CHAPTER 6

EXTINCTION

PLATE 97

PTEROSAUR RHAMPHORHYNCHUS*A ATTACKED A BY RAYFINNED FISH *ASPIDORHYNCHUS.

Upper Jurassic (*ca.* 155 million years). Messel Shales, Eichstatt, Bavaria

The fossil record reveals a great array of animals and plants now completely vanished from theliving world.

Credit: Helmut Tischlinger, Jura-Museum Eichstätt.

The cataclysm was as sudden as it was devastating. It came literally out of the blue, shattering the tranquility of Earth's ecosystems. One moment, it was business as usual in the dinosaur communities. The next moment, it was total chaos. A massive comet careened into Earth sending tons of dust and gases up into the atmosphere. Forest fires scorched Earth, and the sun was virtually blacked out. No part of Earth escaped: the creatures that survived the initial blast found their habitats severely disturbed. The dark clouds blanketing Earth lasted for years, blocking so much sunlight that plants could barely photo-synthesize anymore. Whole forests died off. And the tiny photosynthesizing algae floating around on the ocean surface likewise succumbed in great numbers. With the cornerstone base of the food chain effectively put out of commission, the remaining animals—the plant eaters, as well as their carnivorous predators, followed close behind. And then, as the dust was literally settling, leaving the surviving species to regain some equilibrium and set up new ecosystems, disaster struck again. And again. Earth had run into a storm of extra-terrestrial bodies—and life was teetering on the brink of complete annihilation. [Plate 97, see page 153.]

Science fiction? Sounds like it, but this scenario of events ending the Period, 66 million years ago, comes not from the lurid imagination of a fantasy writer, but rather from a Nobel prize-winning physicist and his team of highly competent—and very serious—scientists. Their picture of the cataclysmic demise of the dinosaurs, fueled by the insatiable curiosity that has surrounded dinosaurs since their nineteenth-century discovery, brought the subject of extinction to the forefront: the 1980s became the "extinction" decade. The public was enthralled, especially by reports of dramatically awful catastrophes doing in the dinosaurs. [Plate 98] The scientific community awoke from a long period of dormancy to confront the phenomenon of mass extinction as a high priority item. And it was no mere coincidence that the intense examination of mass extinctions of the remote geological past coincides exactly with a heightened awareness that species are becoming extinct on a daily basis right now. We may well be in the midst of a mass extinction, one in which we ourselves—our species *Homo sapiens*—seems to be playing the unenviable role of arch, if not sole, villain. Suddenly, we have all come to realize that extinction is a very important phenomenon indeed.

PLATE 98

***THESCELOSAURUS WARRENI, JURASSICA,* AN HERBIVOROUS DINOSAUR, CAST OF FOOT.**

Upper Cretaceous (*ca.* 85 million years). Alberta, Canada.

Dinosaurs utterly symbolize mass extinctions of the geological past.

PLATE 99

CLUTCH OF DINOSAUR EGGS POSSIBLY OF *PROTOCERATOPS*.

Cretaceous (*ca*. 90 million years). Flaming Cliffs, Mongolia.

Though one theory of dinosaur extinction holds that their eggs were weakened through a form of geochemical pollution, it is clear that major extinctions events always involve more general ecological factors and affect many different groups of animals and plants at the same time.

Extinction is not news to a paleontologist. It is a fact of life—albeit one that paleontologists up until recently have usually ignored in favor of more "positive" tidings. I myself used to have the feeling that extinction was the "downside," and preferred to focus on the "upside": evolution. But it has long since become clear to virtually every paleontologist that evolution and extinction go hand in hand. The one, in a sense, "needs" the other. It's easy to see how extinction can't occur unless evolution had already produced organisms that could suffer that ultimate fate. But only in the past few years have we come to realize how true the converse is as well: it now is crystal clear that life virtually cannot evolve to any significant further degree *unless* extinction has come along to eliminate a goodly percentage of Earth's living occupants. Thus my own ruling passion—the patterns of evolution—has become deeply entwined with extinction—as we shall see in the next chapter. One can't understand evolution, really, without understanding extinction. And you can't understand extinction without first grasping ecology: the rules that govern how organisms of different species live in the same ecosystems, and the controls that determine how many organisms, and how many different species, can live in any particular habitat area. [Plate 99] The subject is fascinatingly complex. Yet, as we shall see, certain simple generalities do surface. Extinction turns out to be, if not quite as simple as a straightforward cometary collision wreaking earthly havoc would have it, at least reasonably intelligible. . It is, fundamentally, a story of ecological collapse. If we know what holds ecosystems together, we can make some pretty shrewd estimates of what triggers their collapse. [Plate 100] But this gets the cart before the horse: we need to know more about actual extinctions of the geological past, so we can tackle theories of what causes extinction in the first place.

TIME LINES IN ROCK

We have already encountered the geological time scale. It is an indispensable, if formidable, system of names of divisions of geologic time. It allows us to bracket fossils in time, and was especially important in the days before precise radiometric dates were available. But even now, we can radiometrically date fossil-bearing sedimentary rocks only in exceptional circumstances. When I tell somebody that a "Middle Devonian" trilobite is approximately 380 million years old, I mean that rocks called "Middle Devonian" have been dated through analysis of radioactive decay in at least one locality in the world. I know the trilobite is "Middle Devonian" in age because it comes from rocks determined to be about the same age as these precisely datable rocks elsewhere. And we know that because fossils occur in a regular, stratified order through time: rocks are about the same age if they contain the same, or closely similar fossils.

Well and good. Geologists have been determining the relative age of geological strata by looking at their fossil content for almost 200 years now. What we have been somewhat slower to realize is that the divisions of geologic time (worked out, in larger part, by the mid-nineteenth century) are based on actual "packages" of living systems—intervals of geological time recorded in the rock record by the history of discrete faunas and floras. Many species will appear near the beginning and disappear by the end of such packaged intervals of time—though species may appear or disappear at any time within the interval, and some species, of course, will survive into the next succeeding interval. The best evidence that extinctions have occurred, over and over again, is the chart (See page 13.) showing the subdivisions of geological time over the past 4.5 billion years. Life, in essence, *defines* geologic time. The last 540 million years is divided into the familiar Paleozoic, Mesozoic and Cenozoic Eras: ancient, median and recent life. These, the three grand packages of complex life, are demarcated by two of the greatest mass extinction events yet to have hit Earth. [Plate 101]

PLATE 100

***SMILODON CALIFORNICUS*, A TRUE SABERTOOTHED CAT**

Pleistocene (*ca.* 25,000 years). Rancho La Brea, Los Angeles, California.

The largemammal fauna of North America as recently as 10,000 years ago was as rich and varied as that of the African plains today.

PLATE 101

***KAPROSUCHUS SAHARICUS,* A SAHARAN CROCODILE.**

Upper Cretaceous (*ca.* 93 million years). Gadoufaoua, Agadez District, Niger Republic.

Though obviously crocodilian, this species (the name means Saharan "boar crocodile") belongs to a lineage of crocodilians that did not survive the end Cretaceous extinction.

Credit: Paul Sereno, University of Chicago.

The event that closed the Paleozoic was the worst. Paleontologist David M. Raup, of the University of Chicago, has calculated that perhaps as many as 96% of *all species on Earth at that time* may have become extinct! The end-Cretaceous event, more famous because that is when the dinosaurs finally disappeared, was nonetheless far less devastating. But changes in the complexion of the world's ecosystems—particularly the dinosaur-dominated terrestrial ecosystems—was nonetheless so marked that early geologists had no trouble at all drawing a line between "middle" and "modern" ages of life right at the point when the dinosaurs on land, and the ammonites (shelled relatives of squid and octopi) of the seas, disappeared. Because mammals soon replaced dinosaurs as the large-bodied vertebrate constituents of terrestrial ecosystems, the basic structure of ecosystems as they are still familiar to us today was established, and the modern age of life had begun—some 66 million years ago.

But the geological time scale has many more divisions than the simple tri-fold Paleozoic, Mesozoic and Cenozoic scheme would suggest. Some are world-wide in extent—such as the internationally agreed-upon major divisions of the three Eras into twelve "Periods." In turn, each of the periods is further subdivided into Epochs—though here the divisions begin to differ depending upon where on Earth you are looking at them. All this means, in a nutshell, is that true and often global mass extinctions are very real phenomena indeed. And it also means that some extinctions have been more massive, more pervasive in extent than others: they have covered the globe, and affected virtually every major lineage, and every basic kind of ecosystem, in existence. Other events are more minor, striking only some regions, or some habitats, or even just some groups, rather than others. Not surprisingly, these less severe events are more common—and serve as the basis of locally recognized subdivisions of geological time. [Plates 102, 103]

PLATE 102

PLATE 103

PLATE 102

***TIMORECHINUS MIRABILIS,* AN UNUSUAL SEA LILY (CRINOID ECHINODERM).**

Upper Permian (*ca.* 250 million years). Island of Timor, Indonesia.

The mass extinction at the end of the Permian Period was the most devastating of all, killing off these strange crinoids and many other species.

PLATE 103

***DIADECTES SP.,* AN AMPHIBIAN.**

Lower Permian (*ca.* 270 million years). Wichita Basin, Texas.

The Permo-Triassic revolution affected life in all ecological realms.

PLATE 104

***MACHAEROPROSOPUS* SP., A SUPERFICIALLY CROCODILE-LIKE REPTILE.**

Upper Triassic (*ca.* 215 million years). Arizona.

Extinction claimed many groups on both land and in the sea at the end of Triassic times. Phytosaurs were among those that succumbed.

Six major global extinction events stand out over the past 540 million years. In order of occurrence, they are (1) Upper Cambrian (roughly 485 million years ago), (2) Upper Ordovician (*ca*. 445 million years ago), (3) Upper Devonian (some 370 million years ago), (4) Upper Permian (end Paleozoic—252 million years ago), (5) Upper Triassic (201 million) and (6) Upper Cretaceous (end Mesozoic—around 66 million years ago). Others are noteworthy as well. Especially important for us are the Late Pleistocene (Ice Age) extinctions, predominantly of large mammals—an event that may well still be underway. An event, moreover, that is at least partly attributable to the hunting and habitat-destroying activities of *Homo sapiens*—our very own species. The degree to which we have contributed to these extinctions is crucial to our understanding what effects we are having on the world's ecosystems around us right now. The study of extinctions of the remote geological past sheds light on how extinctions occur without our help. Ice Age extinction is the transitional case, where humans enter for the first time into the extinction picture. The urgency for understanding all these events is clearly crucial to evaluating what is going on in the here and now. [Plate 104]

We need to know if there is any common thread to all these extinctions. Let's focus, first, on events at the end of the Cretaceous—not just because the demise of the dinosaurs has made it is the most celebrated case, but because the intensity of work in the last decade makes it the best documented and understood episode of all the mass extinction events. And let us ask, first, what made Luis Alvarez (the Nobelist in physics) and colleagues devise that unearthly scenario of cometary impact with which we started this chapter.

Walter Alvarez, Luis's son, is a geologist. Determined to examine the physical events right before, during and after the boundary between the Cretaceous and Tertiary Periods ("K-T" boundary, for short), he chose an exposure near the Italian town of Gubbio. The rocks there were reputed to hold a particularly complete record of geological time just as the Cretaceous was giving way to the Tertiary. [Plate 105] The boundary itself was fixed by the occurrence of fossils, particularly minute, single-celled shelled amoebae known as foraminiferans. Right at the boundary line, Alvarez collected samples of a .5 inch thick red clay layer—innocuous-looking enough, but nonetheless something of an anomaly, stuck in as it was amidst a thick sequence of limestones.