

*Reconstructing the Murder Scene:  
Contrasting the Volcanic and Impact Hypotheses  
for Dinosaur Extinction*

Our investigation into the late Cretaceous extinction of dinosaurs now brings us to the two currently competing scenarios. One involves terrestrially based causes related to massive volcanic eruptions and the retreat of shallow continental seas. Although some versions of this volcanic scenario are envisioned to have happened quickly, most are thought to have occurred rather gradually in relation to the impact scenario for extinction. That latter hypothesis invokes extremely sudden, catastrophic, extraterrestrial causes triggered by the impact of a comet or asteroid. Both hypotheses suggest that the extinctions at the end of the Age of Dinosaurs resulted from severe climatic effects and changes. They differ, however, in their identification of the triggering mechanism for those changes.

Are these hypotheses testable? Elements of both can be tested with the available geologic and paleontologic evidence, at least to some extent. The question is, "Are they testable to an extent that will allow us to discriminate between the effects of the two events?" In other words, "Can we distinguish the alleged environmental effects of a catastrophic, extraterrestrially derived mechanism from those of a more gradual, terrestrially triggered one?"

In evaluating the weight of the evidence in this case, there are three important criteria that these extinction hypotheses must pass when tested. First, there must be geologic evidence for the mechanism, whether it is a catastrophic extraterrestrial impact or a series of massive volcanic eruptions that may have been associated with a gradual withdrawal of seaways off the continents.

Second, the hypothesis must explain why the effects of that particular mechanism would have fatally affected the physiology of the organisms that went extinct but not other organisms that survived. This is a very complex problem to address, because we are not just dealing with the extinction of many kinds of dinosaurs. In the oceans, late Cretaceous species of single-celled plankton were especially hard hit (fig. 3.01). Also, many multicellular animals such as the nautiluslike ammonites, clams called innoceramids and rudists, plesiosaurs, and ichthyosaurs disappeared near the end of the Cretaceous (fig. 3.02). On land, the end of the Age of Dinosaurs records the extinction of numerous species of marsupials and some species of rodent-like mammals called multituberculates. Pterosaurs and many other species of reptiles, fish and lizards also perished. And in some areas, as many as 50-80% of the plant species apparently went extinct (figs. 3.03, 3.04, and 3.05).

Third, each hypothesis must clearly state how long it took for the mechanism to cause the extinctions. Then, we must find evidence in the rock and fossil records to document that the extinctions actually happened as quickly as predicted by the hypothesis. In other words, we have to be able to tell time precisely enough to distinguish between the effects of more catastrophic and more gradual mechanisms.

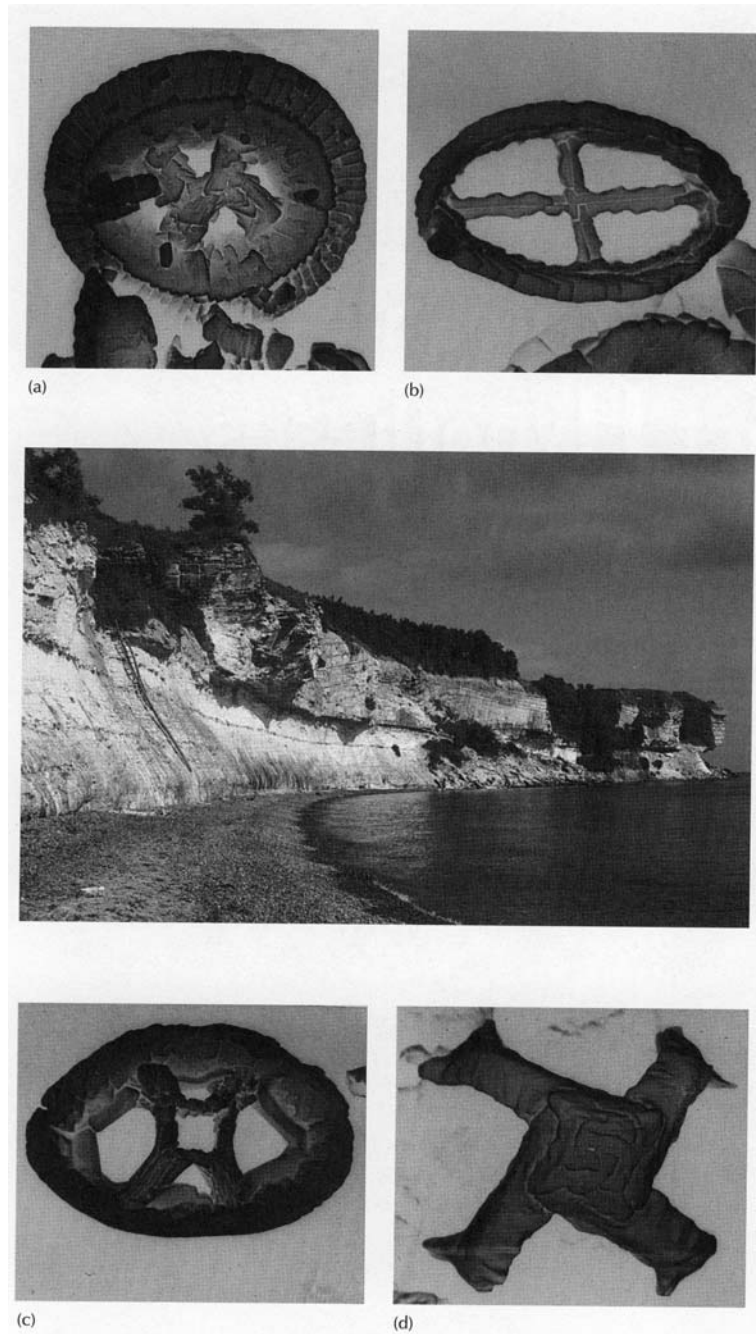


figure 3.01 Microscopic, single-celled, marine organisms, like these coccoliths, have distinctive fossil shells made of calcium carbonate. Many species, like d and e became extinct during the K-T transition and were replaced by new forms in the early Tertiary, like a and b. The evidence for these changes can be found in sequences of rocks that span the K-T boundary, like the one at Stevns Klint, Denmark (c). The K-T boundary occurs about half way up the cliff. Fossils a and b are from Tertiary layers of limy chalk above the boundary, whereas d and e are from layers below the boundary. (from Stanley, S., 1987, *Extinction*, Sci. Amer. Lib., p. 150).

These are tall orders. Yet, only when all three criteria are met can we be assured of a scientifically satisfying solution to the mystery of these extinctions.

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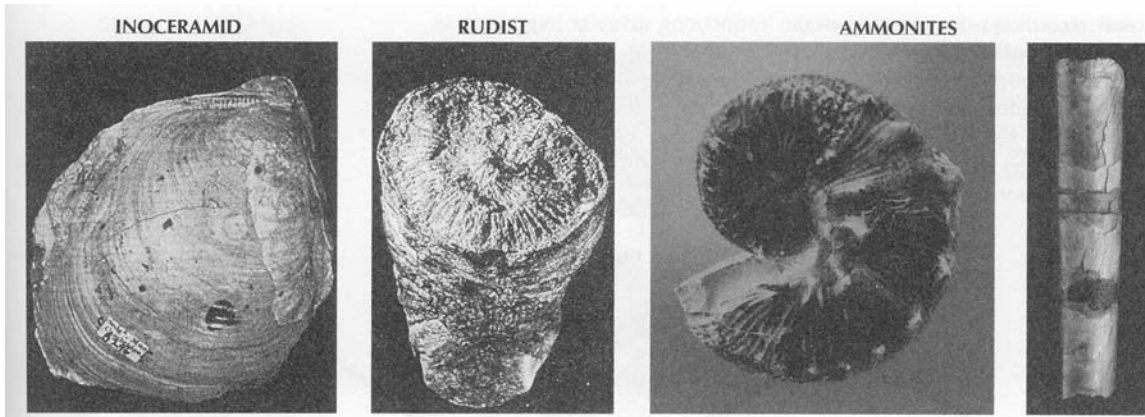
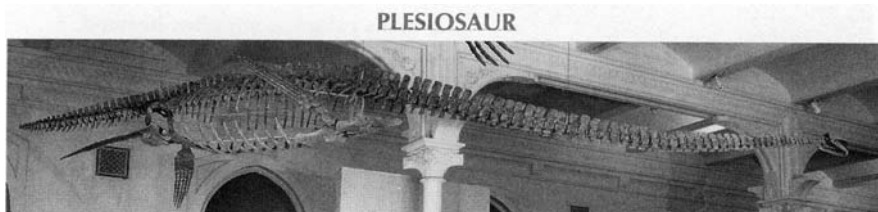
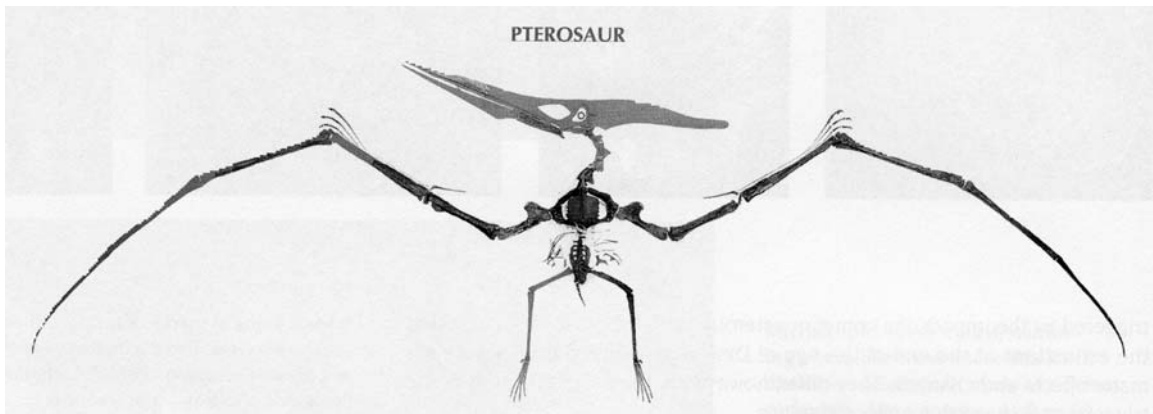


figure 3.02 Several kinds of marine animals without backbones were also decimated near the end of the Cretaceous Period, including two kinds of clams called inoceramids (a) and rudists (b). Also, a whole group of animals called ammonites (c and d), became extinct. Ammonites are fairly close evolutionary relatives of the living nautilus. (a and b from Black, R., 1988, *Elements of Paleontology*, Cambridge Univ. Press, p. 44; c and d from Stanley, S., 1987, *Extinction*, Sci. Amer. Lib., p. 153).



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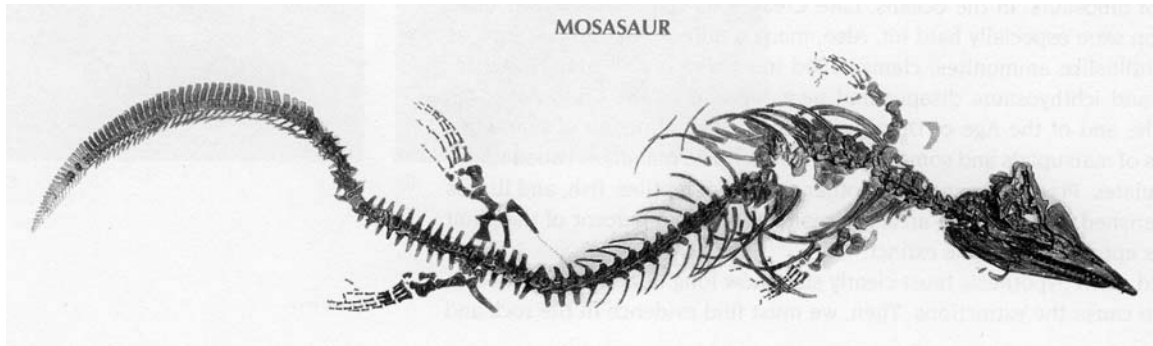


figure 3.03 Several groups of vertebrates other than dinosaurs suffered extinction during the late Cretaceous. They include the flying pterosaurs (a), the marine plesiosaurs (b), ichthyosaurs (c), and mosasaurs (d). (from Stanley, S., 1987, Extinction, Sci. Amer. Lib., p. 119, 120, 122).

To contrast these competing extinction scenarios involving volcanism, seaway retreat, and impact, we might travel back about 65 million years to see what might have happened if each of these events had actually transpired. The setting for each scene will be the long-lost coastal plain along the Western Interior Seaway that extended north from the Gulf of Mexico to connect with the Arctic Ocean. (A detailed listing of the references for the information included in these scenarios will be presented in Chapters 4-7.)

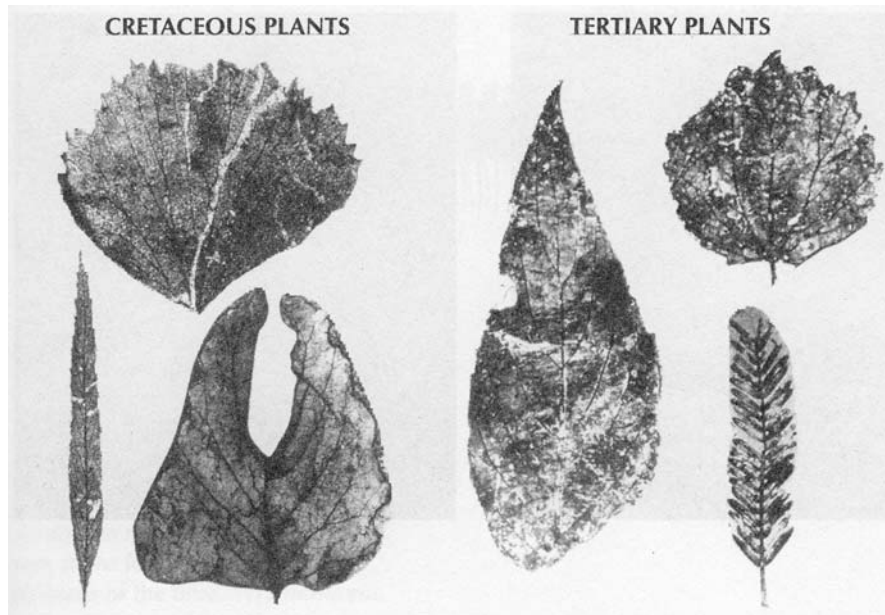


figure 3.04 Although the extent of plant extinctions varied in different geographic areas at the end of the Cretaceous, numerous species suffered extinction in the middle of North America. Here, fossil leaves from six Cretaceous plants (a) are contrasted with fossil leaves from six Tertiary plants (b). (from Johnson, K. R., 1992, Leaf-fossil evidence for extensive floral extinction at the Cretaceous-Tertiary boundary, North Dakota, USA, Cretaceous Research, 13, p. 108-109.)

*A Scenario for Gradual Extinction Resulting from Volcanism and the Retreat of Shallow Continental Seaways*

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The last summer day of the Cretaceous dawns like many others over the past half million years. The atmosphere is thick from ash and toxic gases spewed out of volcanoes in the rising ancestral Rocky Mountains to the west (fig. 3.06), as well as from widespread volcanic eruptions in India, the south Atlantic Ocean, and other areas around the globe. In India alone, these massive eruptions produced about 480,000 cubic miles of basaltic lava<sup>1</sup>, making this volcanic event one of the largest ever recorded in the 4.5-billion-year history of the Earth (fig. 3.07). These flows of lava, piled one on top of the other, are over 1.5 miles thick in some places<sup>2</sup>. In total, they cover an area larger than present-day California. Trillions of tons of toxic pollutants, such as carbon dioxide, sulfur, and chlorine, have been injected into the atmosphere.

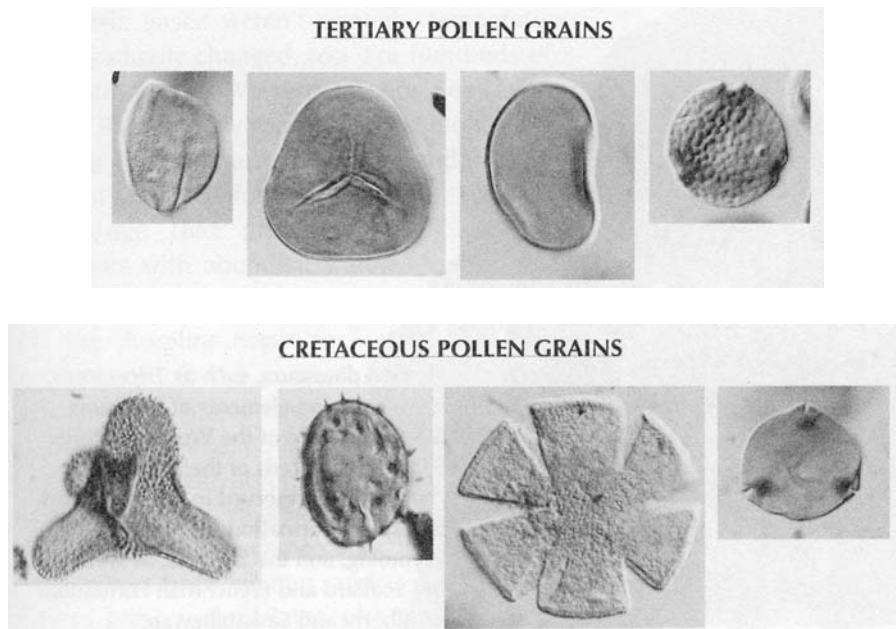


figure 3.05 Fossil pollen from plants also can be used as evidence to document extinctions at the K-T boundary in central North America. Here, microscopic views of pollen grains preserved in Cretaceous rocks are contrasted with similar views of Tertiary pollen grains. All specimens are magnified 1000 times. A-F are Tertiary; G-Y are Cretaceous. (from Nichols, D. J. and Fleming, R. F., 1990, Plant microfossil record of the terminal Cretaceous event in the western United States and Canada, Geol. Soc. Amer., Sp. Pap., 247, p. 449.)

Over time, as a result of deteriorating environmental conditions across the coastal plain and around the globe, the once-thriving populations of the horned dinosaurs, such as *Triceratops*, have dwindled (fig. 3.08). So have those of duckbills, such as *Anatotitan*, and their predatory nemesis, *Tyrannosaurus* (fig. 3.09).

The flora and fauna living along the lush coastal floodplain has been subjected to episodes of corrosive acid rain catalyzed by the air pollution from the eruptions. As if the ash and toxic gases weren't enough, temperatures have gradually changed, too. For hundreds of generations, the Western Interior Seaway has acted like an environmental cushion, helping to keep the temperature and humidity in a comfortable subtropical range that has provided the dinosaurs with abundant water and food. But a million years ago,

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figure 3.06 During the late Cretaceous, volcanic ash and toxic pollutants erupted out of volcanoes involved in the uplifting of the ancestral Rocky Mountains. (from Douglas Henderson in Czerkas, S. and Czerkas, S., 1990, *Dinosaurs: A Global View*, Dragon's World Ltd., Great Britain, p. 196)

the shoreline began to recede back off the continent into the major ocean basins. Over the last 50,000 years, that retreat has accelerated. Consequently, days became hotter and nights became colder; summers grew warmer, and winters grew cooler. Rates of precipitation also changed. During the warmer times of the year, the temperature rises to uncomfortable levels as the result of global warming generated by the volcanic particulates and aerosols.

These environmental changes have already decimated the herds of duckbills, and in turn extinguished the fearsome carnivore that preyed on the duckbills, *Tyrannosaurus*. But on this day 65 million years ago, the last *Triceratops*, weakened by the extreme heat of the noonday sun and the choking dust generated by an eruption the night before, rolls over on its side and breathes its last, finally terminating a lineage that had ruled the continents for over 150 million years (fig. 3.10).

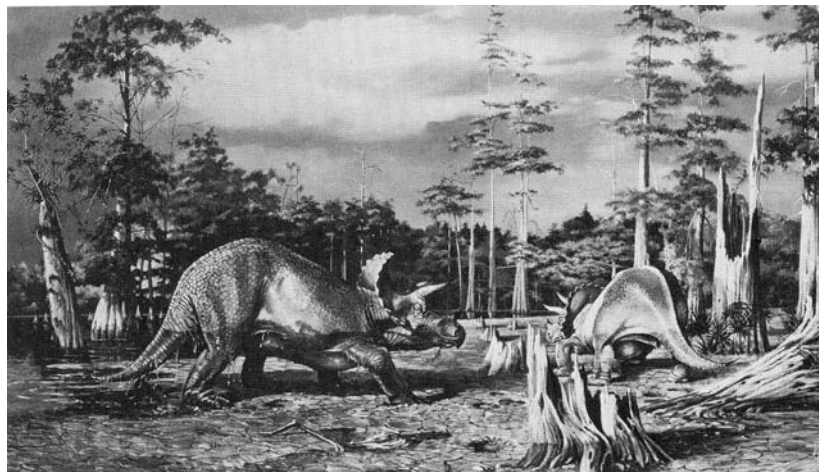


figure 3.07 Horned dinosaurs, such as *Triceratops*, were common elements of the fauna along the shore of the Western Interior Seaway. Hundreds of their skeletal remains are preserved in the Hell Creek and Lance Formations of Montana, Wyoming, and the Dakotas, as well as in the Scollard and Frenchman Formations of Alberta and Saskatchewan. (from Eleanor Kish in Russell, D., 1977, *A Vanished World*, National Museums of Canada/Hurtig Publishers, Alberta, p.117)

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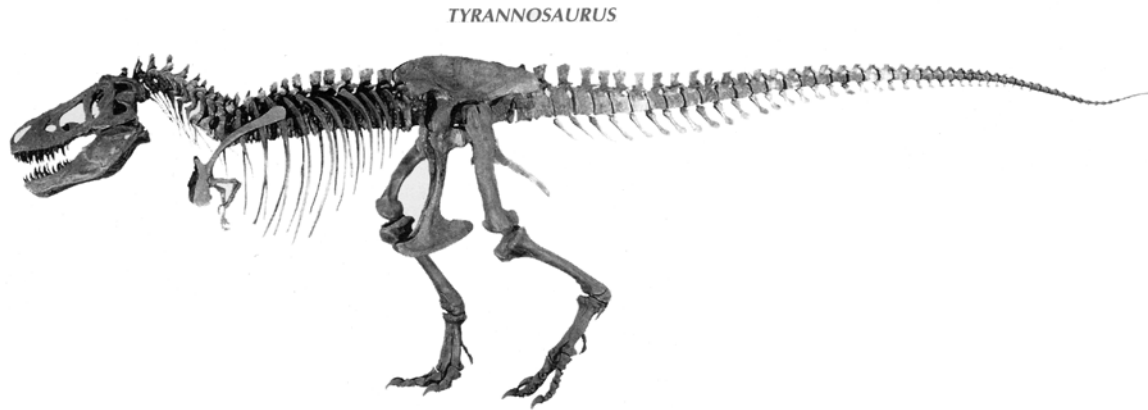


figure 3.08 *Tyrannosaurus* stalks a herd of the herbivorous, horned dinosaur *Torosaurus* along the floodplain of the Western Interior Seaway about 65 million years ago, just before the end of the Cretaceous Period. (from Dingus, L., 1994, *What color is that dinosaur?* Millbrook Press, Brookfield, CT, p. 8-9.)



figure 3.09 The other common group of large, plant-eating dinosaurs at the end of the Cretaceous was the duckbills, such as *Anatotitan* (a). Both *Triceratops* and *Anatotitan* may have been important prey items for the top predatory dinosaur of the time, *Tyrannosaurus* (b). (from Dingus, et al., 1995, *The Dinosaur Halls*, AMNH, p. 81, 32)

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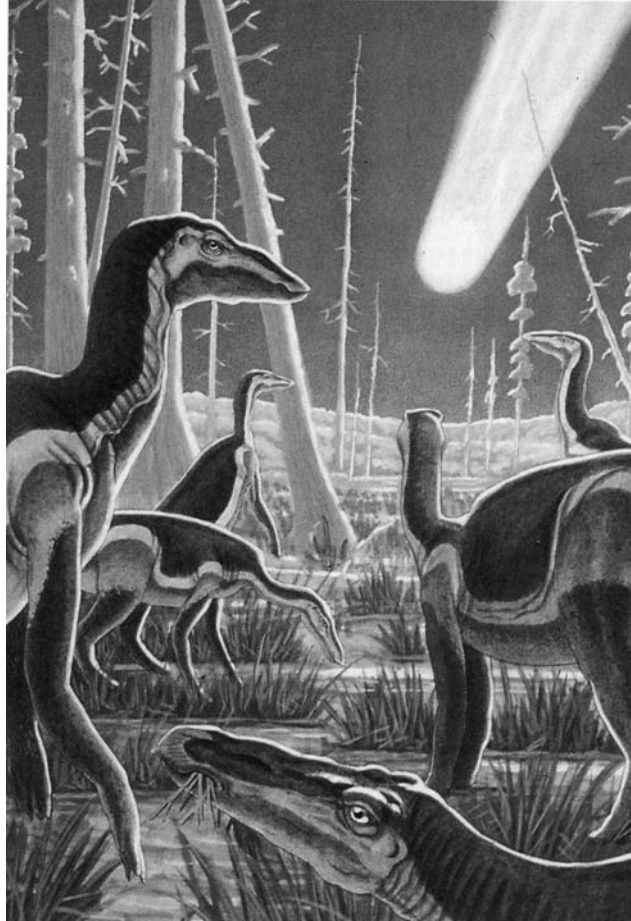


figure 3.12 This hypothetical scene from 65 million years ago shows a herd of duckbills watching a comet or asteroid streak through the atmosphere shortly before it impacts near present-day Yucatan. (from Dingus, L., 1994, *What color is that dinosaur?* Millbrook Press, Brookfield, CT, p. 65.)

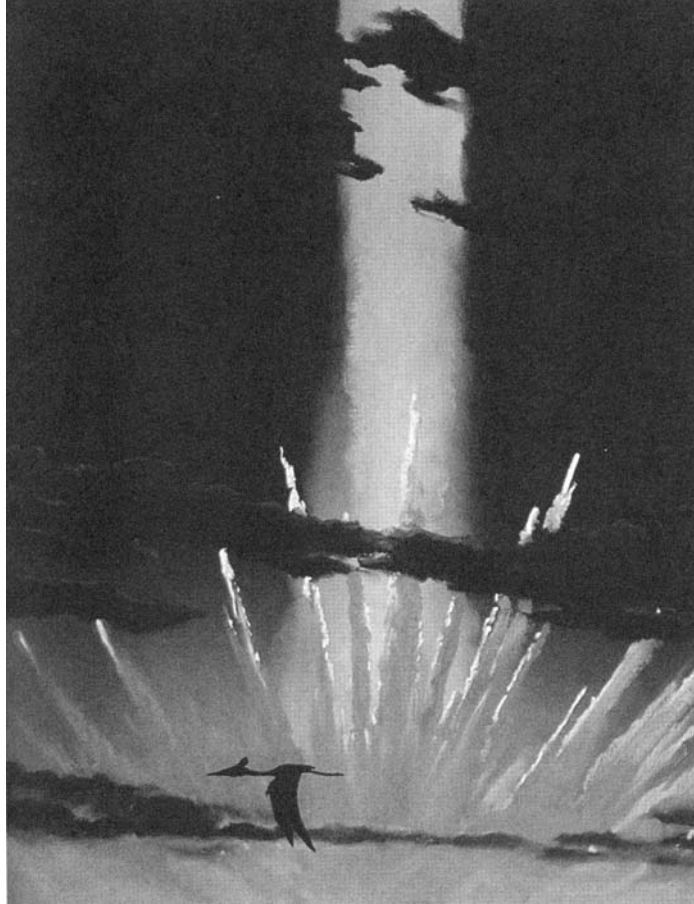


figure 3.13 A pterosaur flies peacefully over the tropical landscape at the moment of impact, as the asteroid or comet smashes into the shoreline of the Yucatan Peninsula at the end of the Cretaceous. A gigantic crater, buried under the surface in that region today, represents evidence for this event. (from Doug Henderson in Czerkas, S. and Czerkas, S., 1990, *Dinosaurs: A Global View*, Dragon's World Ltd., Great Britain, p. 233.)

### *A Scenario for Sudden Catastrophic Extinction Resulting from Impact*

Now, try to envision that very same coastal floodplain, if the catastrophic impact hypothesis were true.

The summer night is calm and pleasant, punctuated only by the occasional grunts and snorts from a sleeping herd of horned dinosaurs. Through the stand of conifers adjacent to the herd, a bull tyrannosaur slowly and intently stalks toward a plump and peacefully sleeping juvenile near the herd's edge (fig. 3.11).

Just as the bull edges within striking distance, the southern sky is ignited by a meteor many times brighter than the sun. It streaks across the Caribbean sky at somewhere between 50,000 and 150,000 miles per hour<sup>3</sup>, ripping completely through the Earth's atmosphere in a matter of only a few seconds (fig. 3.12). The whole herd awakens instantly and, in startled panic, stampedes in the opposite direction, ignoring the tyrannosaur fleeing in their midst.

To the south, the Earth is rocked by the shockwave from the tremendous impact near present-day Yucatan (fig. 3.13). The six-mile-wide meteorite<sup>4</sup> hits the shoreline of

the Gulf of Mexico generating explosion temperatures of several thousand degrees and pressures equal to 1,000,000 times those normally created by the weight of the Earth's atmosphere. It initially excavates a crater between 50 and 60 miles across<sup>5</sup> and between 13 and 25 miles deep<sup>6</sup>. An earthquake of magnitude 13--one million times greater than the strongest earthquake ever recorded in human history--is generated. The explosion blasts 5,000 cubic miles of material out of the crater<sup>7</sup>, 400 cubic miles of which is launched into orbit around the Earth<sup>8</sup> at a velocity equal to 50 times the speed of sound. This is 1200 times the amount of volcanic ash that was erupted out of Mount St. Helens. Part of the Earth's atmosphere is literally blasted away by the ejected debris.

The destructive force of the impact along with the 250- to 300-foot-high tsunamis<sup>9</sup> that it triggers instantly decimate organisms living nearby. Within a few hours, the tsunamis strike other shorelines around the Gulf of Mexico, eradicating near-shore communities living hundreds or even thousands of miles from the impact point (fig. 3.14).

As orbiting particles reenter the remaining atmosphere, they heat it to levels comparable to "broiling" temperatures in your oven. Wild fires are ignited across several regions of the globe. Even at a distance of several thousand miles, the environment along the Western Interior Seaway is severely stressed.

Then, over the next several months after this initial incineration, the atmosphere becomes so choked with debris that no sunlight can penetrate to the ground. Without the warmth and rays of the Sun, temperatures plummet below freezing for one to six months. The surviving plants on which *Triceratops* fed, soon die. With the death of its food source, the *Triceratops* herd perishes, and with the death of the herd, so does the last *Tyrannosaurus* in these gloomy last moments of the Cretaceous. Though dinosaurs had dominated the earth for 150 million years, they disappeared in a geological instant of global cataclysm.

These are both riveting, sensational scenarios. But in our role as scientific detectives, can we find evidence in the geological and paleontological records to confirm that they really happened? That quest will be the focus of the next three chapters.

Notes and References

1. = 2,000,000 cu km

2. = 2.4 km

3. = between about 80,000 and 250,000 km/hr

4. = 10 km

5. = about 80 to 100 km

6. = about 21 to 32 km

7. = about 21,000 cubic km

8. = about 1,700 cubic km

9. = about 75- to 90-meter-high