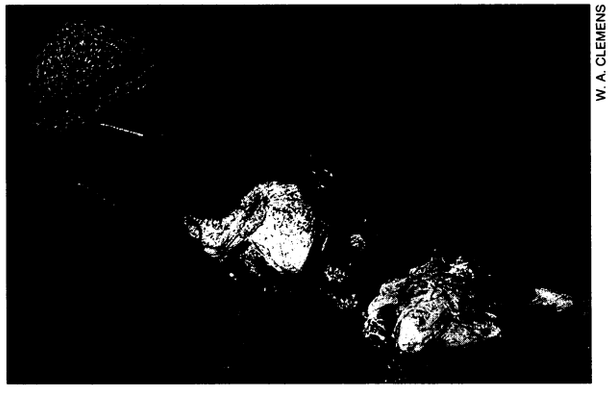
How Lethal Was the K-T Impact?

The asteroid that hit Earth 65 million years ago appears bigger than previously thought, but scientists have new doubts about its ability to kill the dinosaurs

More than a decade has passed since Luis W. Alvarez and his colleagues first proposed that an asteroid impact 65 million years ago kicked up enough of a dust cloud to darken and chill the planet for months, killing off the dinosaurs (*Science*, 6 June 1980, p. 1095). Since then, the theory has gathered force as scientists have gathered more evidence pointing to an impact at that time—the boundary between the Cretaceous and Tertiary periods (K-T). Some researchers now believe the asteroid was so big it was a once-in-a-billion-year event (see story on this page).



W. A. CLEMENS

Casting doubt on a cold killer. Paleontologist William Clemens excavates plaster jackets containing Alaskan dinosaur bones.

Ironically, as more scientists satisfy themselves that an impact did occur, other researchers have begun raising tough questions about whether that impact packed enough punch to make the dinosaurs disappear. Alvarez' original hypothesis has been refined, with global wildfires and other proposed disasters being added to the mechanism of dinosaur destruction, but most catastrophists still include some period of winter darkness in their models. Yet several months of dark and cold might not have been enough to kill off the dinosaurs.

The reason: New findings show some dinosaurs thrived in cold climates. Dramatic evidence comes from Alaska's North Slope, where William A. Clemens and L. Gayle Nelms of the University of California, Berkeley, have found signs, which they reported in the June issue of *Geology* (vol. 21, p. 503-506), that several dinosaur species spent the winters in cold, dark climes. When added to the survival of organisms such as plankton and turtles across the K-T boundary, this creates a puzzle: Whatever happened at the boundary seems to have destroyed cold-adapted dinosaurs while leaving climate-sensitive creatures untouched. And how can you explain that with an asteroid impact? "Not with the simplistic idea of turning off the lights for 3 months," says Tom Rich, a paleontologist at the University of Monash in Australia. "Clemens' paper shoots that

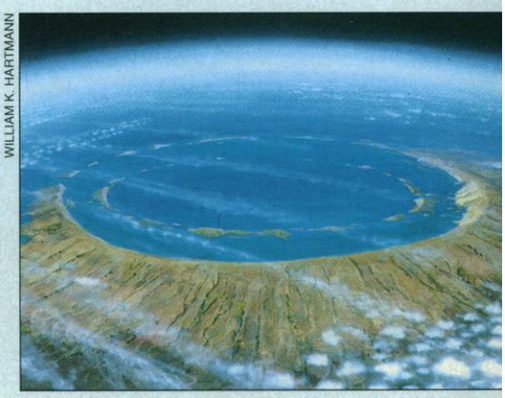
A Bigger Death Knell for the Dinosaurs?

Most geologists agree that a sizable comet or a smallish asteroid struck the Yucatan coast at the same geological instant as the last of the dinosaurs disappeared 65 million years ago, along with many other creatures. But while many geologists hold the impact responsible for the extinctions, paleontologists tend to think the impact and the extinctions coincided by chance. For one thing, the diameter of the buried crater—180 kilometers—seemed to imply a catastrophe of the size that planetary scientists calculate should occur every 100 million years or so. What's so startling, ask these doubters, about the association of a relatively commonplace cataclysm with the extinction? But a paper in this issue of *Science* argues that the impact 65 million years ago was truly extraordinary.

On page 1564, a group led by Virgil Sharpton of the Lunar and Planetary Institute in Houston reports a new analysis of the surface traces of the Chicxulub crater, which lies buried beneath almost 2 kilometers of Yucatan sediment. These researchers see the faint outlines of a scar that is nearly twice as large as had been thought—300 kilometers in diameter. That would imply an impact so large as to be "very unusual, perhaps unique," says Sharpton. "Perhaps Earth has not experienced such an event since complex life appeared" 1 billion years ago, he says. If he and his colleagues are right—and other geologists are intrigued, but far from convinced—the impact could easily have left a unique mark in the history of life.

It might seem that a crater's size is easy to determine, but when the crater is as deeply buried as Chicxulub, evidence has to come from subtle surface effects of the buried rocks, such as variations in the strength of Earth's magnetic field and gravity. In the studies that revealed the crater's existence in 1991, researchers detected a bull's eye pattern of gravity variations amounting to one ten-thousandth of total gravity across a circle some 180 kilometers wide. Sharpton and his colleagues have now removed spurious points from those gravity data, added new points, and reprocessed the refined data. The ring of ever so slightly heightened gravity outlining the 180-kilometer circle remains. But added to it is an even fainter ring at 300 kilometers—the outer limit, Sharpton and his colleagues think, of the crater.

"The outer ring is very subtle," admits Sharpton. "But its subtlety is consistent with what we know about how craters form." Large ones like Chicxulub form in two steps. The impact creates a deep "transient" crater. The walls of that initial crater collapse within minutes of the impact, partially filling the transient bowl and enlarging the crater to its final size. Geologists had thought that the 180-kilometer ring at Chicxulub marked the outer bounds of the



WILLIAM K. HARTMANN

down." But catastrophe theorists, far from giving up the argument, now contend that the lights may have gone off for a much longer period.

Clemens and Nelms' arguments begin with the climate on the North Slope in the late Cretaceous. As indicated by plant fossils found only in cold areas, the region had a mean annual temperature of 2 to 8 degrees Centigrade, not unlike the climate of present-day Anchorage. The Slope lay well within the Arctic Circle and experienced 3 months of darkness annually. Previously, researchers had suggested that the dinosaurs spent only summers in Alaska, migrating south before winter. Yet Clemens and Nelms argue that their fossils show some dinosaur species were year-round residents.

Their primary evidence comes from a collection of teeth of young hypsilophodonts—lightly built, agile creatures that stood a little less than 2 meters tall. "If they were migratory and hatched that far north," says Nelms, "then within a few months, when they were still quite small, they would have had to travel thousands of miles—something I have a hard time imagining." Nelms and others believe the juveniles' small size argues against a 2100 kilometer journey. The scientists actually suspect that hypsilophodonts may not have migrated at all; the fossil record indicates these creatures did not live in herds, and herding behavior is a signature of most migratory animals.

Further, it seems that hypsilophodonts may have been particularly adapted to cooler, more seasonal environments. Not only are their fossils found in Alaska, but recently five new genera have been unearthed in southern Australia—from an area that in the Early Cretaceous lay within the Antarctic Circle. Clemens and Nelms also suspect that several other species of dinosaurs, including the carnivorous troödon and vegetarian dromaeosaur, overwintered in cold, dark regions.

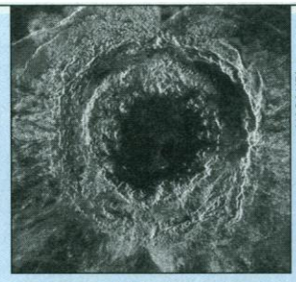
The absence of amphibians and reptiles in the Alaskan deposits reinforces Clemens' and Nelms' doubts. These species are common only in Cretaceous deposits from more temperate latitudes, indicating that they were not adapted for cold. But, says Clemens, "it's the dinosaurs (except for birds) that went extinct, while these other creatures survived—which is exactly the opposite of what you would expect" if the cold and dark actually did the dinosaurs in.

Given some past testy exchanges between paleontologists and impact theorists on this subject, some of those theorists seem surprisingly easily persuaded of trouble with the cold, dark killer theory. "The biggest uncertainty we face is the kill mechanism," says H. Jay Melosh, a planetary scientist at the University of Arizona. Adds Owen B. Toon, an atmospheric scientist at NASA Ames Research Center, "Clemens' paper does make it harder to understand the extinction of small dinosaurs from the cold and dark."

Toon and Melosh, however, don't think that cold and dark were the only potentially lethal consequences of the impact. Melosh favors death-by-acid-rain, and Toon suggests global wildfires generated by the asteroid would have caused considerable trouble for dinosaurs large and small. Other catastrophists argue that the period of dark cold may have been 5 to 10 years, rather than just a few months—and even the most highly winterized dinosaur would have had trouble coping with that. At a geochemistry meeting this spring, Kevin Pope of Geo Eco Arc Research in La Canada, California, and his colleagues suggested such an extended winter would result if the impact triggered the formation of clouds of sulfuric acid, which stay in the atmosphere for years.

But any univeral mechanism, be it fire or 10 years of ice, faces the same problem, says Clemens. "The real question is, How did the others—how did any animal—manage to survive? [Impact theorists] have got to come up with a hypothesis that puts equal weight on survival. So many of these catastrophists want to kill the dinosaurs, they forget the rest of the biota. Birds, mammals, and amphibians managed to survive, and that tells you that there is something wrong with most of these hypothetical horrors."

–Virginia Morell



NASA/JPL

Bull's eye. Multi-ring craters on Venus like the one above inspired an artist's conception of the 65-million-year-old Chicxulub crater *(opposite page)*.

collapse. Sharpton, though, thinks that ring is too prominent to be the rim of the collapse and interprets it as the edge of the smaller, transient crater. The subsequent collapse, he says, apparently extends all the way out to 300 kilometers.

"This is very exciting," says planetary scientist William Hartmann of the Planetary Science Institute in Tucson, although he and others stress that the larger size is far from certain. Other researchers such as Richard Pike of the U.S. Geological Survey in Menlo Park, who has studied the new analysis, aren't convinced that the subtle outer ring is real. And an analysis of similar, though less thoroughly processed, gravity data by Mark Pilkington and Alan Hildebrand of the Geological Survey of Canada in Ottawa and C. Ortiz Aleman of City University in Mexico City failed to reveal a 300-kilometer ring. "We see no reason at the moment to suggest" that there are as many rings as Sharpton and company suggest, says Pilkington.

Even if the new gravity ring is ultimately accepted, says Hartmann, a convincing argument that the ring represents the outer limit of the crater will also require independent evidence of shattered rock out to 300 kilometers. A few wells were drilled across Chicxulub to search for oil long before the crater was recognized, but assessments of the rock retrieved from them differ. Pilkington notes that a drill hole just outside the 180-kilometer ring but well inside any ring at 300 kilometers revealed undisturbed rock, according to the initial evaluation by the drillers. Sharpton counters that the drillers were wrong. He has inspected the drill samples himself in Mexico City and saw plenty of impact debris, he says.

Another sort of geologic evidence—a ring of sinkholes concentric with the gravity rings—is also being interpreted as a sign of a larger crater, albeit not as large as the one Sharpton infers. Kevin Pope of Geo Eco Arc Research in La Canada, California, and his colleagues are suggesting that the 170-kilometer sinkhole ring delineates the flat inner floor of the crater. If that's the case, then by analogy with large craters on other planets, the full crater would be at least 240 kilometers.

Sharpton's version of the crater, spanning a full 300 kilometers, would imply an impact eight times as powerful as was thought. But so little is known about the global effects of a large impact that impact specialists can't say how much more devastating an impact of that magnitude would have been. And though a bigger impact could strengthen the case for a causal link to the extinctions, it won't help paleontologists explain the puzzling pattern of extinctions (see main story).

Nevertheless, a larger impact could help explain why, after more than a decade of looking for other impact-extinction pairs, researchers have turned up only two other possible examples, both much less convincing so far than the cataclysm 65 million years ago (*Science*, 8 January, p. 175, and 11 January 1991, p. 161). With a 300-kilometer crater, the event could be unparalleled on Earth. Indeed, only one other impact known to have taken place in the inner solar system over the past few billion years—Mead Crater on Venus—would be as large, says Sharpton. And that would make the dinosaurs the unluckiest beasts of all.

–Richard A. Kerr