Clues in the Clay

Sixty-five million years ago, an extraterrestrial body may have hit the earth. But did the impact cause extinctions?

BY CHERYL SIMON

The story of the Cretaceous-Tertiary extinctions 65 million years ago smacks of a 1930s mystery. Unwitting victims, violent and sudden death and the hint of an elusive killer present a complex scientific problem that the human imagination cannot resist. The clay layer that marks the boundary between the Cretaceous and Tertiary periods in the geologic record shows that *something* happened then. In one of five great known extinction events in earth history, more than 50 percent of the genera living on earth, including (perhaps) the dinosaurs, disappeared.

Scientists intent on solving the puzzle have speculated that the extinctions were caused by an extraterrestrial event such as a supernova, an impact by a comet or meteor, or a solar flare. Until two years ago there was little evidence that any of these events occurred (SN: 6/2/79, p. 356). But then, Luis Alvarez, Frank Asaro and Helen Michel of the Lawrence Berkeley Laboratory and Walter Alvarez of the University of California at Berkeley reported that to their surprise they had found unusually high levels of the element iridium in the boundary clay.

The earth's own iridium is concentrated in the core; most of the element found in the crust comes from extraterrestrial sources such as the interstellar dust that falls steadily onto the planet. At the Alvarez site in Gubbio, Italy, however, where rocks contain one of the most complete records of the Cretaceous-Tertiary boundary, levels of iridium make a spectacular jump to more than 25 times normal levels. Iridium and other rare metals such as osmium, cromium, cobalt, selenium and nickel are abundant in extraterrestrial material. If a large enough body such as a meteorite or comet hit the earth, the Alvarez team suggested, the ensuing dust cloud would blanket the planet, blocking out sunlight for several years and gradually depositing its iridium-rich debris.

Since the original Alvarez announcement, about 25 iridium anomalies at the Cretaceous-Tertiary boundary (five of which occur near the Gubbio site) have been reported worldwide. One of these, described by Carl Orth of Los Alamos National Laboratory, is found in York Canyon about 50 kilometers west of Raton, N.M. The iridium spike, found at the base of a coal bed that formed under a freshwater swamp, is the first recognized in terrestrial sediments — supporting the contention that the hypothetical dust cloud was global in its reach.

In mid-October geologists, paleontologists, atmospheric chemists, physicists and others converged in Snowbird, Utah, to consider whether an extraterrestrial body had hit the earth and how such an impact then or now might affect terrestrial evolution. On the first day of the meeting, many of the scientists were prepared to show that the iridium anomalies, while intriguing, had little to do with foreign bodies and less to do with the extinctions; by the meeting's end four days later, the magic word "consensus" hovered in the air.

The main point of agreement was that the high levels of iridium and other rare metals can be explained only by an impact or close brush with a foreign body. According to Jan Smit of the Geological Institute in Amsterdam, the extinctions are reflected in the clay that accumulated in the first 50 years or less after the event. From his field work at Caravaca, Spain, he finds that up to the boundary layer the Cretaceous sediments show no change in composition. The only zone of differentiation, he says, is the layer where the iridium is found. "Geologically, there is nothing spectacular except that the fauna died out," he says. Immediately above the boundary clay, Smit reports, sediments reflect that within a few thousand years, an instable "pioneering" community of fauna moved in to repopulate the marine realm, filling the spaces left by the missing organisms.

Less catastrophic causes were considered to explain the increased iridium. In one scenario, a change in seawater chemistry could have altered the sedimentation rate or caused a global hiatus in sedimentation of other elements. With a change in the pH of seawater, explained Michael Rampino of the National Air and Space Administration's Goddard Institute for Space Studies in New York, limestone would dissolve, condensing the rare metals into a thinner layer. The shells of calcareous phytoplankton, marine organisms with shells of inorganic carbon, would dissolve. Unlike other affected organisms, such as the dinosaurs, the calcareous phytoplankton were at their evolutionary peak and suffered extensive damage. Eighty-eight percent of Cretaceous species were wiped out, reports Hans Thierstein of Scripps Institution of Oceanography, compared with 19 percent of terrestrial organisms and three percent of freshwater organisms.

The marine extinctions could be ascribed to the seawater change only if there had been time for the sediments to accumulate. At sedimentation rates normal during the late Cretaceous, Thierstein said, the iridium in the boundary would build up in 1.37 million years at Caravaca and in 533,000 years at Gubbio. According to calculations presented at the Snowbird conference, the clay at Gubbio was deposited in less than a year.

Once an impact is assumed, a host of other questions clamor for attention. If a

> The anatomies of unknown winged things,
> And fishes which were isles of living scale,
> And serpents, bony chains, twisted around
> The iron crags, or within heaps of dust
> To which the tortuous strength of their last pangs
> Had crushed the iron crags; — and over these
> The jagged alligator and the might
> Of earth-convulsing behemoth, which once
> Were monarch beasts, and on the slimy shores
> And weed-overgrown continents of Earth
> Increased and multiplied like summer worms
> On an abandoned corpse, till the blue globe
> Wrapt deluge round it like a cloak, and they
> Yelled, gaspt and were abolished; or some God
> Whose throne was in a Comet, past, and cried —
> "Be not!" — and like my words they were no more.
>
> — Shelley, Prometheus Unbound, IV., 303-318

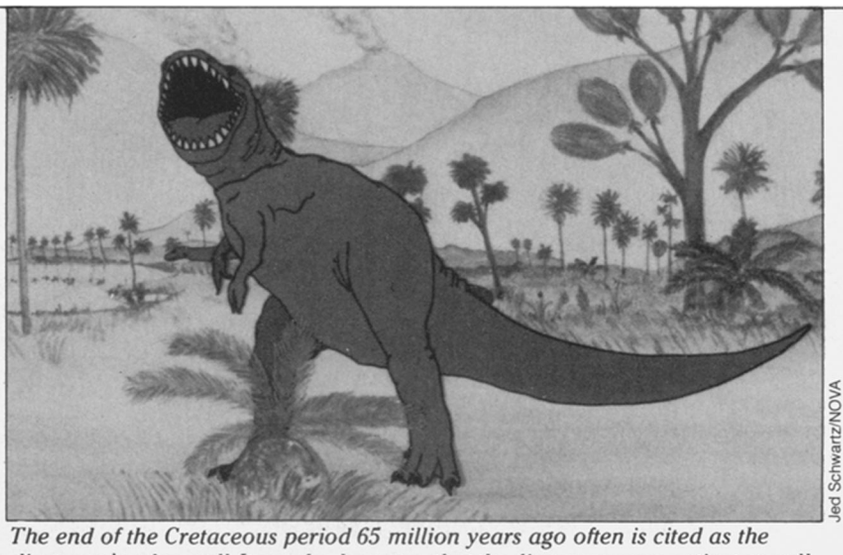
meteorite or comet did hit the earth, would it send up sufficient debris to cause the extinctions? What would the mechanism for the extinctions have been? Why did some organisms survive while others died out? What would the crater look like? Where is it?

Brian Toon and colleagues at NASA Ames Research Center in Moffett Field, Calif., calculated effects of the impact of an object with a radius of 3.3 kilometers and with energy equivalent to 10 million times the Mt. St. Helens eruption. It would send up a cloud of dust that could remain in the atmosphere no longer than six months, rather than the several-year interval suggested by the Alvarez team. Still, there would be too little light for photosynthesis for three months or longer — long enough to cause the food chain to collapse but too short a time to cause total extinctions. "It would be like being in a dark closet," Toon said.

Because of the oceans' large thermal capacity, the temperature of the first 100 meters below the surface would change by a degree or two at most. Over the continents the temperature would drop below freezing for about six months — twice the duration of the loss of light. Thus, marine extinctions could have been caused by cessation of photosynthesis while continental extinctions would have been caused by low temperatures and low light levels that made it difficult for animals to find food.

At times the discussion of possible causes for extinctions echoed the litany of the Ten Plagues. Darkness. Poison. Sudden heating. Sudden cooling. Nutrient enrichment. Nutrient cessation. Change in seawater salinity. Acid rain. Gradual climate change. Regression of the oceans. Some of these are more likely than others, but none is impossible. One favored explanation is that when the object hit, a lot of dust entered the atmosphere. Because less sunlight reached the earth, the atmosphere cooled. When the dust drifted down to earth the water that was thrown up with the dust when (and if) the object struck the oceans created a greenhouse effect. Radiation from the earth, unable to escape through the thick dust and fog cover, would warm the atmosphere. Organisms tend to be more sensitive to warming than cooling, lending credibility to the idea that climate warming may have contributed to the extinctions. At the Cretaceous-Tertiary boundary, for instance, more extinctions are observed in tropical than in northern latitudes.

In addition to the iridium anomalies, the geologic record holds another clue that extraterrestrial bodies hit the earth. Four fields of microtektites, glassy particles that may have formed from melted earth and rock when a meteorite hit the earth, are known. So far, however, none of the fields has been shown conclusively to be associated with impact at the time of the Cretaceous-Tertiary boundary.



The end of the Cretaceous period 65 million years ago often is cited as the dinosaurs' end as well. It may be, however, that the dinosaurs were extinct or well into their evolutionary decline when the rest of the extinctions occurred.

The search for an impact crater of appropriate age and size on land has been fruitless. But what if a meteorite hit the sea? Scientists studying the mechanics of impact cratering believe that debris thrown up by a meteorite or asteroid hitting the ocean would be capable of reaching the atmosphere. It could stay there long enough, they say, to cause production of nitrogen oxides and acids, and atmospheric heating and cooling.

Ejecta from a marine impact would be a mixture of seabed materials, pulverized meteorite and water, explains Jay Melosh, a geophysicist at the State University of New York at Stony Brook. After moving up through five kilometers of water, the shockwave from the impact would propel a stream of dense fog and dust miles up into the atmosphere. The impact would create forces comparable to a steam explosion, Melosh said. With water temporarily compressed to three times its normal density, pressures would be about as great as those in the center of the earth. John D. O'Keefe and Thomas Ahrens of the California Institute of Technology said that ejecta moving at high speeds through the atmosphere could produce high-temperature shock waves, enhancing production of nitric oxide, which could react to deplete the ozone layer for as long as 10 years.

Chances are, an impact crater in the ocean would be more difficult to recognize than one on land, not only because of problems in exploration but because the feature might not look the way one would expect. While craters on land have distinct rims and often sport center peaks, a marine crater is likely to be much broader and more shallow. Basing much of their speculation on information gathered from scaled laboratory simulations and from studies of nuclear explosions, the scientists surmise that the crater might be shaped more like a plate than a bowl and might even be flat. The shock wave would expand horizontally as well — a projectile 10 kilometers in diameter might create a crater 50 kilometers in diameter. Five square kilometers of water would be removed, leaving the seafloor essentially dry. "When the water rushes back in, its erosive power must be something we just can't comprehend," Melosh said.

Other factors, too, could obscure evidence of a crater. The impact could have occurred on one of the mid-ocean spreading centers. In this case, normal spreading would be disturbed, leaving the magnetic record there in chaos. Or the entire feature may have been subducted under the continental margins. In the 65-million-year interval since the hypothetical impact occurred, about half of the Cretaceous seafloor has slipped beneath the continents and back into the mantle as new seafloor is created.

Controversy over the Cretaceous-Tertiary extinctions is far from over. It may still turn out that even if an extraterrestrial body collided with the earth, something else caused the extinctions. Almost separate from the impact question, debate continues over whether the marine and terrestrial extinctions occurred simultaneously or indeed whether the extinctions at that time merit the rubric "catastrophic" at all.

Regardless, recognition that the earth, like the moon and Mercury, is vulnerable to impacts by extraterrestrial bodies is something of a revolution. George Wetherill of the Carnegie Institute of Washington calculates that several extraterrestrial bodies with diameters of one kilometer would hit the earth in a million years, while the largest ones currently known to cross the earth's orbit probably strike only a few times in earth history. Said Eugene Shoemaker of the United States Geological Survey in Flagstaff, Ariz., "In 25 years we've come all the way from where this was an outrageous idea to where it's a paradigm." □