FOLLOWING THE TRAIL OF EVIDENCE

OVERVIEW

This worksheet supports the HHMI short film *The Day the Mesozoic Died*. As students watch the film, they will write down the evidence that led to the discovery that an asteroid struck Earth about 66 million years ago, causing a mass extinction.

(Note: The film states that the mass extinction occurred 65 million years ago; that date was recently revised to 66 million years ago. Refer to the In-Depth Film Guide for more information.)

KEY CONCEPTS AND LEARNING OBJECTIVES

- Earth's 4.6-billion-year geological and biological history is deduced from the analysis of fossils, rocks, and chemical signatures found in sediments worldwide. The layered evidence reveals a pattern of change varying in tempo.
- Catastrophes have played an important role in evolutionary history. The mass extinctions that have occurred in the past 550 million years are examples of catastrophic change.

Students will be able to:

- understand the relationship between the geological time scale and the layered pattern of exposed rocks in the landscape—specifically, that deeper layers are older than layers closer to Earth's surface.
- identify the evidence that the K-T boundary marks a mass extinction event that coincides with an asteroid striking Earth 66 million years ago.
- gain an appreciation for the scientific process, which consists of asking questions, making observations, formulating hypotheses, and gathering and evaluating evidence.
- understand that scientists draw conclusions based on multiple lines of evidence and hypotheses from a range of scientific disciplines.
- appreciate that in the earth science field, scientists don't typically conduct experiments to test hypotheses; instead, they gather evidence to either confirm or refute hypotheses.

CURRICULUM CONNECTIONS

Curriculum	Standards
NGSS (April 2013)	MS-PS3.C, MS-LS2.C, MS-LS4.A, MS-LS4.C, MS-ESS1.C, MS-ESS2.A, HS-LS2.B, HS-LS2.C, HS-LS4.C, HS-LS4.D, HS-ESS1.C, HS-ESS2.A, HS-ESS2.E, HS-PS1.C,
Common Core (2010)	CCSS.ELA-Literacy.RST.6-8.1, CCSS.ELA-Literacy.RST.6-8.2, CCSS.ELA-Literacy.RST.6-8.4, CCSS.ELA-Literacy.RST.6-8.8, CCSS.ELA-Literacy.RST.9-12.1,CCSS.ELA-Literacy.RST.9-12.2, CCSS.ELA-Literacy.RST.9-12.4, CCSS.ELA-Literacy.RST.9-12.8
AP Biology (2012-13)	4.B.4, 1.C.1, SP5
IB Biology (2009)	5.1, 5.4.8, D.2.7, D.2.9, D.1.3, G.2.6, G.2.7

KEY TERMS

evidence, hypothesis, theory, Cretaceous, Tertiary, iridium, asteroid, meteorite, supernova, foraminifera, pollen, spores, extinction, fossil, sediment

TIME REQUIREMENT

This activity requires two 50-minute class periods.

SUGGESTED AUDIENCE

This activity is appropriate for middle school earth and life sciences and high school biology, earth science, chemistry, and physics (all levels including AP and IB).

PRIOR KNOWLEDGE

Students should be familiar with hypothesis testing and the difference between a fact and an opinion. They should also know what a fossil is and understand that older fossils are found in deeper rock layers than younger fossils. They should be aware of Earth's geological time scale and its relationship to the relative timing of past events.

MATERIALS

Students will need the student version of this activity. Note that there are two versions of the student handout, one with extra support for taking notes.

TEACHING TIPS

- Show students a poster of Earth's geologic time scale (for example, the poster "Earth Evolution: The Intersection of Geology and Biology," available at http://www.hhmi.org/biointeractive/posters/2012%20Changing%20Planet.jpg). Point out the Mesozoic era and the Cretaceous period. Explain that the Mesozoic is often referred to as the Age of Reptiles, including dinosaurs.
- Discuss the following questions with your students:
  - What do you think caused the extinction of the dinosaurs and how do you know?
  - Were dinosaurs the only species to become extinct at the end of the Cretaceous period?
  - How can scientists determine what Earth was like millions of years ago?.
- Give students the accompanying worksheet; note that there are two versions. The second version provides more guidance on taking notes. Explain that as they watch each act of the film, they should be paying attention to the key scientific evidence uncovered by the scientists featured in the film about what led to the extinction of the dinosaurs and many other species at the end of the Cretaceous period.
- At the end of each act, students should pair up (or work in small groups) to write down the evidence presented in that act and what the evidence means in the table provided in their worksheet. To give students a better idea of what they should write down, the evidence presented at the beginning of the film has already been entered in the worksheet. Spend a couple of minutes reviewing that evidence.
- You may want to ask your students to record some information—such as, locations, dates, chemicals, and fields of study—on scrap paper as they watch the film. These notes will serve as reminders when working in small groups at the end of each act.
- After students have had time to compare and discuss their lists, ask some of the groups to share one or two pieces of evidence they recorded. Ask the class to determine whether these examples represent a scientific fact or an opinion.
- At the end of the film, lead a class discussion on which facts provided key clues for or against the asteroid-impact hypothesis.
- After this discussion, students should complete their worksheets.

ANSWER KEY

(This is an example of a completed table. Students' responses will vary.)

EVIDENCE PRESENTED	WHAT THE EVIDENCE SUGGESTS
Forams were large and diverse in the Cretaceous period, but at the start of the Tertiary period, most foram species went extinct.	**There was a mass extinction of forams; this mass extinction happened at the same time as the dinosaur extinction.** **With the forams gone, the base of the food chain was gone.**
The change in foram fossils occurred 65 million years ago, the same time as the dinosaurs disappeared.	**Extinctions documented in the fossil record line up exactly with the K-T boundary.**
The change in foram fossils was observed at two different locations more than 1,000 km apart.	**The foram extinction was widespread rather than a local event.**
The K-T boundary at Gubbio had 30 times more iridium	**The amount of iridium is low in Earth's crust but high in**

than is found in Earth's crust; iridium was found at the K-T boundary all over the world.	**asteroids; the iridium in the K-T boundary might have come from outer space, maybe from an asteroid or supernova.**
There was no plutonium-244 in the K-T layer.	**A supernova would have released plutonium-244; since this isotope of plutonium was not found in the K-T layer, a supernova explosion cannot explain the iridium.**
The K-T layer contains glasslike beads, called spherules, that form when vaporized rock cools and falls back down to Earth.	**Something happened that generated immense heat, enough to melt rock into glass.**
The K-T layer also contains shocked quartz, which is rock shocked by an explosion or impact.	**Shock waves from the impact caused deformations in quartz (shocked quartz).**
The amount of iridium in the K-T boundary suggests that the asteroid was 10 km in diameter.	**An asteroid this size would have caused a huge amount of destruction.**
The Cretaceous mud is very uniform up to the K-T boundary.	**The world was in a steady state up to the K-T event.**
In Texas, scientists found boulders and other large rocks that came from different places.	**Tsunamis scoured the bottom of the ocean and redeposited the material; the asteroid probably hit in the ocean.**
In Haiti, scientists found tektites, which are melted rock.	**Finding tektites in Haiti told the scientists the crater was probably near the Gulf of Mexico.**
There are abnormal gravitational fields near Chicxulub; this site is also full of shocked quartz.	**This is the crater that formed when the asteroid hit Earth 65 million years ago.**
The rocks at this site are 65 million years old. The abnormal gravitational field matches a crater about 200 km in diameter.	**The age and size of the crater match what Alvarez predicted.**
In the Hell Creek formation, scientists find dinosaur bones up to the K-T boundary but never after; the bones suggest that different species of dinosaurs lived there.	**Many species of dinosaurs lived in the Cretaceous and then went extinct.**
The rocks where the crater is contain lots of sulfur.	**Sulfur and other debris could have shot up in the air, blocking the sun.**
Fossil pollen from the Cretaceous represents many different species; about 60% of plant species disappeared at the K-T boundary.	**About 60% of species went extinct at the K-T boundary.**
After the K-T boundary, scientists find mostly fern spores.	**Ferns were the first plants to repopulate the devastated planet.**
After the K-T boundary, scientists find fossils of smaller animals that lived in holes	**The survivors were small animals; many mammals were killed but enough survived to repopulate the planet.**
SCIENTIFIC DISCIPLINES MENTIONED IN THE FILM **Students may mention any of the following: geology, physics, chemistry, astronomy, paleontology, biology, botany.**	

QUESTIONS

1. *What piece of evidence initially convinced Dr. Alvarez that a mass extinction had occurred at the K-T boundary?*

There were many different foram fossils below the boundary between the Cretaceous and Tertiary periods and fewer above the boundary, which means that the boundary marks the time of the mass extinction.

2. *What was the first clue that an asteroid had struck Earth at around the same time as the mass extinction?*

They found a high concentration of iridium, an element rare in Earth's crust but abundant in asteroids, at the boundary between the Cretaceous and Tertiary periods.

3. *What additional observations and findings supported the asteroid-impact hypothesis?*

Scientists have found glass spherules, shocked quartz, and tektites in the K-T layer. These findings are consistent with a collision or explosion that generated an immense amount of heat and high-energy shock waves. Near the Gulf of Mexico, scientists have found tsunami deposits. Scientists have found a 200-km-diameter crater in the Yucatán peninsula that matches the age and predicted size of the asteroid.

4. *Which piece of evidence definitely showed that an asteroid had struck Earth? Explain your answer.*

The crater at Chicxulub was the smoking gun. Finding a crater that matched the age and size of the asteroid provided direct evidence for the impact. All the other evidence before was indirect.

5. *How does the asteroid-impact hypothesis explain the extinction of the dinosaurs and other species?*

A strike by a 10-km asteroid would have caused tons of dust and debris to be blown into the atmosphere, blocking the sun for many years. Photosynthesis would have stopped, resulting in the death of plants and eventually animals.

6. *Provide two or more examples from the film that illustrate how scientists use multiple lines of evidence and a range of disciplines to draw conclusions.*

- **A geologist discovered the K-T boundary and noticed the differences in foraminifera populations.**
- **Paleontologists analyzed and interpreted changes in fossils of foraminifera, dinosaurs, and other species below, at, and above the boundary.**
- **Physicists measured iridium levels in Earth's crust and at the K-T boundary.**
- **Astronomers suggested that a supernova or an asteroid could have been responsible for the high iridium levels found at the K-T boundary.**
- **Botanists were involved in explaining the changes in plant populations and breakdown of food chains**

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