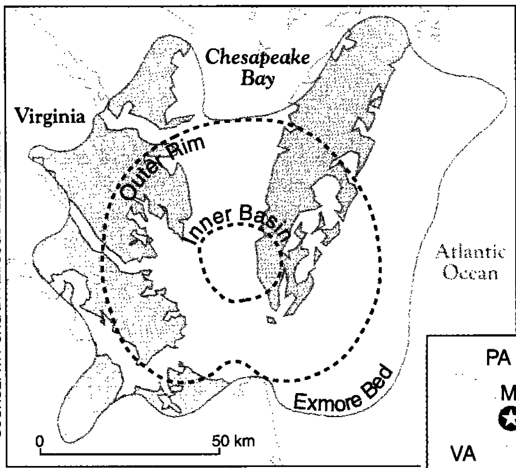
Making an Impact Under the Chesapeake

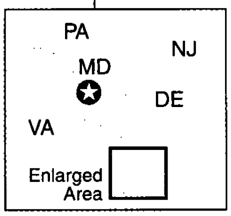
Giant impacts seem to be in season. Just as Jupiter starts to recover from its pummeling by kilometer-size comet pieces, the scar of a similar impact may have turned up much closer to home. If a group of U.S. Geological Survey (USGS) geologists is right, the east coast of North America was blasted by a meteorite a few kilometers across some 35 million years ago. Besides leaving an 85-kilometer-wide crater—the seventh largest ever identified on Earth—the impact could have strewn debris as far as South America, triggered the formation of Chesapeake Bay, and driven some marine plankton to extinction.

"Your first reaction when you hear about something like this is to doubt it," says oceanographer Kenneth Miller of Rutgers University. But after reading the paper by Wylie Poag of the USGS in Woods Hole and his colleagues, which appears in the August issue of *Geology*, Miller was intrigued. A layer of chaotic debris buried beneath lower Chesapeake Bay certainly implies some violent event, Miller says. And Poag's claim that images of the bay, made by bouncing seismic waves off buried sediment layers, reveal a large impact crater is "reasonable," if not completely convincing, says Miller.

The first hints of something unusual beneath the Chesapeake came in the 1950s, when USGS geologists studying ground water drilled through some curious sediments beneath the Virginia shore of the Bay. Sediments are normally found in neat, separate layers, but drilling samples of this particular sediment bed hinted at a jumble of different sediment types. In the mid-1980s, USGS drillers recovered complete cores from this 60-meter-thick layer, dubbed the Exmore bed, which revealed a hodgepodge of pebble-, cobble-, and boulder-size chunks of sediment up to 2 meters in diameter. Microfossils in the chunks showed that the original sediments were laid down anywhere from 100 million years ago to 35 million years ago, when the bed was formed. It was as if whole sections of sea floor were scooped into a giant mixer, churned up, and spewed out. By 1991, Poag and his colleagues had found clues to the identity of that mixer: traces of minerals in the bed that had been altered by the extreme pressures of a shock wave, presumably generated by an impact.

Now Poag and his colleagues think they can see the buried crater itself. Examining seismic soundings of the sediments made by both a company exploring the lower Chesapeake for oil and gas and the USGS, the researchers spotted three places where undisturbed, horizontal layers of sediment are broken off at nearly vertical faults—the remnants, they think, of the crater rim. Well





SOURCE: W. POAG *ET AL.*/USGS ILLUSTRATION: C. FABER SMITH

A big splat under the Chesapeake? A 35-million-year-old debris bed overlying a double-ring structure suggests an impact.

within the outer rim, the group sees a concentric inner "peak-ring," where the basement rock rises, then drops into a central depression. Such bull's eye structures are known from other craters, says Poag, such as the Ries crater of southern Germany.

Over time, Poag thinks, the low spot left by the impact might have become the focus of the network of river valleys that was ultimately drowned to form the Chesapeake Bay. Another legacy of the impact may be the glassy spherules, called tektites, that are strewn in a thin layer over 9 million square kilometers of the southeastern United States, the Gulf of Mexico, and Caribbean Sea. Geologists have assumed that these tektites splashed out of an impact crater as molten rock, but the crater has never been found. Poag thinks the Chesapeake Bay crater might fit the bill: It's about the right size, the right age, and in the right kind of basement rock to match the tektites' composition.

What the impact meant for living things 35 million years ago is less certain. The crater didn't form at the same time as any major extinctions, and interpreting its effects is complicated by the fact that several other large impact craters formed at about the same time on other continents. Still, says tektite specialist Billy P. Glass of the University of Delaware, there are hints that the meteorite did claim some victims: Five species of microplankton seem to have died out just when the tektite field was laid down.

Before researchers search too hard for distant effects of the impact, though, they want to confirm it. After all, says Miller, interpreting seismic data "can sometimes be something of an art." Lubomir Jansa of the Geological Survey of Canada in Dartmouth, Nova Scotia, who has discovered his own impact crater on the sea floor, adds that "if [Poag] wants to prove it, he has to drill in the center," where the most abundant shocked minerals and even melted rock should be. That is exactly what Poag wants to do, but he needs money to do it. So the scientist is looking for a deep-pocketed partner with an interest in deep sediments.

–Richard A. Kerr

ASTROPHYSICS

Are Quasar Twins an Optical Illusion?

Searching for a missing lens can be exasperating, as any contact wearer knows. That's all the more true when the lens is somewhere in the far reaches of the universe. For more than a decade, astronomers have been looking for something very much like a lens in front of a pair of apparently identical quasars, or distant starlike objects. Since most quasars are sparsely distributed across the sky, these close twins seemed likely to be an optical illusion. The blaze of a single quasar, astronomers guessed, was being split into two images by the light-bending gravity of a galaxy or cluster of galaxies between the quasar and the observer. One problem: no one could find this gravitational lens.

Now, by merging pictures from telescopes in Hawaii, Arizona, and Chile to produce an exposure that is effectively more than 22 hours long, J. Anthony Tyson of AT&T Bell Laboratories and a team of astronomers have uncovered what may be part of the long-sought lens: an extremely dim and distant galaxy hidden in the glare of one of the quasar images. Other scientists, such as Edwin Turner of Princeton University, think the record-breaking photographic feat—reported in the 20 August *Astrophysical Journal Letters*—is strong evidence pointing towards a lensed system. "It's an extraordinary powerful observation, one of the deepest ever made," Turner says.

Not everyone is convinced that Tyson and his colleagues have spotted the missing lens. More than the mass of a single galaxy is needed for the lens, and the group's evidence for an additional cluster near the detected galaxy is tenuous. "I don't think it's proven," says lens expert Chris Kochanek of the Harvard-Smithsonian Center for Astrophysics (CFA). Even if the lens is accepted, it only brings a new puzzle into focus. The lens seems to have formed so soon after the Big Bang that theories of structure formation in the universe don't give it time to come together.

When the quasar system, known as Q2345+007, was first spotted, most researchers thought its lens would be obvious. Separated by 7 seconds of arc, the images are more widely separated than those produced by any other gravitational lens. Deflecting light so sharply would require a vast concentration of mass—an entire cluster of galaxies, which should be easy to spot. But when Tyson and his co-workers took their first crack at the system in 1986, they drew a blank. "That was puzzling. A lot of people looked at the absence of anything big and massive as evidence against the lensing hypothesis," recalls Tyson.

For his latest lens search, Tyson joined with AT&T colleague Philippe Fischer, Gary Bernstein of the University of Arizona, and Puragra Guhathakurta of the Space Telescope Science Institute. To find extremely dim objects that might not have been evident in previous single images, they superimposed 19 different images taken over a period of 10 years. The group then carefully subtracted the light of quasar A from quasar B and vice versa. If these images truly are the same quasar, their light should be equal; any light remaining after the subtraction must come from objects previously obscured by quasar's brightness.

When quasar B was taken out of the picture, a very faint galaxy popped into view about 1 arc second from the center of its image. The team labeled it G1. They also found hints of clusters of distant galaxies in front of the quasar. The researchers placed these objects a similar distance from Earth and began to model these components into a lens. Two models involving G1 and a cluster of galaxies could produce the 7-arc-second separation seen in the images.

If those models are correct, notes Tyson, it means that "one riddle has been replaced by another." The new dilemma is that a compact structure that could provide enough light-bending mass for the lens, more than 10^{13} solar masses, shouldn't have condensed as early in the history of the universe as the models assume. Based on G1's dimness and other clues, Tyson and his colleagues argue that the galaxy and thus the overall lens are a vast distance from Earth: a redshift of 1.49, in astronomers' usual measure of distance. Since looking further away in the universe is like looking back in time, this distance is only a few billion years after the Big Bang.

Most theories of the universe's history have difficulty producing such large concentrations of mass that quickly, says Tyson. The lens, he adds, would be particularly hard to reconcile with a "closed" universe, one that has enough mass to stop expanding eventually; closed universes form structure even later than open universes, he explains. "In any model of the universe, 1.5 would not have been the optimal choice for the redshift of the lens," agrees CFA's Ramesh Narayan.

The only way to settle whether the twin quasars are really lensed may be to detect a "time delay" between brightness changes in the two quasar images, because the light path of one image to Earth should be slightly longer. Since the time lag could be years, it may take another decade to settle the debate over this unlikely pair of quasars.

–John Travis

PARASITOLOGY

Mistreating a Long-Time Host

The evolutionary arms race between disease-causing pathogens and their hosts eventually ends in détente—or so scientists have long believed. New aggressors, such as the fungus that attacked Dutch elms in the United States, are particularly vicious at first. But over time, successful parasites are supposed to evolve to become less of a threat. Killing off your host is not only bad manners, but also deadly to the parasite itself. "People have believed that to harm the host is to harm the parasite," says evolutionary biologist Dieter Ebert of the Centre for Population Biology, Imperial College at Silwood Park in England.

But now, on page 1084, Ebert reports a case in which parasites maintain a high level of viciousness towards their long-time hosts, while treating new acquaintances more kindly. In a lab study of a minuscule parasite that infests water fleas in the ponds of Europe, he found that the parasite was most virulent when it came from the same pond as the fleas. But the parasite was more benign towards less familiar water fleas, from more distant ponds.

Ebert's findings support an emerging theory that pathogens can evolve to be either more or less virulent in a long-time host—depending on the way the parasite is transmitted to the host and on the environment in which they live. The findings also bolster results reported last year by Allen Herre of the Smithsonian Tropical Research Institute, who found that a parasitic roundworm that afflicts fig wasps becomes more virulent over time if it can move easily from host to host (*Science*, 5 March 1993, pp. 1402 and 1442). Ebert's discovery "is consistent with the new view that virulence can be maintained in parasites," says Emory University population biologist Bruce Levin, who studies the evolution of bacteria and viruses. "It says niceness and everyone getting along is not a necessary outcome."

T.E. ADAMS/VISUALS UNLIMITED

Familiarity breeds virulence. Long association between a parasite and these water fleas does not make the parasite any more benign.

The unlucky host in this case is a common water flea in Europe, *Daphnia magna*. Some, but not all, of these flea populations have long been plagued by a protozoan called *Pleistophora intestinalis*, which reproduces in the flea's intestines, causing diarrhea. The parasite is spread "horizontally" to other fleas through diarrhea in the pond water. In his lab, Ebert used fleas from England, Germany, and Russia to breed nine distinct uninfected populations. But he only used parasite strains from England. And when Ebert introduced these parasites to each flea population, he found they produced more spores in fleas from English populations to which they were already adopted.

This flies in the face of conventional wisdom that hosts and parasites who have had time to adapt to each other should get along better, says Ebert. Now, it seems that anything is possible: behavior like that of the Dutch elm fungus may actually be the exception, and not the rule. "This is the first time we've shown that any level of virulence may be possible (over time) in an animal where you have purely horizontal transmission," he says. But many studies have shown that when parasites are passed in "vertical" transmission—from parents to offspring—they still appear to evolve to become more benign, Ebert says, because they need a host healthy enough to reproduce and pass them on to the host's progeny.

The implications of these findings are far-reaching, says Ebert. One alarming thought is that the behavior of disease-causing pathogens in humans, such as the virus that causes AIDS, may be even less predictable than previously believed. "Now, the deeper question is under what conditions will natural selection favor greater virulence?" asks Levin. A lot of people not interested in water fleas will be very interested in that answer.

–Ann Gibbons