You thought you were having a bad day

President's Column – August 2011

Title: You thought you were having a bad day?

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My fascination with dinosaurs started very early, reading “All About Dinosaurs” by Roy Chapman Andrews as my first book outside of grammar school when I was just six years old. I suspect that dinosaurs also represented the first introduction to science for many who have pursued careers in the study of the Earth. What other animals appeal to the imagination like dinosaurs, so much like science fiction monsters, yet whose fossilized remains confirm their existence?

Dinosaurs roamed the Earth for over 150 million years and would probably still be the dominant animals were it not for their mass extinction at the end of the Cretaceous. The cause of the mass extinction has been one of the most hotly contested geological debates over the last several decades, and many details remain mysteries despite the intense ongoing research efforts.

Dinosaur extinction theories can be broken into two main categories. The first category includes theories that propose the demise took place gradually, adhering to English geologist James Hutton’s principles of uniformitarianism. These principles, first presented by Hutton before the Royal Society of Edinburgh in 1785, state that ancient geologic deposits resulted from the same geological processes operating on Earth today.

The uniformitarian dinosaur extinction theorists generally invoke long-term environmental stresses, as caused by major episodes of volcanism, changes in oceanic current circulation patterns, evolution of plant life, or reversal of the Earth's magnetic poles, (Dingus and Rowe, 1997). Some theorists state that the dinosaurs had simply become too big to be successful anymore, but this is not likely as the largest of the land-dwelling dinosaurs disappeared well before the end of the Cretaceous. The volcanism responsible for the formation of the Deccan Traps in India, one of the largest eruptions on Earth in terms of volume, is thought to be associated with the release of large amounts of toxic gases that poisoned the dinosaur's atmosphere close to the end of the Cretaceous.

The alternate theories for the dinosaur's demise consider the extinction to be the result of a cataclysmic event that quickly wiped out the dinosaurs. Some of these theories date back prior to Hutton's time, such as the 1742 proposal by French scientist Pierre de Maupertuis that argued comet impacts on the Earth caused extinctions by altering the atmosphere and oceans. Rene Gallant wrote an essay in 1964 on the biological and geological effects of meteorite impacts including the possibility of mass extinctions (Dingus and Rowe, 1997). Paleontologist Dale Russell and astrophysicist Wallace Tucker...
proposed (1971) that climatic changes caused by a nearby supernova explosion caused the dinosaur extinction. The father-
son team of Luis and Walter Alvarez along with fellow researchers at the University of California, Berkeley, published their
theory of a bolide (asteroid or comet) impact being responsible for the dinosaur extinction in 1980. The Alvarez team had
discovered an anomalous amount of the element iridium in a clay layer at the upper contact of the Cretaceous. Iridium is
very rare in the Earth’s crust, but relatively common in meteorites, so they reasoned that the source of the clay layer iridium
was extraterrestrial (Alvarez, 1997).

The first clay sample analyzed by the Alvarez team was collected by Walter and his colleague Bill Lowrie while they were
conducting paleomagnetic studies near Gubbio, in the of the Apennine Mountains of northern Italy. The Gubbio-area
stratigraphic section, the Scaglia rossa limestone, had been recognized as one of the most continuous sequences of the
Cretaceous and overlying Tertiary rocks preserved in the world owing to its deposition in deep marine waters far below wave
base. Italian paleontologist Isabella Premoli Silva had taught the younger Alvarez and Lowrie how to identify the Cretaceous-
Tertiary (or “K-T”) boundary Scaglia rossa clay layer on the basis of the significant difference in foraminifera fossils (tiny
single-cell marine fossils visible with a hand lens, also known as forams) present in the limestone layers above and below.
The Cretaceous forams are much more abundant and larger than the Tertiary forams, suggesting that there was a major
environmental change at the boundary—perhaps the same change that caused the dinosaur extinction.

Although the initial paleomagnetic study objective of deciphering the complex tectonic history of the Mediterranean region
was not successful, the studies did indicate numerous magnetic reversals. More importantly, this work focused the younger
Alvarez and Lowrie on a new problem: the nature of the K-T boundary clay. They brought the clay sample to the elder
Alvarez who considered techniques that would enable them to determine the period of time necessary for the clay to be
deposited—an important detail when considering how long it took for the foram environmental changes and the dinosaur
extinction to occur. Frank Asaro, a nuclear chemist who worked with the elder Alvarez at the Lawrence Berkeley Laboratory
was recruited to use neutron activation analysis, a technique Asaro had developed a few years prior, to evaluate the clay.
Asaro found the clay contained about 9 parts per billion of iridium, much higher than the anticipated amount.

The next step for the Alvarez team was to determine if the iridium anomaly in the Gubbio clay layer was unique or more
widespread. Walter conducted research on other localities that might contain the K-T boundary and then traveled to
Denmark where the boundary is preserved in a coastal outcrop known as the Stevns Klint cliff to collect more samples. Asaro
found anomalous levels of iridium in the Danish samples as well.

The Alvarez team realized that the iridium anomaly at the two European localities did not mean the anomaly was worldwide,
but at the time, they did not know of any other localities to look for the K-T boundary layer. They started to focus on an
explanation for the origin of the iridium anomaly and evaluated the possibility that a supernova was responsible as had been
proposed by Russell and Tucker (1971). Additional neutron activation analyses were performed in an effort to find evidence
for other elements that would indicate a supernova had occurred, but proved to be negative.

The team began considering the possibility of a giant impact, but there were still details that required an explanation. They
struggled with how an impact could have affected both the forams and the dinosaurs. The elder Alvarez consulted with Chris
McKee, a Berkeley astronomy professor who convinced Luis to take the impact theory more seriously. Luis considered the
volume of dust that would be thrown into the atmosphere by a large impact. He had read a description of the 1883
Indonesian Krakatoa explosion that produced enough dust that London had brightly colored sunsets for months half way
around the world. If the scale of an explosion were much bigger, as caused by a large impact, the elder Alvarez reasoned it
could produce enough dust to block sunlight all over the world, killing photosynthetic plants, collapsing the food chain
and causing a mass extinction. The elder Alvarez calculated the size of the impact necessary to produce the volume of dust
necessary to block sunlight and the rest of the team verified his calculations. The team published their interpretation of the
iridium anomaly caused by a large impact in the June 1980 issue of Science.

Other researchers also found the iridium anomaly confirming the Alvarez team’s work at Gubbio and Stevns Klint, as well as
at different localities. Jan Smit from the Free University in Amsterdam is credited by Walter Alvarez with independently co-
discovering the iridium anomaly at Caravaca, Spain.
Other impact-related features, (“tektites” or the molten glass formed at impact and “shocked” quartz that only forms under the extreme pressures of an impact) were also found associated with the iridium anomalies. But as the evidence for the impact hypothesis accumulated, there remained a major weakness: where was the crater? The Alvarez team worried that if the impact had occurred on part of a plate that was subsequently subducted, there would be no evidence preserved. Several craters were considered as candidates but were dismissed because of problems with the age or size.

Unknown to the impact theorists, the crater had been discovered in 1978 by two geophysicists Glen Penfield and Antonio Camargo, working for the Mexican state-owned oil company Petróleos Mexicanos, or Pemex. They were interpreting part of an airborne magnetic survey of the Gulf of Mexico north of the Yucatán peninsula when Penfield identified a huge ring-shaped structure he interpreted as an impact crater. He named the crater “Chicxulub” (Mayan for “the devil's tail”) for a small town near the geographic center of the impact, Puerto Chicxulub. Pemex restricted the amount of information that could be released, but let Penfield and Camargo present their Chicxulub crater interpretation at the 1981 Society of Exploration Geophysicists in Houston. Frustrated by a lack of physical evidence (cores of the crater rocks acquired by Pemex during the 1950s had been lost in a warehouse fire and searches for cuttings samples at some of the Pemex well sites also proved unsuccessful), Penfield temporarily gave up pursuit of his crater theory. Almost ten years later, Penfield was contacted by a University of Arizona graduate student, Alan Hildebrand, who had learned about the Yucatán peninsula crater and the pair were able to obtain samples that confirmed the ring structure was an impact crater.

Evidence supporting the Chicxulub crater as the correct age and size to be responsible for the iridium anomalies which are now identified at over 100 localities world-wide continues to accumulate. These localities include one identified by Kirk Johnson, Vice President of Research and Collections and Chief Curator of the Denver Museum of Nature & Science, about 40 miles east of Denver. Johnson and his co-workers at this locality have identified sanidine-feldspar-bearing ash layers that closely bound the iridium layer. Radiometric age dating of the feldspars has enabled the most accurate absolute age determination of the iridium layer yet, which Johnson vividly describes as a “bad day on earth.”

Although there is increasing agreement that the impact at Chicxulub is responsible for the anomalous iridium layer (Schulte, et al., 2010), there still remain some unresolved questions regarding the impact's role in the mass extinction of the dinosaurs. Some paleontologists contend that the extinction began well before the impact, but the fossil record is not well preserved and there are likely errors with this interpretation. Others argue that not all species became extinct during the impact, so how were these species able to survive as the dinosaurs perished? Still others interpret that modern birds descended from the dinosaurs, so that dinosaurs did not truly become extinct at all (Dingus and Rowe, 1997).

Whatever the final outcome of the ongoing debate over the dinosaur extinction, I'm just glad that I wasn't around on the day that the impact occurred at Chicxulub!

I want to thank Don Stone for his wonderful artwork that graces the cover of this Outcrop issue and illustrates the location of Denver relative to the Chicxulub crater. We would have been toast!

**Selected References**


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The Planetary and Space Science Centre (PASSC) maintains a list of all 178 known meteor impact sites at: http://www.passc.net/EarthImpactDatabase/index.html.


