Extinction of Dinosaurs

Introduction

Sixty-five million years ago the dinosaurs died out along with more than 50% of other life forms on the planet. This mass extinction is so dramatic that for many years it was used to mark the boundary between the Cretaceous Period, when the last dinosaurs lived, and the Tertiary Period, when no dinosaurs remained. This is called the Cretaceous/Tertiary (or K/T) boundary, and the associated extinction is often termed the K/T extinction event. The name "Tertiary" is a holdover from the early days of geology, and many geologists now prefer the term "Paleogene" for the time period that immediately follows the Cretaceous. These scientists refer to the Cretaceous/Paleogene or K/P boundary, which represents the same moment in time as the K/T event. Since their discovery in the nineteenth century, the reason for the dinosaurs' demise has been a matter of speculation and debate. Early paleontologists, working prior to Darwin's theory of evolution by natural selection, suggested that dinosaurs represented the remains of animals that had perished in the Biblical Flood. This explained both the fact and speed of their disappearance. But as other extinctions came to light, and Darwin's theory gained acceptance, this explanation fell out of favor.

For many decades, the fossil record of dinosaurs was poorly known. During that time it was clear that dinosaurs had gone extinct, but it was not yet understood that this extinction was relatively sudden and simultaneous with those of many other species. Only at the end of the nineteenth century did paleontologists realize that nearly all dinosaurs had gone extinct within a brief period of time at the end of the Cretaceous Period.

For most of the next century, scientists focused on explanations for how the extinction might have occurred. Most theories focused on climate change, perhaps brought on by volcanism, lowering sea level, and shifting continents. But hundreds of other theories were developed, some reasonable but others rather far-fetched (including decimation by visiting aliens, widespread dinosaur "wars", and "paläoweltschmertz"the idea that dinosaurs just got tired and went extinct). It was often popularly thought that the evolving mammals simply ate enough of the dinosaurs' eggs to drive them to extinction.

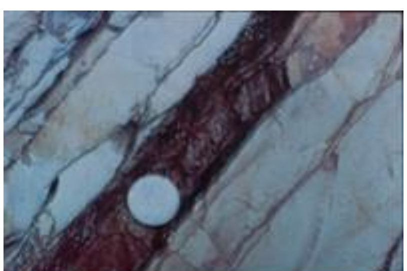
Regardless of the details, most of these theories shared the common thought that dinosaurs were a group of animals that had reached the end of their evolutionary life. Their extinction was seen as inevitable, the product of having evolved for too long. In most extinction scenarios, the dinosaurs were simply unable to cope with competition from mammals and the changing climate, and so they all went extinct.

As dinosaur science began to alter this hypothesis, producing a new view of dinosaurs as successful and viable organisms, many of these extinction theories became less tenable. New information from fossil localities suggested that many other organisms, most unrelated to dinosaurs, had also gone extinct at the same time. New theories were required to explain these new discoveries and newly understood facts. A favored theory was that tectonically induced climate change interfered with food chains, disrupting them enough to cause widespread extinction among many different organisms.

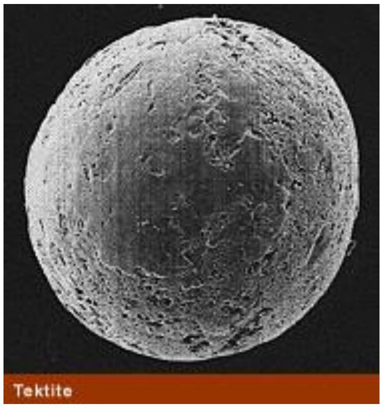
Alvarez Hypothesis: Origin and Evidence


The asteroid approaches Earth (Mary Parrish)

In the late 1970's geologist Walter Alvarez, and his father, Nobel-prize winning physicist Luis Alvarez, identified an unusual clay layer at the K/T boundary in Italy. This clay contained an unusually high concentration of the rare-earth element iridium 30 times the level typically found in the Earth's crust. Why was the discovery of iridium so important? Although iridium is rare in the crust, it is abundant in many meteorites and asteroids as well as the Earth's core. With this evidence, Alvarez hypothesized that an asteroid must have struck the Earth right at the K/T boundary. Further investigation has revealed that this iridium-rich layer of clay occurs at more than 100 sites around the world, providing evidence that this was truly a worldwide event.


Gubbio clay

It was estimated that to produce the amount of iridium in the clay layer, the impact object would have been 10 km in diameter. Further evidence of an impact was discovered in the form of small grains of impact-shocked quartz and beads of impact glass (tektites) within the clay layer. Shocked quartz is formed by high-pressure shock waves, and is found at nuclear bomb sites and in meteor craters. Tektites are formed from the condensation of vaporized meteorite particles. Although shocked quartz has been found in K/T layers worldwide, tektites decrease in size with increasing distance from the impact site until they are altogether absent.

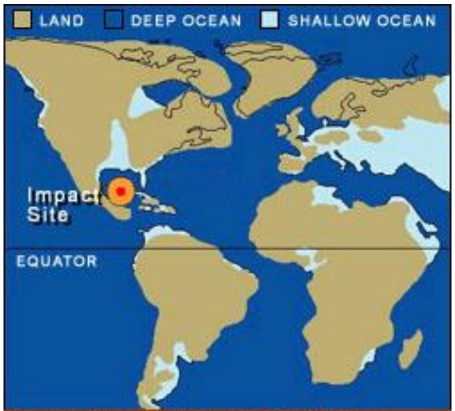


These pieces, along with high levels of iridium, provide evidence for an extraterrestrial impact at the end of the Cretaceous Period. Thus, the end of the dinosaurs' reign may have been caused by an asteroid, not by sea level change or volcanism. Initially this theory was highly controversial, but today an extraterrestrial impact is considered to be a key factor in the K/T extinction event.

One of the main objections to the Alvarez theory was the absence of a 65-million-year-old crater anywhere on the Earth's surface. Surely such an enormous asteroid impact would have left a sizable crater behind. In 1991, geologists discovered evidence for a huge crater at Chicxulub (pronounced CHIK-shoo-loob), on the Yucatan Peninsula in Mexico. Although the crater had long since been buried by hundreds of meters of sediment, surveys of magnetic and gravitational fields revealed its circular structure. In addition, recent sensitive topographic mapping has shown a low mound that represents part of the crater's rim. At 180 km across, and dated to 65 mya, the crater is of the right size and age to have been caused by a 10 km asteroid hitting Earth at the end of the Cretaceous Period.

Effects of the Asteroid Impact

The devastation caused by such an event is difficult to imagine. The asteroid would have hit with the force of 100,000 billion tons of TNT. This would have generated an earthquake one thousand times greater than the largest ever recorded, with winds of over 400 kph. A massive fireball would have boiled nearby seas, destroying everything for thousands of kilometers. Forests throughout most of North America and some of South America would have been flattened by the shock wave. Evidence of a giant tsunami has been found around the Gulf of Mexico and Caribbean, as well as in Spain and Brazil. It may have had an effect as far away as New Zealand.



Map showing asteroid impact in Gulf of Mexico

Despite the enormity of the destruction from the initial impact, the dinosaurs and their contemporaries might have survived and eventually recovered, but the subsequent long-term effects of the blast were even more deadly. Ninety thousand cubic kilometers of debris would have been blasted into the atmosphere, some reaching into space only to re-enter at high speeds. This could have heated the atmosphere sufficiently to ignite global forest fires. While the heavier pieces of ejecta settled back down on Earth, fine dust particles would have remained in the atmosphere and significantly blocked sunlight, causing an effect called an "impact winter". There is much debate about the duration and severity of the impact winter following the K/T impact, but the darkness and cold temperatures might have reduced photosynthesis and collapsed food chains globally.

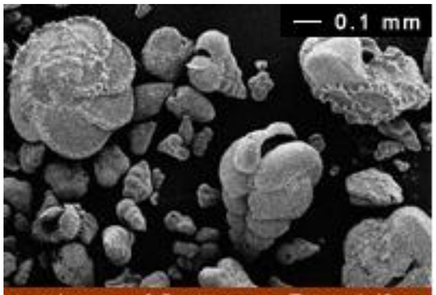
The amount of carbon and sulfur contained in the rock at the impact site would have aggravated these devastating effects. As much as 100 billion tons of sulfur and 10 trillion tons of carbon would have been vaporized by the impact and blown into the atmosphere. The resulting sulfate aerosols would have stayed in the atmosphere for several years; the resulting carbon dioxide would have stayed airborne for several hundred years. Initially the sulfate aerosols would have contributed to global cooling by blocking out the sun, before precipitating as acid rain. After the dust and sulfates settled out and ended the cooling, global warming would have begun. The carbon dioxide levels, being two to three times normal, would have caused extreme greenhouse conditions, raising global temperatures by as much as 10°C. Although some life forms may have survived the years of darkness and freezing temperatures, many surely died out in the subsequent centuries of heat.

Other Extinction Hypotheses

Although the impact hypothesis is the most widely accepted explanation of the K/T extinction, other theories still remain. Evidence of widespread volcanism, particularly at the Deccan traps in India, correlates with this moment in time as well. Prolonged volcanism could have led to atmospheric and climatic changes similar to those proposed for an asteroid impact. However, volcanism does not provide an alternate explanation for the high levels of iridium in the clay layer, because high concentrations of iridium occur deep in Earth's core rather than in the mantle, which is the source of the magma that was erupted.

One debate centers on whether the extinction was truly as sudden as it appears, or whether this is an artifact of the geological record. Some scientists believe that dinosaurs went extinct gradually, and were doing so for millions of years prior to the K/T boundary. Studies in the Western Interior of North America have suggested that the latest layers of Cretaceous sediments contain fewer dinosaur species than those below. These results have been challenged by other researchers, who claim that no such decrease is apparent in the Late Cretaceous record.

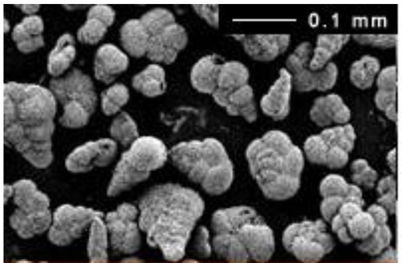
Deep-sea Evidence for the Impact Hypothesis



specimens of Cretaceous Foraminifera

The general acceptance of the K/T asteroid impact theory has led many scientists to focus on the specific mechanisms that may have contributed to this dramatic extinction event. Although the impact was an important factor in the extinction of so many organisms, the event has also proven to be complex. In particular, the selectivity of the extinction has puzzled many paleontologists:

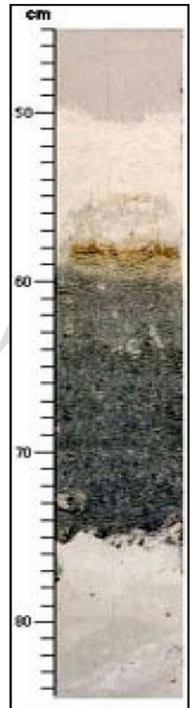
why did dinosaurs go extinct but not crocodiles or turtles? Why did marine reptiles, belemnites, and ammonites disappear, but not fish or sharks? Why some mammals and not others?



specimens of Tertiary Foraminifera

Other scientists have focused on the extinction record preserved in deep-sea sediments in order to better understand the chain of events that followed the asteroid impact. Dr. Brian T. Huber, micropaleontologist in the National Museum of Natural History Dept. of Paleobiology, has studied evidence from a deep-sea drilling core taken 500-580 km of the northeastern coast of Florida during an Ocean Drilling Program cruise. Huber studied microscopic marine organisms called foraminifera taken from the core. The specimens were extracted from both Cretaceous and Tertiary age sediments. In one 40 cm core interval, he noticed a dramatic difference between the types of planktonic (floating) foraminifera that were alive prior to the boundary event and those that lived after. Prior to the extinction, large, ornate planktonic foraminifera were abundant, but afterward most specimens belonged to smaller, less ornate species. Overall more than 90% of the Cretaceous planktonic foraminifera had gone extinct. This is comparable to the extinction rate of calcareous nannofossils, another group of microscopic fossils that are abundant in the deep-sea sediment. In addition to the foraminifera, Huber also found specimens of shocked quartz and tektites, direct evidence of the impact itself.

The core also offered visual clues to the changes that occurred at the time of the extinction. The sediment undergoes a dramatic color change from white Cretaceous chalk in the lower portion of the core, to a dark gray, coarse-grained tektite layer in the middle, to a whitish gray Tertiary muddy chalk in the upper part. At the top of the tektite layer is a very thin, rust-colored, iron-rich layer known as the fireball layer. This rust layer, which has been found at a number of complete K/T impact horizons around the world, contains actual particles of the asteroid along with fine soot and ash that rained down on Earth's surface after the collision. This provides further evidence supporting the asteroid impact hypothesis.



deep-sea core showing dark-colored impact debris

Post-Extinction Recovery

It has been estimated that the planet took 1-2 million years to fully recover from the asteroid impact. In deep-sea sediments, several very small sized species of foraminifera with simple, unadorned shells appeared within several thousand years after the extinction event, but several million years elapsed before species diversity, shell ornamentation, and shell sizes increased to values comparable to those that occurred before the impact event. The small sized planktonic foraminifera are considered opportunistic species that had rapid rates of reproduction and higher tolerances to changing environmental conditions. A similar pattern of extinction and recovery has been observed in the North American fossil land plant record. In southwestern North Dakota, where the fossil record of land plants is most complete and best studied, abrupt extinction of 70 to 90% of plant species was immediately followed by a dramatic increase in the abundance of ferns. Because the North American forests were decimated by the asteroid impact, ferns were able to rapidly disperse and dominate much of the newly cleared land surface for hundreds to thousands of years afterwards.

Full recovery of North American forests, resulting from appearance of new species and repopulation by surviving species, took from several hundred thousand to over a million years.

Of the many long-term effects produced by the global devastation at the K/T boundary, the most obvious is the disappearance of all non-avian dinosaurs. Yet the close of the Age of Dinosaurs meant the start of the Age of Mammals. Although mammals had existed alongside the dinosaurs for hundreds of millions of years, they had remained small and comparatively rare. The extinction of the dinosaurs allowed mammals to come into dominance, as they evolved into new and larger forms throughout the Tertiary Period.


The post-extinction world (Marry Parrish)

Within the first five million years of the Paleocene Epoch, large mammals had appeared for the first time. Some of them were the earliest members of modern groups, including primitive carnivorans and ungulates. The first primates (members of the mammalian order that includes humans) appeared about 10 million years after the K/T boundary event. Modern bird groups diversified as well, in the absence of pterosaurs (which had also gone extinct). Perhaps without the extinction of the dinosaurs, the evolution of mammals and the subsequent rise of humans would have never happened. And although recent history might well be called the Human Age, the time that the human race has dominated planet Earth is but a blink in geologic terms. It is certain that the world will change again. Indeed, we may be in the midst of another mass extinction event right now.