



Cycles of Life:

Innovation through Extinction

By Barbara Elizabeth Stewart

On an oppressive morning in July—so hot that only diehard tourists are willing to brave the Washington Mall—Douglas Erwin, paleontologist and author of *Extinction, How Life on Earth Nearly Ended 250 Million Years Ago* leads the way through the twisting back warrens of the Smithsonian Institution's National Museum of Natural History. It's another world from the many grand exhibits in the public areas—a tangle of narrow hallways, offices, and storerooms for the museum's vast collections.

Erwin, a senior paleobiologist and curator of the Paleozoic mollusc collection, stops in his office, whose windows overlook the other

Smithsonian museums and whose shelves are crammed with the rocks and books that are his tools, along with a bumper sticker: "Do not meddle in the affairs of dragons, for you are crunchy and good with ketchup." At the museum, he's able to immerse himself in the world's largest collection of fossils, rocks, and scientific and historical objects of all kinds—126 million lots—and consult with colleagues whose expertise in the sub-specialties of paleobiology are as finely honed and extensive as his own. "Fossil experts," he says. "Insect experts... banana experts."

The Santa Fe Institute, where he's a professor, is the polar



LEFT: An Anomalocaris—*Anomalocaris saron*—from the Chengjiang fauna in China cruises over the Cambrian seafloor in search of prey.

RIGHT: Doug Erwin



an extraordinary diversification of marine animals, and ended 252 million years ago in the end-Permian with the greatest extinction event in Earth history. He spends his days at SFI exploring the most sweeping questions of biological evolution: How did life, in a relatively short time, evolve and explode in variety during the Cambrian period? And what happened during the end-Permian extinction that nearly ended life on Earth? Why did it happen? Did the same catastrophe create the terrestrial and marine extinctions or were there different causes? How did animal forms revive, expand, and innovate afterwards and how rapidly did that occur? What were the evolutionary pressures and biological needs that led them to develop as they did?

Those questions lead to the search for theories and to more questions still: Were the end-Permian extinction and others throughout history, like a set of giant hands sweeping pieces off a chessboard and leaving the board intact or did the entire ecological structure significantly change? “The board collapses entirely, and as the game resumes, it becomes half chess and half backgammon, with some

rules drawn from poker,” Erwin writes. What are the similarities between the biological innovations of recent times and those in the distant past? Erwin has pursued answers through fieldwork in locales as far-ranging as South China, Australia, and west Texas, through investigation of gastropods and other fossils, and by reading literature and conversing with experts in his own and other disciplines.

In *Extinction: How Life on Earth Nearly Ended 250 Million Years Ago*, the most recent of his six books and some 100 research papers, Erwin explores the possible causes of Permian-Triassic extinction, the most catastrophic of the six major extinctions on earth, in which 70 percent of all terrestrial vertebrate species and 95 percent of marine life were killed during a relatively short period. This extinction was once thought to have lasted as long as 10 million years, but in the scenario that Erwin and his colleague Sam Bowring at Massachusetts Institute of Technology have developed, it may have been as short as 100,000 years—the geological equivalent of a year versus a week. The contrast between the richness of fossil evidence before and after the

opposite, with its sparseness and broad windows looking out at piñon/juniper forest and distant mountains, and, most important, its fundamentally different intellectual approach. At SFI, Erwin’s focus turns from the concrete world of things toward broader, at times more abstract, viewpoints. “I interact with people in wildly disparate fields,” he says. “People who are happy to look at different problems and find different ways of looking at the same problems.”

Erwin’s primary focus is the Paleozoic era, that major interval of geologic time that began about 545 million years ago during the Cambrian explosion with

end-Permian extinction is so sharp that a contemporary of Darwin's thought the evidence indicated separate creations, meaning the second did not build on the first at all.

Erwin began studying the end-Permian extinction as an undergraduate at Colgate University, delved into it deeply for his dissertation at the University of California, Santa Barbara, and continued his research during his years as a professor at Michigan State University and at the Smithsonian. A fan of Tony Hillerman's Southwest mysteries, his book approaches the subject like a gigantic paleontologic

sending thick layers of ash swirling around the earth and blocking sunlight. However, Erwin notes, while the Yucatán impact site and the striking excess of iridium in the strata have made the Cretaceous-Tertiary extinction theory widely accepted, there is no such evidence for the end-Permian extinction.

Another likely culprit is volcanism during the million-year-long eruptions of the Siberian flood basalts, which spread lava over an area larger than Australia. Even geologists have little understanding of such massive volcanic eruptions, but such eruptions could have produced much acid rain

disappearance of oxygen in the seas, which may have occurred for various different reasons, could have killed marine life and disrupted life on land. Finally, there is what Erwin calls the "Murder on the Orient Express theory," that the extinction was the result of most or all of these causes.

As to which is correct, Erwin writes, "We don't know, or at least I don't know..." After 25 years of research into the subject, he says it is no longer especially important for him to decide on the causes. "Ten years ago, I was sure I knew what it was," he says. "I was wrong several times. I've given up. I'm curious and would very much like to know, but I'm not emotionally invested in the answer."

His primary focus over the past several years has been biological evolution and innovation. He's looking at the Triassic period, but even more closely at the Cambrian radiation 545 million years ago, when major animal groups appeared for the first time. Understanding how innovation occurs has implications for the world of today and the future development of life. "I'm always more interested in what happened after the extinction than in the cause—in how life recovered," he says.

To find answers, he's exploring fields that, on the face of it, seem quite separate from paleontology: primarily economics and developmental biology, which he's been studying intensely, especially at SFI. He's exploring major evolutionary factors such as development of genes involved in

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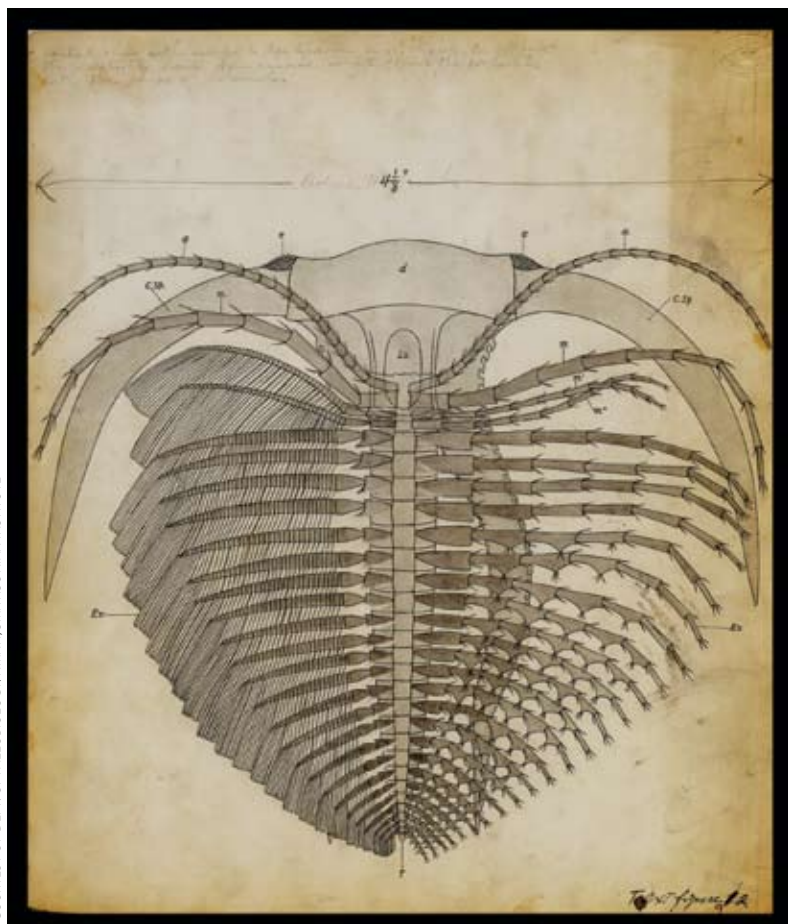
whodunit, presenting the history of its exploration. He begins with descriptions of the varied end-Permian fossils, which contrast with the stark strata of the period that followed, the Early Triassic. He considers the evidence and scientific reasoning behind seven theories that have been put forward for the cause of the extinction.

One possibility is an extraterrestrial impact, similar to the massive meteoric crash in the Yucatán Peninsula that Luis Alvarez and Walter Alvarez theorized was the cause of the extinction of the dinosaurs 65 million years ago. It was a crash that incinerated everything for thousands of miles,

and triggered a short period of global cooling followed by a long interval of global warming. Atmospheric oxygen levels may have plummeted too, possibly asphyxiating life in the oceans.

Erwin rejects as a cause the formation of the super-continent Pangaea, formed by land masses that collided into a single vast area extending from the north to the south of the globe. This incident supposedly forced formerly isolated species into competition that severely decreased biodiversity.

Glaciation is another theory—catastrophic freezing that may have resulted in decreases in sea levels by 250 meters or more. The



This reconstruction of Marrella, prepared using an ink-wash technique, was found in the drawers containing archival collections belonging to Charles Doolittle Walcott (1850–1927), fourth secretary of the Smithsonian Institution and discoverer and collector of the famous fossils of the Burgess Shale. Marrella is one of the most common fossils found at the Cambrian Burgess Shale locality in British Columbia, Canada.

the building of plants and animals over hundreds of millions of years, changes in climate and marine chemistry, and the relationship between the environment and animals. For instance, he says, “It’s relatively clear that the oxygen levels in the oceans and the atmosphere rose subtly just before the development of animals. You can’t make a big animal without a certain level of oxygen.”

He finds points of convergence in evolutionary paleobiology and economics as well. The similarities between increasing biological

diversity and the growth of economic wealth, for instance, intrigues experts in both paleobiology and economics, he says. “It’s not like all the wealth has been sitting around in bank vaults since the Roman times.” How is wealth created? he wonders. What is the relationship between technological innovation and increasing economic prosperity? or between new evolutionary innovations and increased ecologic complexity? Similarly, how did the diversity of life forms innovate and proliferate?

Another convergence point is in

the development and construction of new niches. “How do you make room for personal computers?” he says. “Computers require a network of other technological and economic links, from plastics for cases to computer operating systems. But they also create new opportunities as well: flat screen monitors, mousepads, and the Internet.” Erwin sees similarities in how both economic and biological systems construct these networks, and by doing so, produce the positive feedbacks that lead to increased wealth, or increased biodiversity.

His professional homes in Washington and Santa Fe are “maximally different,” he says—so much so that the adjustment back and forth is often physically and intellectually dizzying. At the Santa Fe Institute, he says, “I’ll walk up to Sam Bowles at tea and like an idiot, I’ll ask something like, ‘How do economies expand, anyway?’ And we’ll have a great conversation. Or I’ll talk to Murray Gell-Mann about the evolution of languages. Or Cormac McCarthy about particle physics.”

“Santa Fe,” he says, “is about looking for generalities. The museum is about reveling in particularities.” ◀

Barbara Elizabeth Stewart, a journalist who lives in New York City, has written stories on science and other subjects for The New York Times, The London Observer, and More magazine, among other publications, as well as the Carnegie Corporation.