now, after years of arguing this line, Hoffman had a small, somewhat theatrical confession to make in his AGU talk about the nature of reversing fields. "This is difficult. A lot of this [data] is coming from my own lab; it's embarrassing. It has taken myself and my therapist 2 years to say this—it's dipolar." Hoffman's change of heart came after he inspected newly retrieved records of the changing orientation of the field during several reversals of the past 2 million years, recorded in cooling lava flows.

Clement had also leaned toward a complex field during reversals. But at the AGU the lower debris layer at sites in New Mexico, Colorado, and Wyoming. What's more, Shoemaker, who also studies asteroids and comets, astrophysicist Piet Hut of the Institute for Advanced Study, and their colleagues have proposed a single astronomical mechanism for multiple impacts. They envision a comet in an orbit that carries it disastrously close to the sun. The dirty snowball at the comet's heart breaks up under the stress, and the pieces slowly spread apart.

That is hardly farfetched; astronomers have watched more than 20 comets break up over the past 150 years. The additional requirement—improbable though not impossible—is that the debris field end up on Earth's orbital path. The planet's motion would then have carried it through the debris field once each year, the way Earth now passes annually through streams of comet dust that create meteor showers. That would open the way for at least two impacts, perhaps more.

As a result of these developments, more researchers are taking the possibility of a double impact seriously. But the two-impact scenario raises a host of new questions. For one, how closely spaced were the impacts? Paleobotanist Jack A. Wolfe of the USGS in Denver recently claimed an interval of less than 4 months on the basis of a site at Teapot Dome in Wyoming that he thinks preserves debris from two impacts falling into a lily pond during one growing season. That interval is a bit short even for Shoemaker's mechanism. At the other extreme, Fastovsky figures it would have taken at least 120 years for impact glass to weather into the type of clay he sees in Montana.

Another question proponents will debate: Where are the craters from two separate impacts? Izett and Shoemaker suggest that the 180-kilometer Chicxulub structure in the Yucatan is responsible for the lower layer. Circumstantial evidence is mounting that it was linked to the mass extinction (*Science*, 15 November 1991, p. 943), and as the largest known impact, it would have had the power to blow enough debris into central North America to form the thicker lower layer. For the upper layer, the 32-kilometer Manson crater in Iowa seems right, Izett and Shoemaker say. On its own, Manson had seemed a poor candidate for being the killer crater because of its small size—it released one two-hundredth as much energy as the Chicxulub impact.

The giant Chicxulub impact probably would still have been the primary driver of the mass extinction, says Shoemaker, but it could have had a little help from its Iowa companion—and perhaps from other impacts as well. The search for killer craters may not be over soon. ■ RICHARD A. KERR

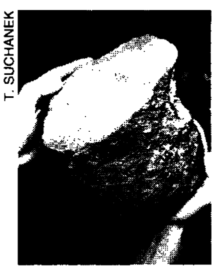
meeting, he described work with Douglas Martinson of Lamont-Doherty Geological Observatory of Columbia University in which the researchers compared the behavior of the field recorded during a reversal 1.1 million years ago in North Atlantic and equatorial Pacific sediments and in lava flows at one site in the South Pacific. This diversity of records should eliminate any distortions present in a single region or recording medium, says Clement. The result: consistent indications that "at least in this one reversal there is strong evidence for a dipolar field" during a flip-flop.

Soon it will be the theorists' turn to make sense of the reversing field, says Clement. "If we can give them some constraints as to what is happening during a reversal, they can get more constraints on their models" of the field. ■ RICHARD A. KERR

Extinction With a Whimper

Few researchers now doubt that a comet or asteroid—or several in quick succession (see story on page 160)—struck Earth at the time of the mass extinction 65 million years ago. It might seem reasonable to assume that all the species that vanished in the mass extinction were victims of the impact. But there is growing evidence that some species were in trouble before the impact, probably because of gradual environmental change.

One of the strongest indications yet of a gradual component to the mass extinction comes from an early application of a new dating technique to paleontology. Stratigrapher Nicola Swinburne of the University of California, Berkeley, has reaffirmed that rudists, bizarrely shaped bivalves that lived much as corals do, disappeared gradually before the impact.


T. SUCHANEK

Lingering death. *A rudist.*

Swinburne's study, reported last month at the American Geophysical Union meeting in San Francisco, is only the latest to find that the rudists declined gradually, but it sports an important distinction. Like other researchers, Swinburne combined fossil finds reported from around southern and central Europe, North Africa, and Arabia, carefully weeding out inconsistencies in classification. But in establishing a chronology of the species' disappearances, she abandoned the usual strategy of relying on marker fossils of an assigned age as benchmarks—a technique she says can distort the rudist record. Instead, she took advantage of the steady change in the ratio of two strontium isotopes in seawater during the 12 million years before the impact to date the rudist shells themselves, based on their isotopic composition.

Swinburne's isotopically dated compilation paints a clear picture of gradual extinction. From a peak in the number of extant species and genera about 75 million years ago, rudist diversity went into a sharp decline about 70 million years ago. Some researchers have seen a sequence of abrupt drops and intervening plateaus in the decline of rudists around this time, which they have interpreted as evidence of a drawn-out shower of killer comets. But the decline Swinburne traced was steady. Such "stepwise" extinctions only appear when the database is poor, she says.

Rather than some extraterrestrial influence, the steady decline in rudist diversity points to an environmental cause, says Swinburne. The diversity decrease paralleled a decrease in the area of shallow marine waters, the rudists' habitat, as the seas retreated from the continents. Swinburne concludes, as others have, that the retreat drove most of the rudists' decline. And the resulting extinction, which traditionally had been lumped into the mass extinction of 65 million years ago, seems to have come before the impact; the youngest rudists in Swinburne's compilation fall more than a million years short of it.

"After years of anecdotal evidence," says paleontologist David Jablonski of the University of Chicago, "it would appear that hard data are beginning to emerge suggesting" that environmental changes during the few million years before any impact were already gradually taking their toll. With Swinburne's study, that notion would seem to be established firmly for the rudists. Moreover, another major fossil group—the bivalve inoceramids—also shows signs of a gradual disappearance, shortly before the impact.

On the other hand, the dinosaurs, the spiral-shelled marine ammonites, freshwater clams in Montana, and plants in North Dakota seem to have been getting along just fine until they disappeared from the geologic record right where the impact left its mark (*Science*, 11 January 1991, p. 160). But there's no reason why the mass extinction need be explained exclusively by a single mechanism, notes Jablonski. Maybe the worst mass extinction of the past 200 million years was the result of a catastrophe that happened to strike just when things were already going downhill. ■ RICHARD A. KERR