

Impact Craters and the K/T Boundary

Summary

Students investigate meteorite impact craters and analyze evidence for the K/T boundary impact in particular.

Learning Objectives

Students will be able to:

- Define and describe a meteorite impact crater.
- Gather information about individual impact craters.
- Describe a replica of a K/T boundary core.
- Practice assessing geologic age using marine sediments.
- Evaluate data related to the K/T mass extinction.

National Science Education Content Standards

- Grades 5-8: Earth and Space Science: Earth's history
- Grades 9-12: Earth and Space Science: Origin and evolution of the earth system

Ocean Literacy Essential Principles

- Earth has one big ocean with many features.
- The ocean and life in the ocean shape the features of Earth.

Target Age: Grades 7-12

Time: Four class periods. Two each for Parts 1 and 2.

Materials

- Access to computers with internet and Google Earth (free to download)
- *Blast from the Past* poster at <http://www.oceanleadership.org/posters/blastfromthepast>
- Replica of the K/T boundary core or core photographs, available

at http://www-odp.tamu.edu/publications/171B_IR/IMAGES. (Images: 1049A17X.PDF, 1049B8H.PDF). To inquire about the availability of core replicas, contact Deep Earth Academy at learning@oceanleadership.org.

- Student pages, included
- Map of the world or North America with latitude and longitude

Background

The Cretaceous Tertiary boundary (~65.5 million years ago) is marked by the mass extinction of about 75% of all species found on Earth. The dinosaurs are the best known and most talked about "victims" of this event. Although there have been many hypotheses to explain this mass extinction, the current working theory is an asteroid impact. For the asteroid to cause the level of devastation that has been recorded in the geologic record, it would have to have been approximately 10 km (6 miles) in diameter. The crater left by such an impact would be approximately 180 km, or 110 miles, across.

When the asteroid hit the planet, it sent ejecta (debris that is ejected during the formation of an impact crater) both into and through the atmosphere. As these ejecta settled, two things happened simultaneously. Large pieces of rocky material rained back into the atmosphere, becoming fireballs that would have heated the atmosphere and the surface of the planet to boiling temperatures. While this happened, a layer of dust settled in the upper atmosphere blocking all incoming sunlight for weeks to months.

Though this hypothesis may sound convincing, is there any evidence it actually happened? Yes. The primary

evidence that such an event took place in Earth's history was first uncovered by a group of geochemists led by Luis Alvarez of the University of California, Berkeley. What they discovered was a pervasive layer of clay that was rich in iridium. Iridium (Ir) is an element normally found only in trace amounts on Earth, but it is common in meteorites. The presence of iridium in a larger-than-expected amount in this one location in Earth's sediments tells scientists that something very unusual must have happened when the sediments were deposited.

Note: It is important for students to understand latitude and longitude before beginning this activity. Below is a quick introduction to this topic, if needed.

Latitude and longitude are lines that form an imaginary grid over the Earth, enabling us to locate geographic points exactly. Both latitude and longitude are measured in degrees (°). Latitude refers to distance either north or south of the equator. The "starting point" for latitude is the equator; the equator is 0°. The poles are the "end points" for latitude. The North Pole is 90° N, and the South Pole is 90° S. Longitude is used to locate points east and west. The reference point is the prime meridian, 0°. The prime meridian runs from the North Pole through the Greenwich Observatory in London to the South Pole. Points west of the prime meridian are measured between 0° and 180° W and points east of the prime meridian are measured between 0° and 180° E. The longitude line (or meridian) exactly opposite the prime meridian is the International Date Line and measures 180°. For more specific measurements, degrees can be broken down into 60 minutes per degree.

What to do

Part 1

1. Make sure that your students are familiar with latitude and longitude before beginning. If needed, go over the concepts briefly.
2. Ask students: What do you think caused the extinction of the dinosaurs? Have students write their answers on slips of paper and put them all in a box. Then choose a student volunteer to pick papers out of the box and read them to the class.
3. Have a brief discussion of the reasons suggested.

4. Ask students: Are meteorite impacts common on Earth? Discuss what the students think. Tell them that today they will investigate a number of impact craters. Like detectives, they will try to locate the one that may have caused the mass extinctions that included the dinosaurs.
5. Take students to the computer lab and hand out the student pages and charts. Have students work in groups to complete the exercises.
6. When everyone has completed their computer research, ask each group to present their findings to the rest of the class.
7. When all the presentations are finished, gather the class to take a look at the core replica or photo of the K/T Boundary and describe what they see.

Part 2

1. Hand out the Cretaceous-Tertiary Boundary Exercise and give students ample time to complete it, either alone or in groups.
2. When everyone finishes, gather the class for a discussion of their investigations and conclusions.

For Further Exploration

There are several very good websites for this topic. A short, starter list includes:

The Planetary Science Institute website, <http://www.psi.edu/projects/ktimpact/ktimpact.html>.

The NASA/UA Space Imagery Center website, http://www.lpl.arizona.edu/SIC/impact_cratering/Chicxulub/Chicx_title.html. (This link contains an animation of the processes associated with an impact event.)

The History Channel also has a DVD, "Meteor: Fire in the Sky", which discusses the events of 65 million years ago. It can be purchased online at <http://www.history.com>. Follow the links to the store.

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Student Page

Instructions

1. Use the internet to generate a list of possible impact craters.

<http://www.solarviews.com/eng/tercrate.htm>

following website has good information and links regarding the Chesapeake Bay.

<http://geology.rutgers.edu/chesapeakebay.shtml>

2. Complete the attached chart using the information you find.

3. Which crater(s) are of an appropriate age and size to have caused the mass extinction?

5. Use *Google Earth* to check out each impact structure. Use the “fact” buttons to gather information about each site. You can also rotate the picture to get a side view of the structure. (Note: Go to <http://www.thinklemon.com/pages/ge> and download the Google Earth files, and then open them into Google Earth. The file to use is *Impact Structures Top 25*. Each impact crater will have a little “fact” button except the *Chicxulub* and *Chesapeake Bay* craters. They are also the only craters that cannot really be seen from an aerial perspective.)

6. What do you see in these impact craters now?

4. The Chesapeake Bay in Virginia is also an impact crater. Could it be “the” crater? The

Impact Crater Information Chart

	Name of Crater	Location	Latitude and Longitude	Diameter	Age
1.					
2.					
3.					
4.					
5.					
6.					
7.					
8.					
9.					
10.					
11.					
12.					

Cretaceous-Tertiary Boundary Exercise

Cretaceous-Tertiary Mass Extinction

The fossil record indicates a major mass extinction at the end of the Cretaceous (Figure 1). Most famously, dinosaurs went extinct. Less known is the fact that many marine organisms and other terrestrial organisms also went extinct at that time. Furthermore, the pace of extinction was not uniform among all groups. Some groups saw dramatic rapid extinctions, some experienced more gradual extinctions, and other groups suffered both a gradual decline and a rapid final extinction pulse.

Unraveling the final events of the Cretaceous requires a geologic record (or set of records) that captures the full range of events, both before and after the mass extinctions. This requires a high-resolution sediment record to see the details. Appropriate records are generally only deposited and preserved in the ocean and obtained with scientific ocean drilling. Understanding the events at the end of the Cretaceous also requires a careful examination of the available data, including anomalous geochemical signals, unusual sedimentary features, and of course, the patterns of extinction. There are many possible explanations for the pattern, including volcanoes, meteors, and climate change. A meteor impact is currently the most widely accepted explanation. (The Cretaceous-Tertiary boundary is often referred to as the K/T boundary because K is the abbreviation for the Cretaceous and T is the abbreviation for the Tertiary.)

What evidence is there of a meteor impact? Scientists have found a layer of iridium-rich clay that occurs all over the world in the same stratigraphic location. It is this layer that forms the K/T boundary. Iridium is significant because it is a rare element in Earth's crust. There are, however, two places that iridium is abundant: meteorites and Earth's core. This layer could therefore be extra-terrestrial in origin, as is currently believed, or it could be the result of massive volcanic activity. The volcanic activity that formed the Deccan Traps deposits in India may have been responsible for the mass extinction at the K/T boundary. At the very least, they contributed to the extinction

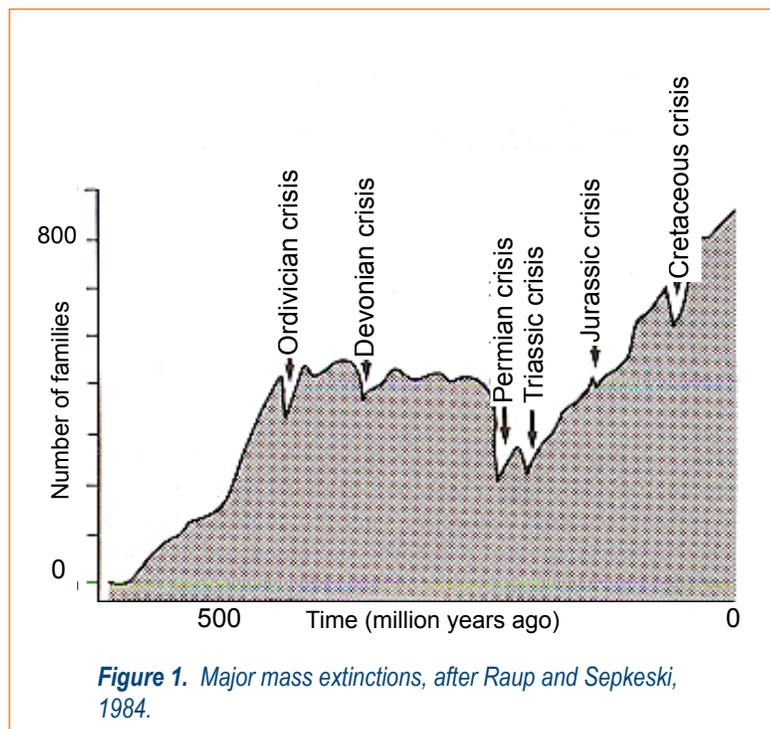


Figure 1. Major mass extinctions, after Raup and Sepkeski, 1984.

event. Data indicates that roughly two thirds of the Deccan Traps were formed in a short period of time (1 million years), about 65.5 million years ago.

Volcanic activity this extensive, like a meteorite impact, could have had a similar effect on the planet. Large volumes of dust would block incoming sunlight—dropping global temperatures and preventing photosynthesis from occurring. Once primary producers die out, there is less and less food available as you work your way up the food chain, causing more and more extinctions. Global firestorms would add to this process by releasing large quantities of carbon dioxide into the atmosphere. Tsunamis caused by the associated seismic activity would also have been devastating.

I. Location.

- Find the Yucatan peninsula on a map. Identify the longitude and latitude (degrees).
- Describe the shape of the Yucatan peninsula. Use a large map to determine if there are any other continental margin features of this shape on Earth. If so, where?



Figure 2. http://www.lpl.arizona.edu/SIC/impact_cratering/Chicxulub/Drilling_Project.html

- The most likely site of impact is on the Yucatan peninsula (Figure 2), near the town of Chicxulub. Unfortunately, millions of years of sedimentation have buried this structure. It is possible to determine what the crater looked like in the past (Figure 3). Look at Figure 4. Observe the continental margin in the region. Describe the changes in water depth with respect to horizontal distance.

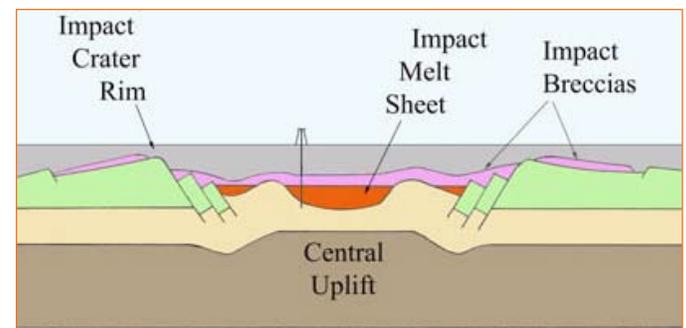


Figure 3. http://www.lpl.arizona.edu/SIC/impact_cratering/Chicxulub/Discovering_crater.html

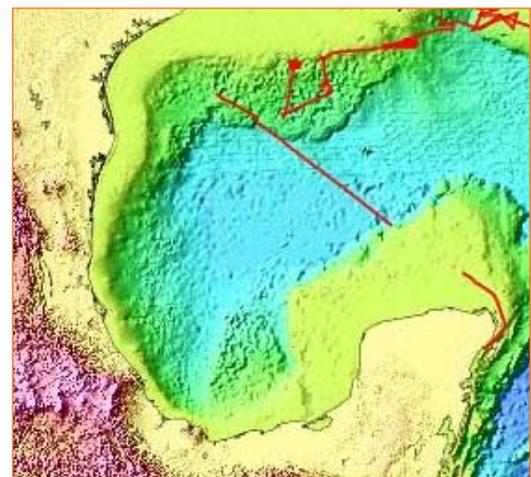


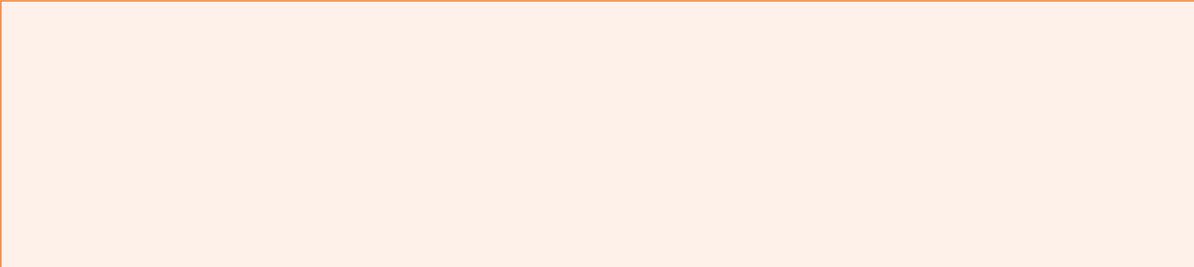
Figure 4. Gulf of Mexico bathymetry (U.S. Geological Survey, <http://walrus.wr.usgs.gov/infobank/gazette/html/bathymetry/gm.html>)

II. Core Replica

The core replica or photo you have in your class is part of a core recovered by the Ocean Drilling Program (ODP). It is a replica of a real core that is on display at the Smithsonian Institution.

- A. There are four distinct layers within the core, with gradual changes occurring in each layer. Look closely at the major changes you see. Describe each section in terms of color and texture, including grain size and shape. How does it change from the bottom to the top? What might those changes mean in terms of an impact? At what depth is the K/T boundary? Can you determine what the sequence of events at the impact might have been?
- B. Use the information gathered above to create a core log. Describe the core by entering appropriate information on the attached core description chart. Note differences in color, texture and layers, and at what depth from the top of the core they occur. Consider the top of the core to start at zero, and measure downward. Add notes to clarify your observations. Once you determine the total length of the core section, use the given increments to represent your core (you'll probably want to use one box for each 10 cm). Start at the top for zero, and work down. On your core log, note major changes in lithology (characteristics of the sediment). Draw in any changes that you observe.

Core Description Chart

Core Sketch	Depth (cm)	Lithology (sediment characteristics)	Notes
			

III. ODP Site 1049

Two cores were drilled by ODP through sediments that span the K/T boundary. One was recovered off the southeast U.S. coast at ODP Site 1049. Results from that expedition form the basis of an educational poster, *Blast from the Past*, produced by ODP and the Smithsonian (available online at <http://www.oceanleadership.org/posters/blastfromthepast>).

- A. Use a large map to identify the location of Site 1049 (shown to the right). Determine the distance (in km) from the impact site of the Chicxulub impact crater. Show your work.

Record it: _____ km.

What is the distance from the impact crater to where you live? _____ km.

Over 15 cm of debris rained down at this location. Consider the impact on your town. Would you expect a similar thickness of impact debris where you live?

- B. Drawing on class notes, list the evidence for a meteor impact at the end of the Cretaceous. This should include data additional to marine data (e.g., Ir anomaly, etc). Explain how they relate to a meteor impact.

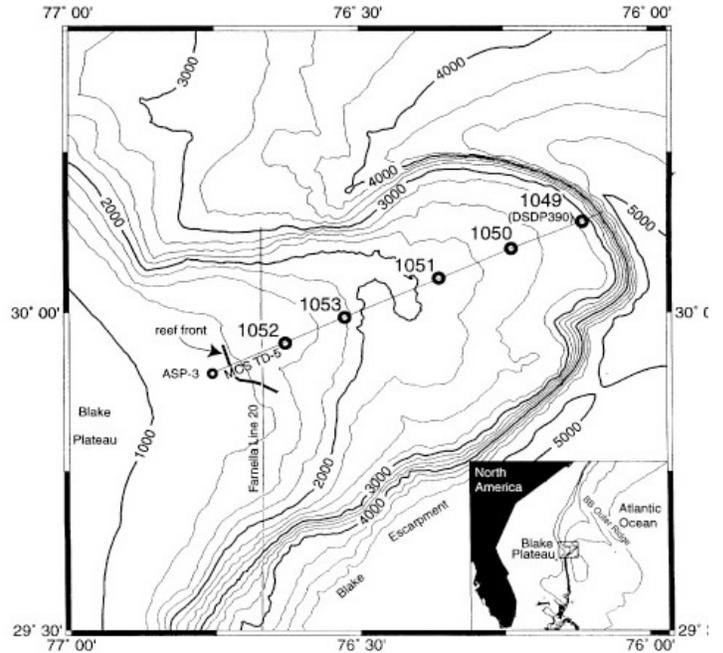


Figure 5. Location of Leg 171B Sites 1049 – 1052. After Norris et al., 2001.

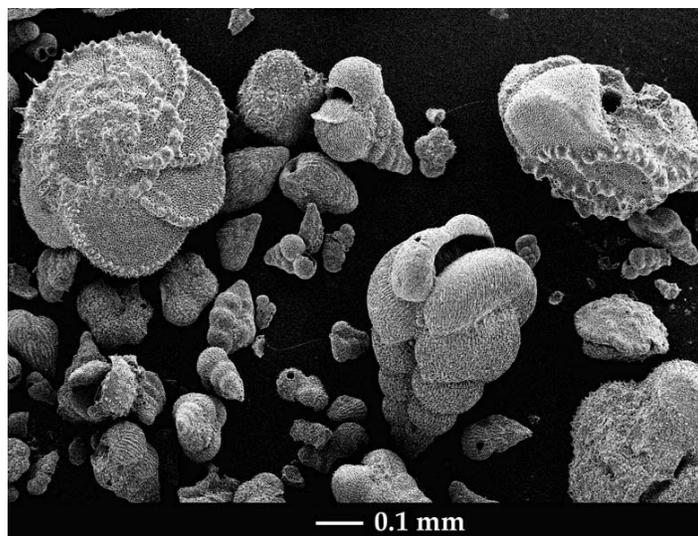
- C. Using the *Blast from the Past* poster as a guide, explain in a few paragraphs the sequence of events associated with the meteor impact, as recorded in the sediments of Site 1049. Be sure to include how the data (sediments) support the hypothesized impact.
- D. Are there any other explanations for the demise of the dinosaurs? If so, list them. Can any of them reconcile all the available data?

IV. Sediments

Plant-like and animal-like plankton live in the surface of the sea. Some produce calcareous and siliceous shells. The two major groups of calcareous microfossils (phytoplankton) are coccolithophores (calcareous nannofossils) and foraminifera (zooplankton). These accumulate in the deep sea after the organism dies. Vast regions of the ocean floor store thick deposits of planktonic shells of animals that once lived at the ocean's surface.

A. An average rate of deposition of these shells in the deep sea is approximately 2 cm/ k.y. Calculate the length of time represented by the interval of sediment below the debris layer. (Divide the length of the core by the average rate of sedimentation, or thickness/ rate = time). Refer to your core description. Show your work and don't forget to check your units.

B. Perform the same calculation for the debris interval. Knowing that deposition of this interval took one year or less, calculate a rate of sedimentation for the debris interval using a time of one year. How much time is represented by this interval? Show your work and don't forget to check your units.



Foraminifera present in the core prior to the impact event. Photo from ODP educational poster, Blast from the Past.