Extinction Wars

The saga continues: In this episode, some scientists carry on the battle over the cause of the dinosaurs' demise and the extinction of other creatures during the history of the earth, while others brandish some interesting points on acid rain, comet showers and extinction styles

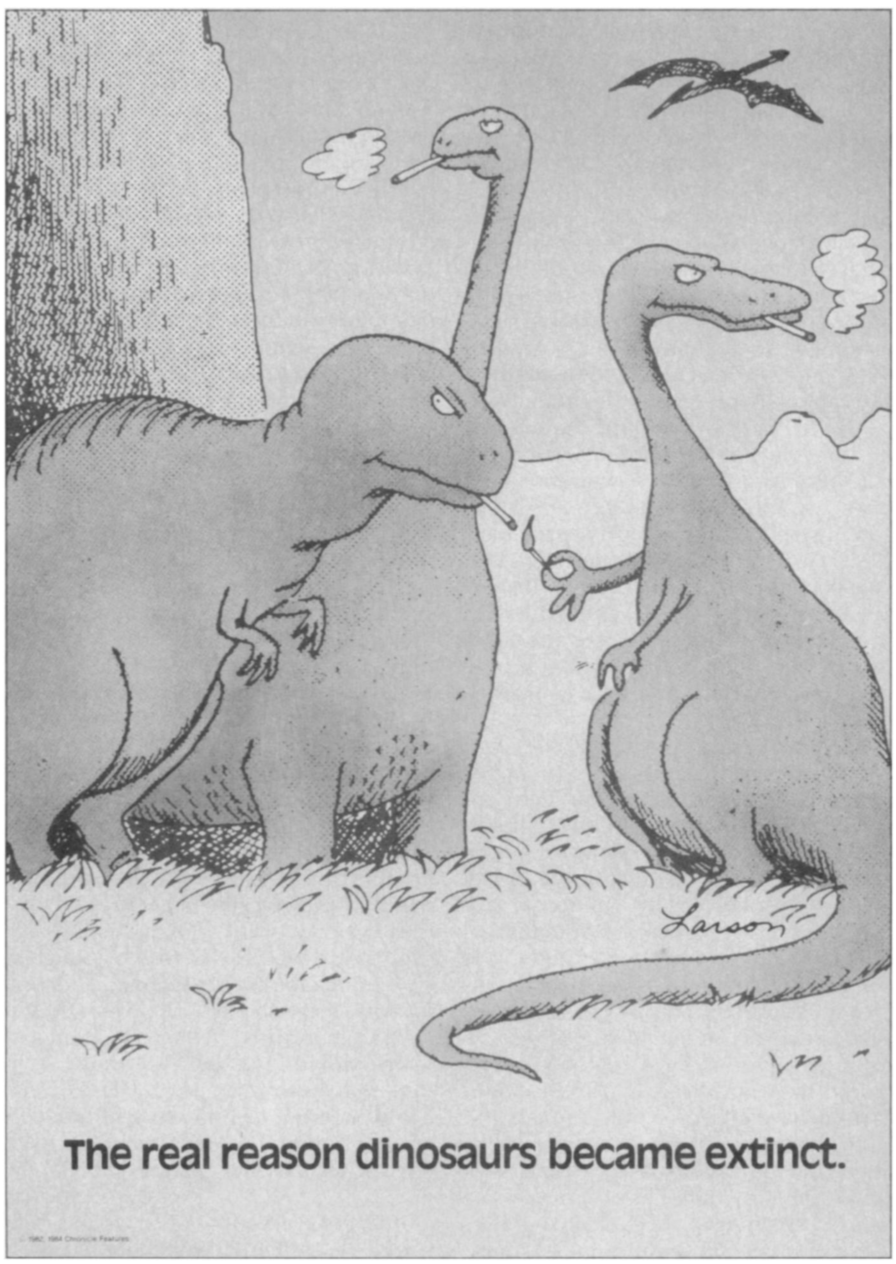
By STEFI WEISBURD

With all the paleontologists looking up to the stars for an explanation of what caused mass extinctions of life on our planet, and with all the astrophysicists looking at the rocks below their feet for clues to comet showers or asteroids that might have bombarded the earth, it's a wonder that more scientists aren't complaining of neckaches.

But if anyone is getting a neckache it's probably the audience of the Great Extinctions Debate. Scientists and journalists who attended a special session in San Francisco at the recent meeting of the American Geophysical Union were treated to a Ping-Pong match of sorts. Proponents of the impact theory, which holds that an asteroid wreaked havoc on the earth 65 million years ago, killing off the dinosaurs and other species (SN: 6/2/79, p. 356), faced off against others who believe that an unusually large bout of volcanic activity was the villain (SN: 3/16/85, p. 172).

Apart from the sometimes intense crossfire between these two most vocal groups, some new or less publicized ideas vied for attention. The papers presented at the session entitled "Where are we now on iridium anomalies, extinctions, impacts, volcanism and periodicity?" included a look at the acid rain produced by either an extraterrestrial body or volcanoes, the mathematics of a comet shower and a reminder from paleontologists that past species didn't simply bow out in unison.

In his paper on acid rain, atmospheric chemist Ronald G. Prinn of MIT painted a bleak picture of parts of the world after a comet impact: Under dark, reddish-brown skies, animals would be asphyxiated by the noxious and pungent air and burned by the acid rain, which would also defoliate trees, turn soils to



The real reason dinosaurs became extinct.

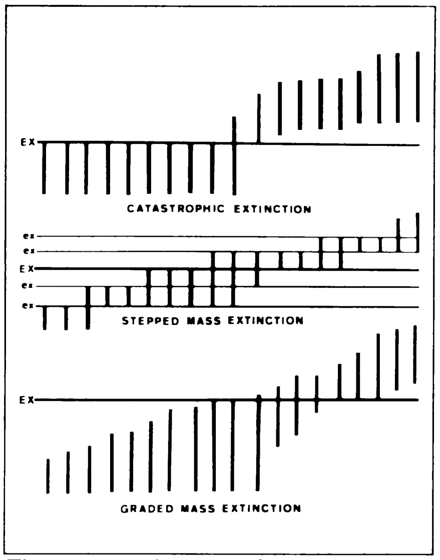
powder and leave pockmarks on those rocks that it did not dissolve completely.

Prinn and his colleagues began four years ago to examine the caustic atmospheric consequences of a large impact. They have drawn on theoretical and experimental studies of thermonuclear explosions, lightning, spacecraft reentry and the Tunguska meteor, which hit Siberia in 1908. Like a large asteroid or comet streaming toward the earth, all of these events shock-heat the atmosphere, causing nitrogen and oxygen in the air to combine, forming nitric oxide (NO). If the resultant concentration of NO exceeds about 1 part per million (ppm), the NO radicals react with one another to form NO_2 and other oxides, which can then combine with water to form nitric acid and hence acid rain.

To get a sense of the range of nitrogen oxides (NO_x) and nitric acid produced by an extraterrestrial body in the most recent calculations, Prinn and Bruce Fegley, also at MIT, considered two kinds: a comet imparting much of its energy to the atmosphere as it comes in at a grazing angle, and an iron asteroid, which heats up less of the atmosphere as it falls nearly vertically toward the surface. The most severe environmental effects result from the comet, but even for this Prinn thinks the estimates are conservative.

Prinn calculates that after a comet impact, NO_x levels would jump to 10^7 to 10^8 times that currently in the troposphere; and assuming it took two years for the atmosphere to completely mix, "essentially pure nitric acid would be pouring over about 10 percent of the global surface in the first few months." As a result, he says, the amount of weathering of the land by acid rain in one year after a comet impact would be comparable to that accomplished by current processes over 100,000 to 1 million years. One important consequence, which Prinn and Fegley are now studying in detail, is that the acid would dissolve almost every trace metal in the soil, polluting the water supply with a potentially toxic excess of trace metals.

As if that weren't enough, the high concentrations of NO_2 in the upper atmosphere would absorb sunlight, allowing very little visible light to illuminate plants and warm the surface below. And comet-enriched NO_2 levels in the lower atmosphere could asphyxiate animals that breathe and cause defoliation in plants. The acid rain generated in the comet case could also significantly increase the acidity of the oceans. In fact, acid would be added to the oceans in quantities five times greater than that required to begin dissolving the calcium carbonate shells of ocean animals. "If this comet case is the relevant one, we're talking about a pretty nasty event," says Prinn. He adds that a swarm of smaller comets, one hitting the earth every 1,000 years or so, would result in even more



Three major theories of mass extinction are now being debated. A catastrophic extinction results from some event that wipes out many different species within a very short time. It was the model first suggested by those proposing that an asteroid had smashed into the earth. A graded mass extinction – the classic theory of paleontologists and biologists – takes place gradually over a few million years, striking first those organisms that have adapted to very specific environments, then those adapted to a greater diversity of environments. Within a graded mass extinction are episodes of accelerated extinction, which are presumed to be caused by environmental changes and not by catastrophic events. Some researchers are now suggesting a hybrid model in which a series of short-term extinctions – some, but not all, caused by catastrophic events – spans up to 3 million years. This stepped mass extinction theory also supposes that extinctions will be "graded," starting with the most ecologically sensitive organisms.

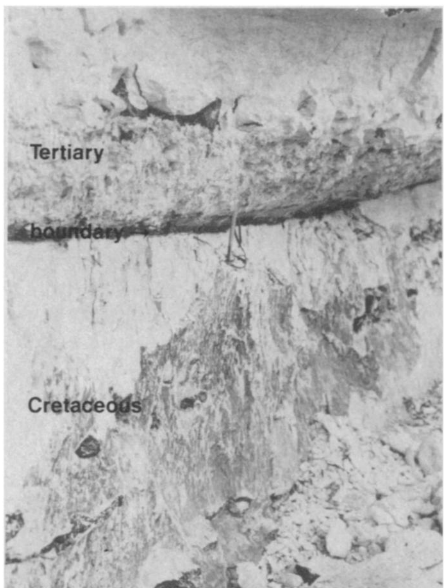
dramatic environmental damage.

Prinn and Fegley conclude that if an impact is the culprit, it is far less likely that an iron asteroid caused extinctions, because in that case, NO_x levels would be expected to rise to only 100 to 1,000 times present levels and the acidity of the rain would be no more than 10 times as great as measured today.

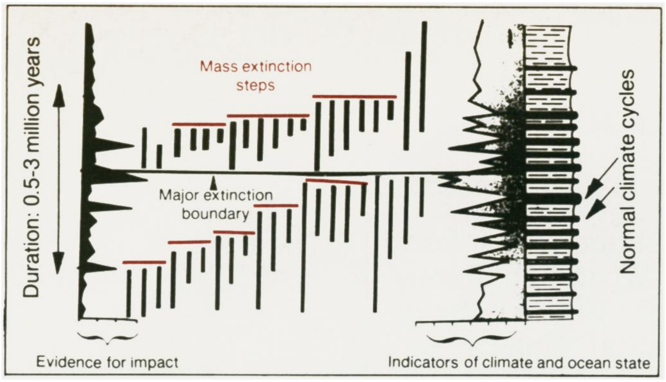
For Prinn, one of the more appealing aspects of the acid rain theory is that it may explain why some species perished during times of mass extinctions while others survived. By dissolving calcium carbonate-shelled organisms, acid rain favors silicate-shelled life, he says. Moreover, animals with the best chance of surviving would include those that live in buffered freshwater lakes, those that could hide out or hibernate in burrows and those that lived far from the impact site. At the recent meeting in Orlando, Fla., of the Geological Society of America, Stephen M. Dickson and David J. Erickson of the University of Rhode Island in Narragansett suggested that as long as the acidity of the oceans was high, selective extinctions might be caused by the trace elements such as cobalt, nickel and lead added by a comet or asteroid to the oceans, since organisms appear to have different tolerances to these toxins.

Acid rain also plays a role in the volcanic theory of the origin of mass extinctions, whose strongest proponent, Charles B. Officer from Dartmouth College in Hanover, N.H., presented a paper at the San Francisco meeting. According to Officer, the dust, sulfur dioxide and other gases spewed out during a period of volcanic activity, which was about 100 times as intense as that occurring worldwide today, would produce acid rain, global cooling, a reduction of the pH of the oceans and an increase in ultraviolet light bathing the planet. Officer uses these changes to explain the selective extinctions, with the result that "while the naked dinosaurs [exposed to the ultraviolet radiation] died out, the small, the feathered and the furried survived." Officer also argues that the gradual death of species over many thousands of years is more consistent with the volcanic theory than with the impact idea.

Prinn, however, has his doubts about the effectiveness of acid rain produced by volcanoes. "The concentration of acid



Much of the extinction debate revolves around several centimeters of sediments marking the boundary between the Cretaceous and Tertiary periods. Here the boundary is exposed at Stevns Klint, Denmark, the site of the most detailed study of boundary fossils and chemistry to date. The dark band is the boundary clay, containing unusually high levels of iridium and other rare elements. The last representatives of many typical Cretaceous creatures lie at the base of the boundary clay.



Kauffman

Kauffman's mass extinction model. On the left, the evidence for extraterrestrial impacts at stratigraphic boundaries (such as high levels of iridium, microtektites and shocked quartz) can in some cases be linked to steps of mass extinctions shown in the middle of the figure, but in general they are not directly associated with them. Instead, fluctuations in the temperature and salinity of the oceans (as measured by oxygen isotopes and other indicators on the right) are associated with and totally encompass mass extinction events. Kauffman's group suspects that impacts may put the ocean climate system out of kilter, so that the normal climate cycles (shown on the far right) are greatly exaggerated. As a result of these large swings in climate and ocean chemistry, the organisms adapted to specific environments and those living in the tropics would be the first faced with extinction, followed by the ecological generalists and those living in more temperate spots.

in the volcanically produced acid rain is about 10^4 times less than the cometary event," he says. "It would take about 10,000 years of volcanism of the kind that Chuck Officer is talking about to make a pH change of 0.5 in the ocean [the cometary case]. On that time frame the [top] layer of the ocean will be mixed with the [deep] waters, so I don't see how you get a big change in pH of the ocean from a volcanic event."

When Walter Alvarez at the University of California at Berkeley and his co-workers first proposed the impact theory several years ago, they left the geologic community with the idea that the mass extinctions at the Cretaceous-Tertiary (K-T) boundary 65 million years ago, and perhaps extinctions at other times as well, were instantaneous and catastrophic, rather than gradual. But careful study of extinctions at the K-T boundary, at the Eocene-Oligocene boundary about 36 million years ago and at the Cenomanian-Turonian boundary 90 million years ago show that these extinctions were neither purely catastrophic *nor* entirely gradual, report Erle Kauffman at University of Colorado in Boulder, Gerta Keller at Princeton (N.J.) University and Thor Hansen at Western Washington University in Bellingham. Instead, they say, these extinctions were "step-wise," with some species dying out thousands to hundreds of thousands of years before and after the main extinction boundary and the entire extinction sequence lasting about 3 million years, on the average.

At the San Francisco meeting, Kauffman also noted that there is evidence for impacts (or volcanism, depending on whom you side with), and perhaps even traces of multiple impacts at both the K-T and late Eocene extinction boundaries. But in few cases, he said, do these impact events coincide in the stratigraphic record with major extinctions. And the Cenomanian-Turonian extinction record contains no direct evidence of impacts at the boundary at all. Rather, Kauffman's group found that the steps of large extinctions are usually associated with changes in ocean chemistry and with large and rapid drops in temperature of 2 to 5°C—as measured by the ratios of oxygen isotopes in deep-sea sediments.

"The driving force for mass extinction, the real killers, seem to be these large-scale temperature fluctuations," says Kauffman. His group suggests that the impacts (or volcanoes) could have upset the chemical and thermal structure of the world's oceanic system, putting it so off balance that the relatively small fluctuations in temperature associated with the earth's normal climate cycles would trigger a series of huge temperature swings. These swings, says Kauffman, would have killed off the most temperature-sensitive organisms first, such as those best suited to tropical climates.

Motivated by the emerging view of step-wise extinctions, Kauffman joined forces with Alvarez, astrophysicists Piet Hut at the Institute for Advanced Studies in Princeton and Paul Weissman at the Jet Propulsion Laboratory in Pasadena, Calif., crater expert and astrogeologist Eugene Shoemaker at the U.S. Geological Survey in Flagstaff, Ariz., and others in a study of comet showers to see if they might be linked to sequences of extinctions. "The interesting thing about a comet shower is that it might resolve the controversy between the gradual versus catastrophic view of mass extinctions," says Hut, who presented the group's paper at the meeting.

With a numerical model of the orbits of comets perturbed by passing stars, interstellar gas clouds or a proposed solar-companion star, Hut's group arrived at a curve representing the number of comets that might hit the earth over time. While they can't predict absolute numbers of comets in a shower, and while there is not enough observational information to confirm the shape of their curve, they are encouraged by the calculated duration of each shower for the case of passing stars as perturbers: 1 million to 3 million years, a value consistent with the extinction record around the boundaries studied by Kauffman's group. If gas clouds or a solar companion are used in the calculations, this period is a little longer, on the order of 2 million to 4 million years. Hut also cites geologic findings supporting the notion of comet showers. These include a cluster of craters formed at about the same time in the Eocene and the finding in Eocene sediments of at least two globally distributed horizons of microtektites, small glassy spheroids created during an impact.

In their abstract, the researchers conclude that "the hypothesis of comet showers as the driving mechanisms for mass extinctions is clearly viable and has already acquired a mass of circumstantial evidence from recent observations." Hut adds that comet showers are not "an *ad hoc* solution which astronomers can come up with if pressed. [They] are really something which naturally follows from the most reasonable formation scenario of the solar system." Weissman, however, stresses that any connection between a comet shower and an extinction boundary is still far from proven, and the notion that comet showers are responsible for the proposed *periodic* annihilation of species is tenuous at best. He notes that the expected 100 million years between comet showers is much greater than the 30 million years or so separating extinctions in the fossil record.

In regard to the whole extinction debate, a bit of Weissman's sentiment is echoed by Frank Kyte from the Institute of Geophysics and Planetary Physics at the University of California at Los Angeles. He presented a review of the physical evidence in the geological record for an impact at the K-T boundary—from the high concentrations of iridium (an element rare on earth but abundant in extraterrestrial bodies) to microtektites. Kyte strongly believes that a K-T impact did occur, but to tie the impact to an extinction, he says, is still a leap of faith—and more so for some than for others. "You will never convince some paleontologists that an impact killed the dinosaurs unless you find a dinosaur skeleton with a crushed skull and a ring of iridium around the hole," he joked at a press conference following the session.

Whatever the eventual outcome of the extinction debate, most observers agree that the meeting of minds from so many different disciplines in order to unravel the extinction mysteries of the past—and perhaps understand what might befall the planet in the future — has created quite a fascinating show. □