WEIGHING THE EVIDENCE FOR A MASS EXTINCTION
PART 1: IN THE OCEAN

INTRODUCTION

The boundary between the Cretaceous (K) and Tertiary (T) periods is marked by a layer of clay found all over the world that is extraordinarily rich in iridium—an element that is rare in Earth's crust but common in asteroids. This layer of clay was deposited about 66 million years ago, at the time of the mass extinction that wiped out the dinosaurs. Not a single dinosaur fossil has ever been found in rock layers above the K-T boundary. (Note that in 1989, the Tertiary period was replaced by the Paleogene and Neogene periods, and the K-T boundary is now typically referred to as the K-Pg boundary.)

Dinosaurs are not the only species that disappeared at the end of the Cretaceous period. More than 70 percent of marine species and 60 percent of land species went extinct. Among the organisms that went extinct in the ocean were species of microorganisms known as foraminifera. In this activity, you will examine the evidence for a mass extinction event 66 million years ago based on foraminifera fossils found in rock layers below and above the K-T boundary.

K-T boundary found near Gubbio, Italy. The figure to the right shows the K-T boundary (indicated by the position of the pen). It separates two geologic periods, the Cretaceous (K) and the Paleogene (Pg). The Paleogene used to be called the Tertiary (T) period. (Photo courtesy of Philippe Claeys.)

Meet the Forams

Foraminifera (or forams for short) are single-celled amoeboid protists, which are abundant in the ocean. An estimated 4,000 species of forams currently live in the ocean. Forams may live on the ocean floor (benthic forams) or float in the water column (planktonic forams). Most forams have an average size of 0.2 to 1 mm across.

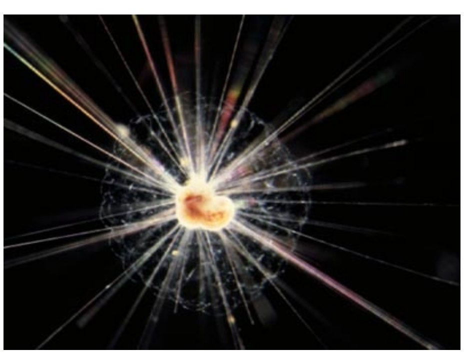

Photo of a living foram. The solid structure in the center is the foram cell, and the translucent structures radiating from the shell are the pseudopodia, used for locomotion and capturing food. (Photo courtesy of Dave Caron.)

Forams produce shells, known as tests, which are commonly divided into chambers that are added during growth. Tests, which are composed of either calcium carbonate or conglomerated grains of sand, surround the soft cell of the organism. As forams die, their tests settle to the bottom of the ocean and become part of the marine sediment.

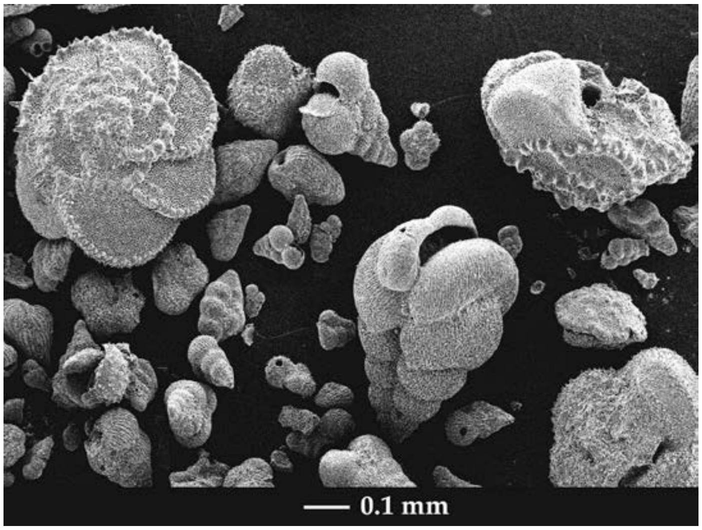

Photo of foram tests as seen through a scanning electron microscope. The morphology and sizes of these tests differ between species. (Photo courtesy of Brian Huber.)

Different foram species lived at different times throughout Earth's history, and as a result the abundance of specific fossil species is a useful marker for determining the age of particular rock layers.

MATERIALS

Each pair of students will need:

- Foraminifera cards
- Ruler
- Scissors

PROCEDURES AND QUESTIONS

Part 1: Observing and Measuring the Forams Near the K-T Boundary

You are a scientist studying forams and you have you excavated fossil forams just below and just above the K-T boundary from an ocean drilling site off the coast of Florida. The scanning electron microscope images on the cards are fossilized foram tests. Separate the cards into Cretaceous and Tertiary piles.

1. Which pile of cards represents the older forams?______________________________
2. Which pile of cards represents the younger forams? ______________________________

3. Notice that the scale bars on each of the cards is the same, so we can compare the sizes of the forams easily. Which foram species are generally larger: those from the Cretaceous period, just below the K-T boundary, or those present in the Tertiary period, just above the K-T boundary?

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4. The outward appearance, or morphology, of forams is highly variable. Other than the forams' sizes, describe other morphological features that are different between forams from the Cretaceous and Tertiary periods.

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5. In one or two sentences, summarize how forams differ across the K-T boundary. Refer to the observations you have made so far in questions 3 and 4.

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You would like to look at forams from other K-T boundary sites to see whether the differences you observed between the Cretaceous and Tertiary forams are also observed in other parts of the world. A colleague has extracted forams from just below and above the K-T boundary at a separate site and she has sent the images of four forams to you for you to analyze.

6. You realize that the images were taken at different magnifications, so you are unable to directly compare foram sizes by eye. However, you can calculate the exact size of the forams by using the scale bar. Follow the directions below for step-by-step instructions on how to calculate the foram size for Sample 1.

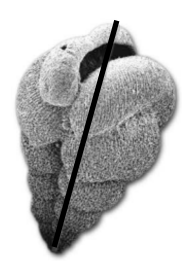
   a. Measure the foram's maximum length in centimeters (cm). The maximum length is the longest length of the foram (The bold line, drawn on the foram above, show the maximum length.) ________________

   b. Measure the scale bar in cm. This line represents 0.1millimeters (mm).

   ___________cm = 0.1mm

Sample 1

Cretaceous



Scale bar → ▬ 0.1mm

c. Calculate the conversion value. To do this, determine how many mm is equal to one centimeter.

Hint: To calculate how many mm equals one cm, you divide both sides of the equation by the length of the scale bar. For example, if the scale bar was 5cm in length (5cm = 0.1mm), you would divide by 5 on both sides of the equation ($\frac{5cm}{5} = \frac{0.1mm}{5}$) to have 1 cm = 0.02mm.

1cm = __________________mm

d. Calculate the exact size of the forams in mm. To do this, take the maximum length of the foram (answer in a) and multiply by the conversion factor (answer to c). What is the size of sample #1?_______________. Write the actual foram size in mm in Table 1 for sample 1.

e. Repeat this process for samples 2-4 shown below. Write the actual size of the forams in table 1.

Sample 2
Tertiary

Sample 3
Cretaceous

Sample 4
Tertiary

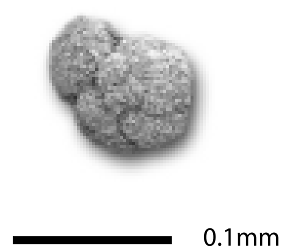


Table 1

Sample number	Age of rock where foram was found	Foram maximum length (cm)	Length of scale bar (cm)	Conversion value (mm/cm)	Actual foram size (mm)
1	Cretaceous				
2	Tertiary				
3	Cretaceous				
4	Tertiary				

7. Compare your foram samples (on the cards) to your colleague's. Write your observations of how forams differ across the K-T boundary. Provide specific measurements or calculations when appropriate.

My Samples (your original cards)	My Colleague's Samples (the ones you measured)

8. Complete the following statement:

   My samples are similar to my colleague's samples in that ______________________________

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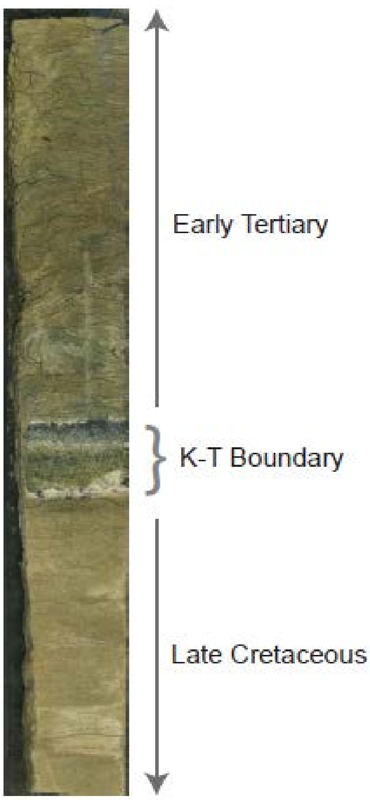
9. You decide you need more data in order to make a conclusion. You analyze 200 forams both at your site and your colleague's site from above and below the K-T boundary and your data is very similar to what you described above. You then analyze other five other sites scattered throughout the globe and also observe similar patterns. What conclusions can you draw from such observations?

Part 2: Analyzing Data on Forams Found Near the K-T Boundary

Figure 1 is a picture of a deep-sea sediment core collected from the North Atlantic Ocean. A core is an intact sample of sediment extracted from the ocean floor by drilling with a hollow drill stem. The unusual band in the middle is the K-T boundary. Scientists take small samples from sediment cores to make detailed observations and perform geochemical tests. In this case, core samples from below and above the K-T boundary were processed to separate out the forams for identification under a microscope. Figure 2 shows the foram species found in each sample. Each line in the figure represents a foram species. The Y-axis shows time, and the thick horizontal line represents the K-T boundary.

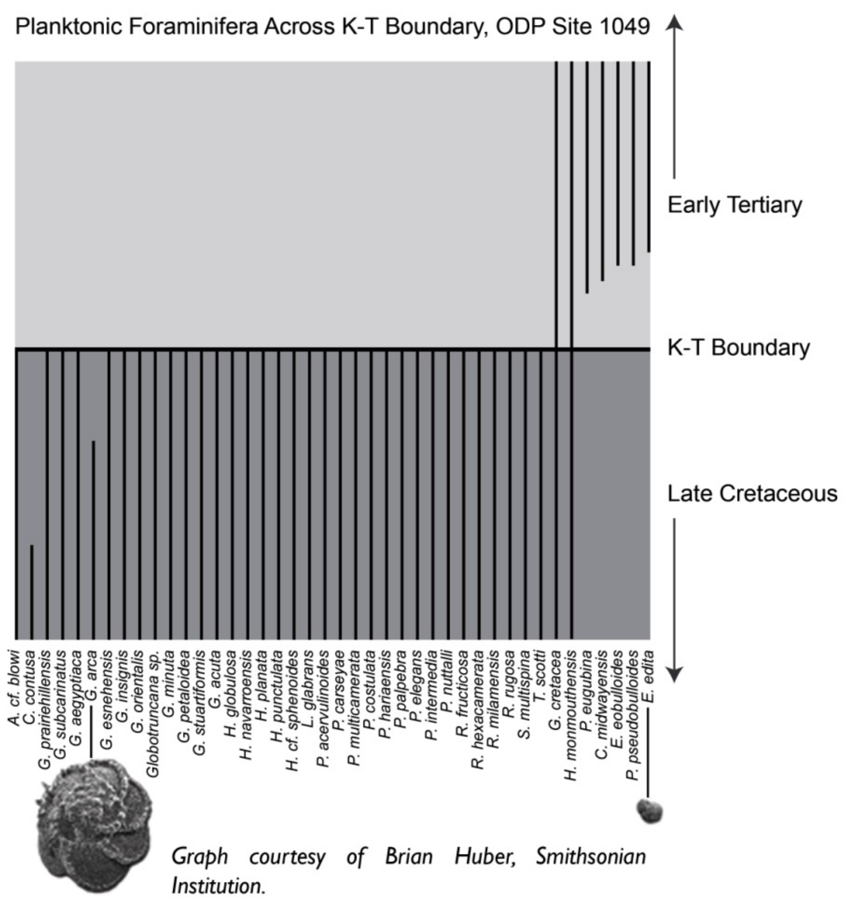
Use the information presented in Figure 2 to answer questions 7-13.

Figure 1



(Image courtesy of Brian Huber.)

Figure 2



Graph courtesy of Brian Huber, Smithsonian Institution.

10. How many foram species are represented in Figure 2? ____________________

11. a. Based on the figure, how many different species of Cretaceous forams appear to have gone extinct at the K-T boundary?

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b. Explain how you can tell from the figure that these foram species became extinct.

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12. a. How many species appear to have survived the K-T event?

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b. Explain how you can tell from the figure that these foram species survived.

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13. Calculate the percentage of forams that went extinct at the K-T boundary.______________________________

14. Calculate the percentage of forams that survived the K-T event.____________________________________

15. The graph shows that some species were found only in the Tertiary period and not in the Cretaceous period. What do you think these species represent?

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16. Based on the film, what event do scientists think caused the extinction of a large percentage of forams?

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Part 3: Size Matters

17. In Part 1, you looked at the differences in size between forams in the Cretaceous and Tertiary periods. Based on your data, were small or large forams more likely to survive after the K-T event?

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18. Why do you think size would make a difference in the ability of some species of forams to survive?

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19. The table below describes some differences between large and small forams.

Characteristics of Large Foraminifera	Characteristics of Small Foraminifera
Delayed maturation—in other words, it takes more time for a developing foram to reach the adult stage	Tend to mature quickly
Larger embryo size	Smaller embryos
It takes more time for the organism to reproduce	Reproduce more quickly
Tend to be specialized for a particular environment and food source	Tend to be "generalists," which means they can live in different environments
Morphologically more complex; sometimes larger forams have symbiotic relationships with other organisms such as algae	Less protected, less complex, and less likely to survive on an individual basis

(Source: Hallock, P. 1985. Why are larger foraminifera large? *Paleobiology* **11**: 195-208.)

Considering the information in the table above, explain how some of the characteristics of large and small foram species could have made them more likely to survive an extinction event? (Hint: An extinction event is usually triggered by rapid environmental change; organisms more likely to adapt more quickly tend to survive.)

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20. The images below are composite photographs showing forams to scale above and below the K-T boundary. Which image, the one on the right or the left, shows forams from below the K-T boundary? Support your answer with information from this activity and the film.

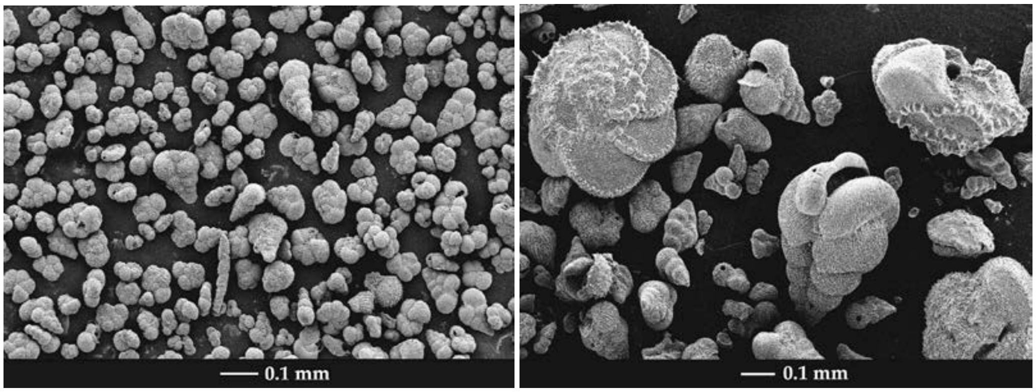

Image courtesy of Brian Huber

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21. Extinctions are a normal part of evolutionary history. The K-T extinction is considered to be one of five major mass extinction events in Earth's history. From what you have learned doing this activity and from the film, why is this considered to be a major mass extinction event?

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