# Meteorites Objects Cart

## Brief Summary

The Meteorites Object Cart provides visitors with the opportunity to explore real objects related to the impacts of meteorites on the Earth, including:

1. Meteorites – Pieces and bits of space material found on the surface of the Earth or another planet.
2. K-T boundary sedimentary sample – An education collection sample showing the relationship between an asteroid impact 65 million years ago and the extinction of the dinosaurs.
3. Replicas of meteorites.
4. Rocks and glass from areas of meteorite impact.
5. Meteor-wrongs – earth rocks that are very similar to meteorites.

## Equipment Required

- Meteorite object cart.
- Meteorites Cart Key (located in 2003 Demo Storage Room)
- Collection samples
- Magnet (located on cart)
- Magnifying glass (located on cart)
- Flashlight (located on cart)

## Educational Strategies

These real objects allow people to actually see and touch material that came from space. Use this firsthand experience as a jumping off point to talk about larger concepts.

## Main Teaching Points

- Meteorites are objects from space that have survived the trip through Earth's atmosphere and landed on the surface.
- Meteorites are shaped/deformed by the trip through Earth's atmosphere.
- Meteorites are often heavy for their size as almost all of them contain metal.
- When meteorites strike the earth they create features called craters.
- The specimens on the cart are both "impactors" and "impactees"--either bits of the asteroids that make the craters or bits from the sides or the bottoms of the craters. The impactors are rocks from space; the impactees are Earth rocks. The enormous stresses of actual impacts can be seen in the melted glass and accordion-like lines on the samples.
- Many scientists think an asteroid impact on the Earth contributed to the extinction of the dinosaurs.
  - Evidence for this is in a thin layer of clay mixed with Iridium and shocked quartz. This layer is found the world over. Iridium is a heavy metal which is not common on the surface of the Earth but is common in asteroids. Shocked Quartz is quartz that has been subject to intense pressure and as a result is fractured and then recrystalized. Shocked Quartz is only found at nuclear blast sites and impact craters. The presence

of these two features indicates an extraterrestrial origin. (For a more detailed discussion of iridium and shocked quartz see page 5 of this handout.)

- Study of meteorites is invaluable to scientists to help them understand the origins of the Solar System.

## Enriching Teaching Points

- The difference between an asteroid, meteoroid, meteor, meteorite & shooting star.
  - Asteroid – a large rocky body in our inner solar system in orbit around the sun
  - Meteoroid – a much smaller rocky body in our inner solar system.
  - Meteor – Material from space that has hit our atmosphere and, thanks to the friction of the atmosphere, begins to burn up and appears as a streak of light.
  - Shooting Star – another term for a meteor, but a misleading term as it is not a star. When people see a "shooting star" they typically are seeing a meteor about the size of a grain of rice burn up in the atmosphere.
  - Meteorite – a small rocky body from space that has survived the trip through the atmosphere and landed on the surface.
- Some meteorites are among the oldest objects in the solar system. Carbonaceous Chondrites have been dated to 4.6 billion years old, and they were around before the Sun lit up. The oldest rock on Earth is only about 4 billion years old.
- Meteorites may vary in size from tiny grains to large boulders. One of the largest meteorites found on Earth is the Hoba meteorite from southwest Africa, which weighs roughly 54,000 kg (119,000 pounds). *(from solarsystem.nasa.gov)*

## Set Up

- Get the cart out of the storage closet
- Unlock the bottom cupboard
- Get out a few of the objects, place them on top of cart, on shelves.

## Suggested ways of presenting touch cart

- Have guests try to figure out which of the objects are meteorites and which are rocks from Earth. They can explore this by using a magnet to see which ones are magnetic (more likely to be a meteorite, but our meteor-wrong is also slightly magnetic), looking at them through the magnifying glass, feeling which ones are heavy for their size (with your assistance), etc.

## Operating Tips

- If the gallery gets busy, you may choose to put out fewer items on the touch cart
- If you are facing challenges with visitors handling yellow touch items, you can keep them out of reach on the shelf, and bring them out only when you feel comfortable using them.

## Object Descriptions (see separate list)

## Questions and Answers

**Where did the Museum get this stuff?**
The objects on this cart were purchased from other collectors for use in at the Museum.

**Is the Earth endangered by the possibility of a doomsday meteor hitting us?**
Not in the near future. We know of a handful of really large (miles in diameter) “Near Earth Objects” that one day could hit Earth. However, these objects are being tracked and no one is forecasting a collision with Earth. There are also billions of smaller objects that cannot be seen until they are very near Earth because they are dark in color and small. Objects such as these (meters in diameter, the size a school bus) strike Earth about once a century. A stony body struck an isolated area of Siberia in 1908 and flattened a forest the size of a county. No one was killed only because of the lack of population in the region. Though fireballs of this size (15 kilotons) are not rare, they are no more destructive than a volcanic eruption, and would have only local effects.

**Has anyone ever been hit by a meteorite?**
Being hit by a meteorite is rare. However, there are a few instances: In Nakhla, Egypt (1911) a shower of stones allegedly killed a dog. And in 1954 a woman was severely bruised by an eight pound stony meteorite that crashed through the roof of her home in Alabama. *(from solarsystem.nasa.gov)*

## Fast Facts

- A widely held theory states that the Moon was formed when Earth was hit by a Mars-sized planetoid over 4 billion years ago. The planetoid contributed to the Earth’s metallic core and the Moon formed from the mass of lighter material that was flung into space and gathered into a spherical body by the force of gravity.
- Hundreds of mapped “astromblemes” (meteor scars) have been mapped across the Earth, some more than 100 km in diameter.
- Why should there be fewer visible craters on Earth than on the Moon or Mars? (there are at least 2 main reasons.)
- The mass of the Earth is increasing daily because of the addition of meteor dust and meteorites.
- There are meteorites on other planets. The Martian rovers Opportunity and Curiosity have both found meteors on the surface of Mars.

## Take down procedure

- Put all of the objects back into the bottom cupboard of the cart.
- Lock the bottom cupboard
- Return the cart to its place in the storage closet.

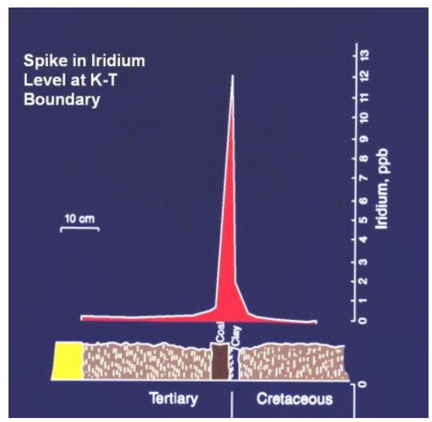
# Additional Science Content

## The Cretaceous-Tertiary Boundary Extinctions of 65.5 mya

*A reproduction of a portion of the K-T boundary near Denver in Prehistoric Journey*

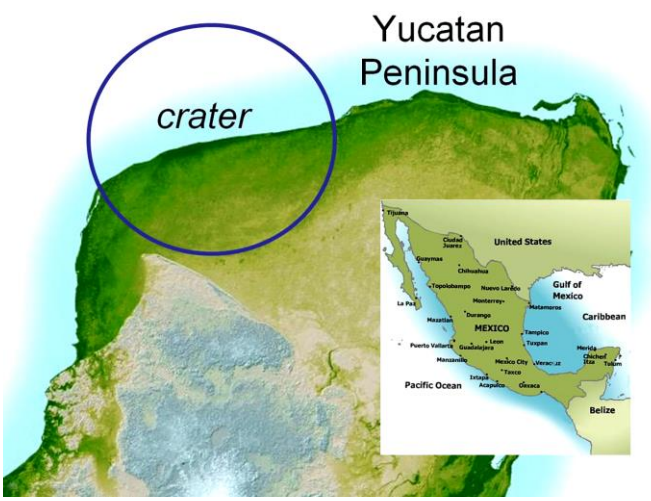
No other event in earth's history has evoked as much speculation as the extinction of the dinosaurs. The end of the Cretaceous period, about 65 million years ago, is marked not only by the extinction of the dinosaurs but also by the demise of flying reptiles and most of the marine reptiles, all of the ammonites and baculites, many North American land plants and marsupials, and a great percentage of plankton in the world's oceans. Whatever killed the dinosaurs must haw been pervasive enough to affect all these life forms.

The end of the Cretaceous is known as the Cretaceous-Tertiary, or K-T, boundary (K for *Kreide,* which is German for chalk), the literal physical boundary between rocks deposited in the Cretaceous period and younger ones deposited in the Tertiary period. Studies of the K - T boundary were greatly accelerated in 1980 when a group of University of California scientists led by Walter and Luis Alvarez discovered an unusually high abundance of the metal iridium at the K-T boundary in Italy, Denmark, and New Zealand. Because iridium is a rare substance on the earth's surface but common in meteorites, they proposed that this particular anomaly was caused by the impact of a six-mile-wide asteroid. The headlines in the popular press blared: "An asteroid killed the dinosaurs!" This proposal landed on the unprepared and unreceptive ears of the scientific community. To paleontologists, it seemed like science according to the tabloid press.




*Graph of iridium, peak at K-T boundary*

But the theory could be tested: Was the iridium anomaly located precisely at the K - T boundary? Could it be found at many places on the globe? Were dinosaur fossils found above it? How were other organisms affected? Was there other physical evidence of an extraterrestrial impact? Where was the crater?




*Location of impact 65 mya*

These questions provoked a massive surge of K - T boundary research. Opposing the theory were scientists who felt that earthbound volcanism was a more likely source of the iridium. To support their claims they pointed to the Deccan Traps, a massive deposit of lava that flowed out of the earth in what is now western India in the late Cretaceous.

Paleontologists were also reluctant to accept the new villain, but it became clear that many had not looked very closely at the time resolution of the fossil record.

Although the K - T boundary is still cause for heated discussion, several major discoveries in the 1980s support the asteroid-impact hypothesis. The iridium-bearing layer has now been found at more than 100 sites scattered around the world, and the boundary layer has been shown to contain shocked mineral grains of a type typically found in asteroid impact craters and nuclear test sites. In 1991, Alan Hildebrand, a Canadian geologist, rediscovered a giant buried-impact crater in late Cretaceous rocks on Mexico's Yucatan peninsula. The crater was originally found in 1981 but somehow escaped the eye of science until 1991. Clearly, an explosive impact had occurred, but was it the cause of the extinctions?

*Fossil pollen from the late Cretaceous*

In the years since the asteroid theory was proposed, many paleontologists have undertaken detailed studies of fossils across the K- T boundary to see if the iridium-bearing layer occurs at the exact level of the extinctions. The most precise results can be achieved from microfossils because they are so small and abundant. A single teaspoon of sediment can yield thousands of specimens. Early results from studies of microscopic fossil pollen and spores in land deposits and fossil plankton in marine deposits showed an incredible coincidence of iridium enrichment and extinction. Robert Tschudy, a palynologist from the U. S. Geological Survey, discovered that fern spores represented almost the entire flora just above the iridium layer and suggested that the high abundance of ferns was due to their rapid colonization of the world after it had been devastated by the aftereffects of an asteroid impact. He recalled scientific studies of how plants had recolonized the Indonesian volcanic island of Krakatau in the years after it had erupted in 1883 and killed everything on it. Ferns were the first plants to colonize Krakatau, and for many years after the eruption, only ferns grew there.

Detailed studies of ammonite extinction by Peter Ward of the University of Washington and of land plants by Kirk Johnson of the Denver Museum of Nature & Science have confirmed that the extinctions were abrupt and coincident with the iridium layer. Many vertebrate paleontologists have been reluctant to accept an extraterrestrial executioner. And although no studies have shown that dinosaurs survived the K - T impact, many scientists still argue that dinosaurs were declining before the impact and suffered a less dramatic fate. The widespread nature of the biological catastrophe, the abrupt disappearance of the Hell Creek dinosaur fauna, and the ubiquitous presence of the iridium anomaly seem to be strong arguments for an extraterrestrial end to the age of reptiles. With the large dinosaurs removed, the stage was set for the age of mammals and the rise of the modern world.

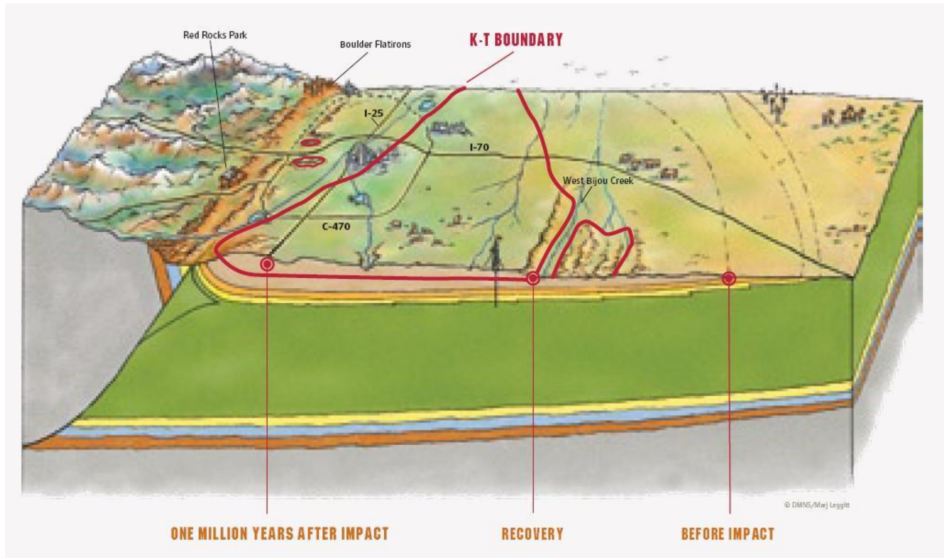
## DMNS Research & the K-T Boundary

*Painting of the moment 65 mya when a 6 mile wide meteorite smashed in to the Yucatan Region*

When a giant asteroid hit Earth on the northern edge of the Yucatan Peninsula 65 million years ago, it triggered an immense shockwave and massive firestorm. Debris from the impact, ejected into the atmosphere, blocked the sun for years, altering ecosystems around the world. More than half of all land and marine species, including dinosaurs, did not survive. When the dust settled back to Earth, it became a record of the impact, a thin layer of pulverized debris only a few millimeters thick settled into in the mud at the bottom of lakes and ponds. This thin layer was eventually buried and became the K-T boundary.

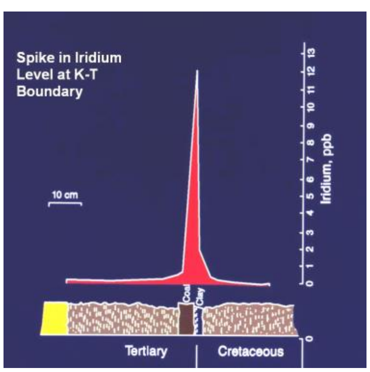
Paleontologists at the Denver Museum of Nature and Science have been working to uncover the story of an entire ecosystem lost in a flash, and what happened afterwards. The rock layers and fossils under Denver provide an excellent record of the Cretaceous-Tertiary mass extinction.

*The dark line shows where you can see the K-T layer exposed. Denver is unique in the world because it is surrounded by the K-T boundary.*

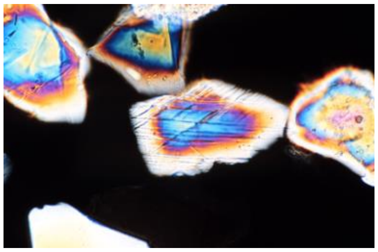



*DMNS Curator Kirk Johnson (front) examines a section of the K-T Boundary near Denver with collaborator Ray Troll (rear).*

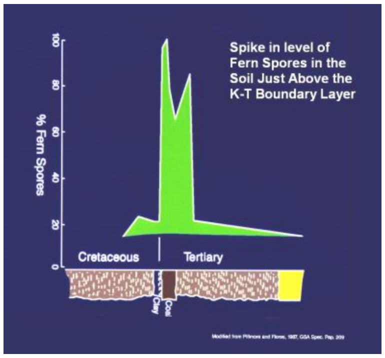
Here is some of the evidence for the large meteorite impact gathered by DMNS curators:



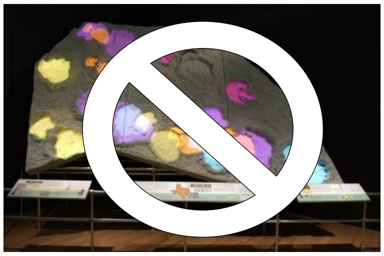

**Iridium spike.** This graph shows a sudden sharp rise in the amount of the trace element iridium in the soil at the K-T boundary layer. Iridium is a rare metal on earth, similar to silver, but more valuable. It is common in asteroids but rare at Earth's surface. The iridium spike indicates a sudden widespread release of this rare element.



**Grains of shocked quartz.** This picture shows a microscope view of grains of quartz that have been fractured and re-crystallized after an intense shockwave of the kind produced at nuclear blast or huge meteor impact sites. These grains were found in the soil level of the K-T boundary, but not above or below it.




**Fern Spike** just above the K-T boundary. This graph shows a sudden sharp increase in the number of fern spores in the soil. After a disaster such as a forest fire or a landslide, ferns are first “pioneer species” to colonize deforested landscapes. In this case the almost-empty landscape provided a excellent environment for ferns to grow in.



**No more dinosaurs.** Dinosaur trackways and fossils are not found above the K-T boundary (except for birds!)

**What the Denver region looked like before and after the impact:**


**Before impact:** The Denver region is a lush, swampy forest. The average temperature was ten degrees Fahrenheit warmer than today with high rainfall and humidity. Dinosaurs browse on broadleaf trees, palms and cycads, tropical species that thrived here. The impact decimated this forest.

**Recovery:** Within a few years after impact, some trees have come back, but ferns, a pioneer species, dominate the landscape everywhere. This bloom of ferns was responsible for the sudden sharp rise in fern spore abundance in the younger soil immediately above the K-T boundary. At west Bijou Creek, east of Denver, a river cuts through the layers of this environment. In this warm tropical climate, alligators (one of the impact survivors) infest creeks. The older soil just below the fern-spore enriched layer contains pulverized asteroid debris marking the exact position of the K-T boundary.

**One million years after impact:** The oldest-known broadleaf rainforests thrive along the foothills of the Front Range near Denver. Their amazing diversity was previously thought to have taken 10 million years to develop following the impact, though fossil leaves collected by DMNS curators shows that it took only about one million years.

## Background materials (websites, videos, articles, digital collections links, etc.)

- http://neo.jpl.nasa.gov/ -- NASA Near-Earth Objects site; includes related link listing
- http://www.jpl.nasa.gov/asteroidwatch/ -- NASA asteroid watch site
- http://www.imo.net/ -- International Meteor Organization site
- http://www.solarviews.com/eng/tercrate.htm - Terrestrial Impact Craters: This site has a great article on the formation of craters. Also has many pictures and interpretation
- http://www.meteorcrater.com Meteor Crater in Arizona
- http://news.nationalgeographic.com/news/2013/13/130214-biggest-asteroid-impacts-meteorites-space-2012da14/ -- National Geographic article
- http://geology.com/meteor-impact-craters.shtml -- map of known meteor craters on Earth
- http://www.nasa.gov/larc/astronomical-impact-in-the-chesapeake-bay/#.VCHUnGNCwUM – NASA site about35-million year-old crater found in Chesapeake Bay
- http://antwrp.gsfc.nasa.gov/apod/ap960604.html Image of crater thought to have been left by meteorite 65 million years ago