
INTO THE CRATER OF DOOM
Science and Discovery on the Chicxulub Impact Crater Expedition
Words By: KEVIN KURTZ - Pictures By: ALICE FEAGAN


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One day, long ago, the world was changed forever. An asteroid wider than our tallest mountain crashed into the Earth. It triggered disasters, destruction, and a mass extinction.


Today, the impact's devastation lies hidden under 66 million years of rock layers. People walked over its buried crater for centuries without knowing it was there. We knew from fossils that dinosaurs once existed, but, for a long time, no one knew why they disappeared.

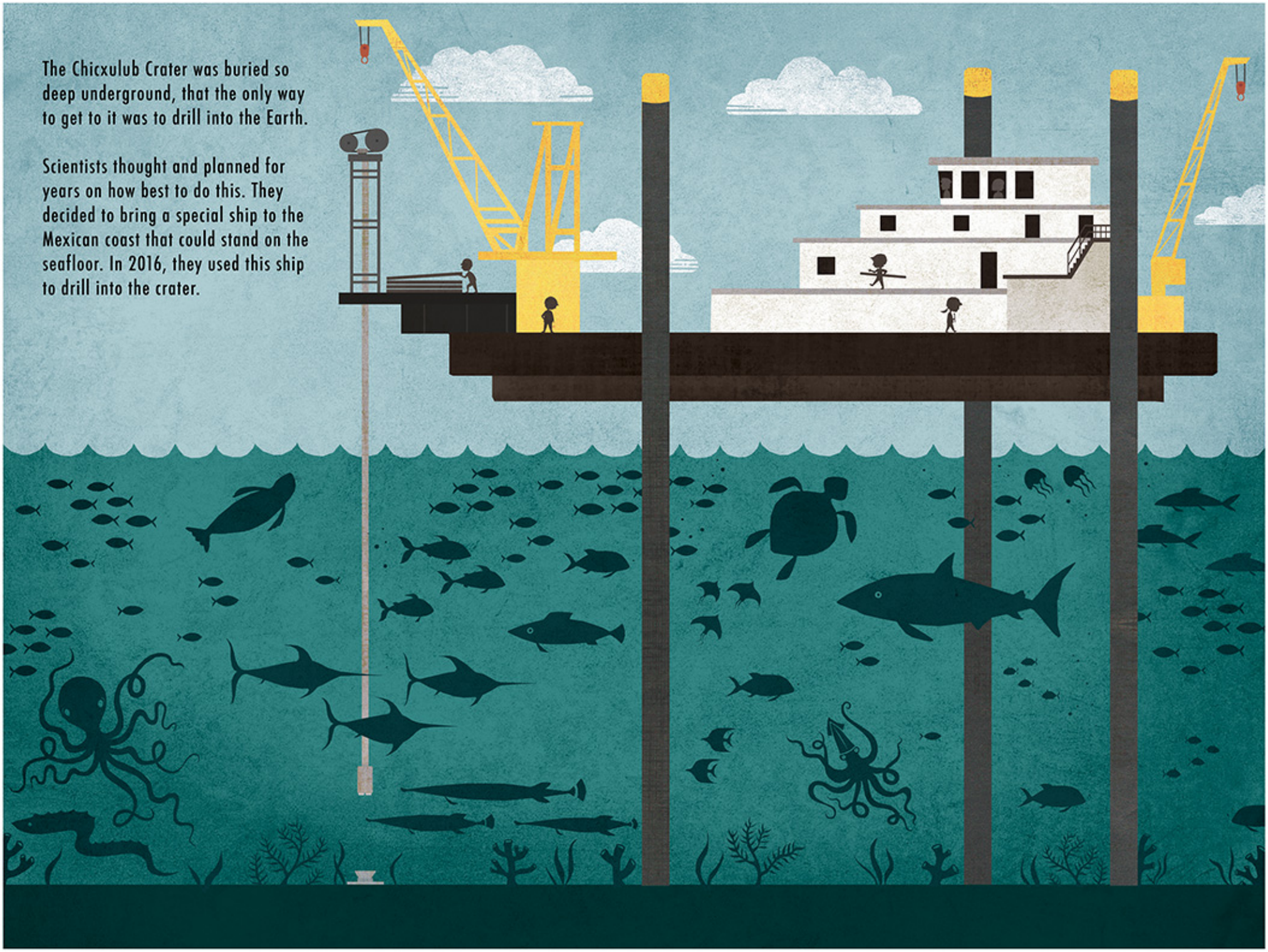
But the clues were there. Scientists noticed an unusual rock layer was always above the dinosaur fossils. This layer contained unusually high amounts of a metal called iridium. Iridium is common in other places in the Solar System, but not on the surface of the Earth. Scientists wondered, "Maybe the dinosaurs were killed by something from outer space?"

These scientists guessed the culprit was a comet or an asteroid. But to support their hypothesis, they had to find the crater.

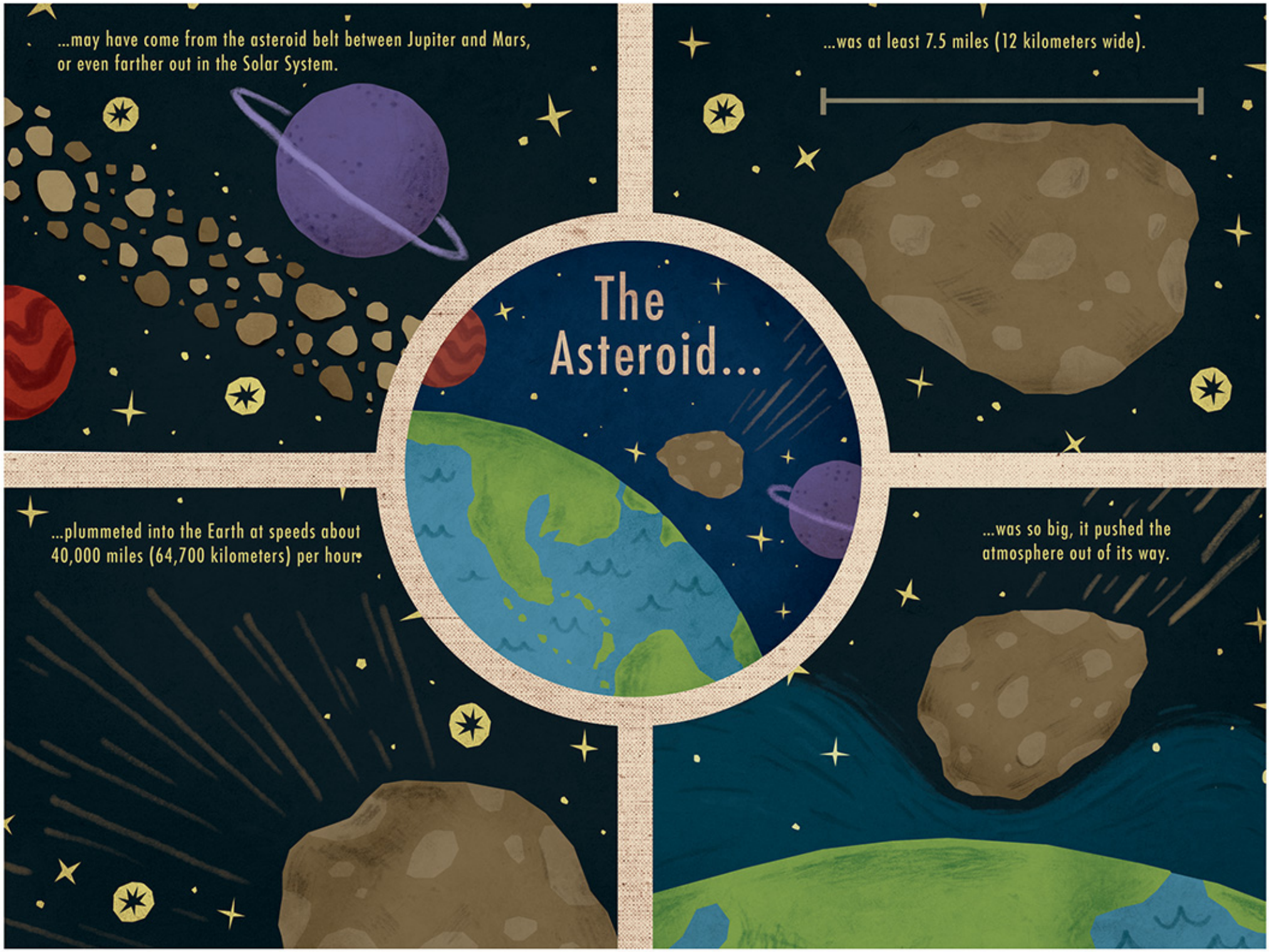
Scientists scoured the Earth for over a decade. Then, in 1990, they found it, buried, half under the Yucatan Peninsula and half under the Gulf of Mexico. They named it the Chicxulub Crater.

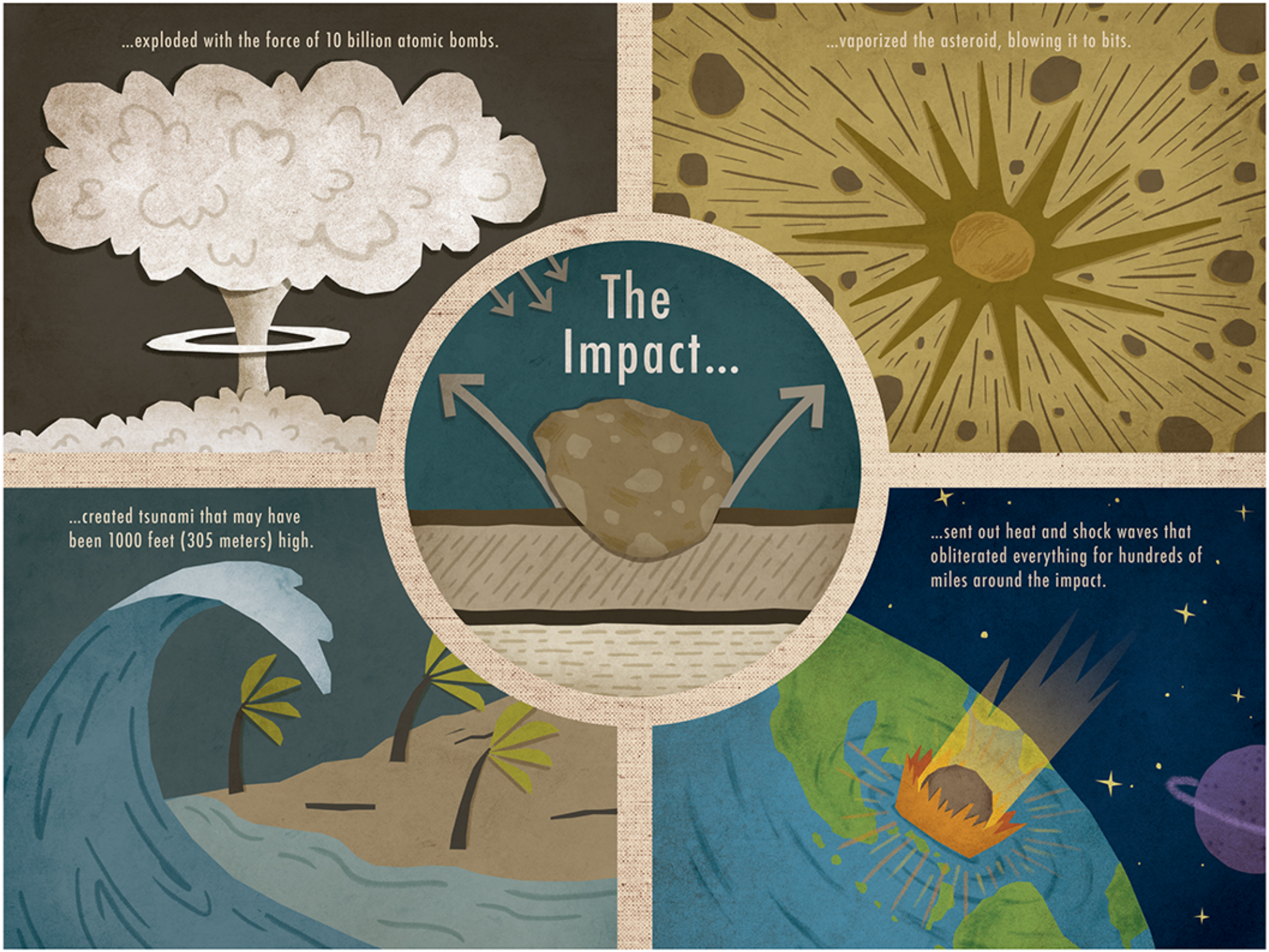
The Chicxulub Crater was buried so deep underground, that the only way to get to it was to drill into the Earth.

Scientists thought and planned for years on how best to do this. They decided to bring a special ship to the Mexican coast that could stand on the seafloor. In 2016, they used this ship to drill into the crater.



The scientists drilled 4,379 feet (1,335 meters) beneath the seafloor, retrieving thousands of feet of cores from the crater. The cores were shipped to a science lab in Germany where a team of scientists studied them to uncover their secrets. The cores told the story of what may have been Earth's most catastrophic day.


...may have come from the asteroid belt between Jupiter and Mars, or even farther out in the Solar System.
...was at least 7.5 miles (12 kilometers wide).
The Asteroid...
...plummeted into the Earth at speeds about 40,000 miles (64,700 kilometers) per hour.
...was so big, it pushed the atmosphere out of its way.

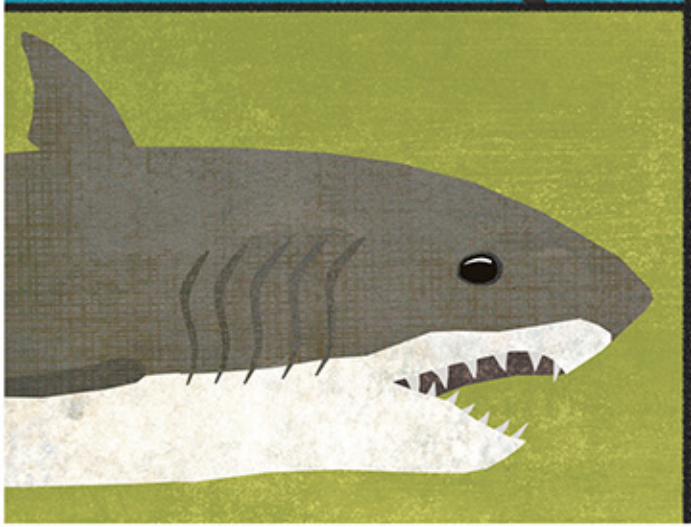

...exploded with the force of 10 billion atomic bombs.
...vaporized the asteroid, blowing it to bits.
The Impact...
...created tsunami that may have been 1000 feet (305 meters) high.
...sent out heat and shock waves that obliterated everything for hundreds of miles around the impact.


...hit with such force that rock miles deep in the ground flowed like liquid.
...shook the Earth, setting off massive earthquakes.
The Impact...
...likely caused volcanic eruptions around the world.
...ejected 12.5 trillion tons (12 trillion metric tons) of rock into the atmosphere.

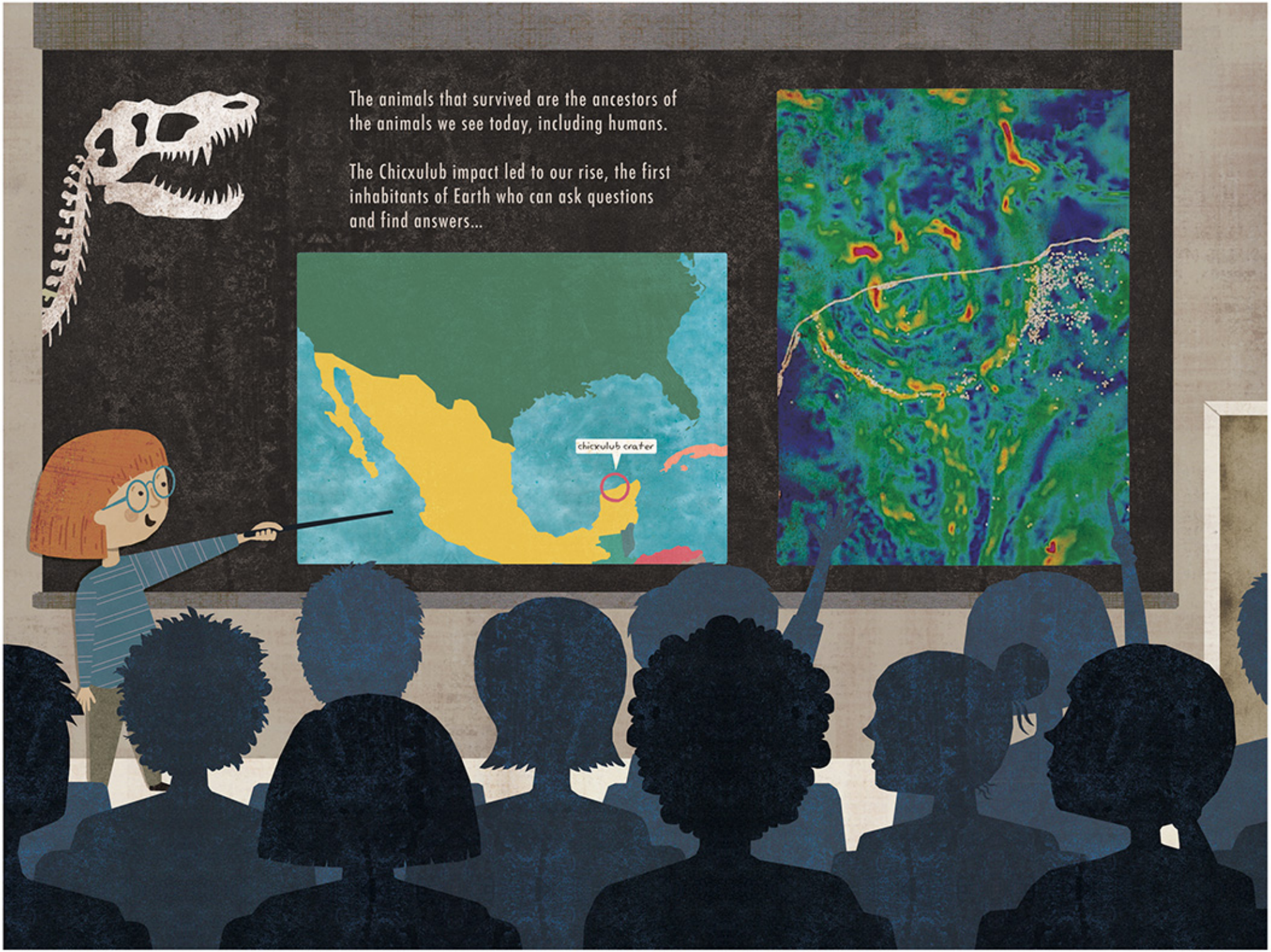

...heated the atmosphere with flaming rocks.
...blocked the sun with dust and sulfur, making it very cold for more than ten years.
The Fallout...
...changed the chemistry, and the food webs, in the ocean.
...released massive amounts of carbon dioxide, eventually causing global warming that may have lasted for centuries.

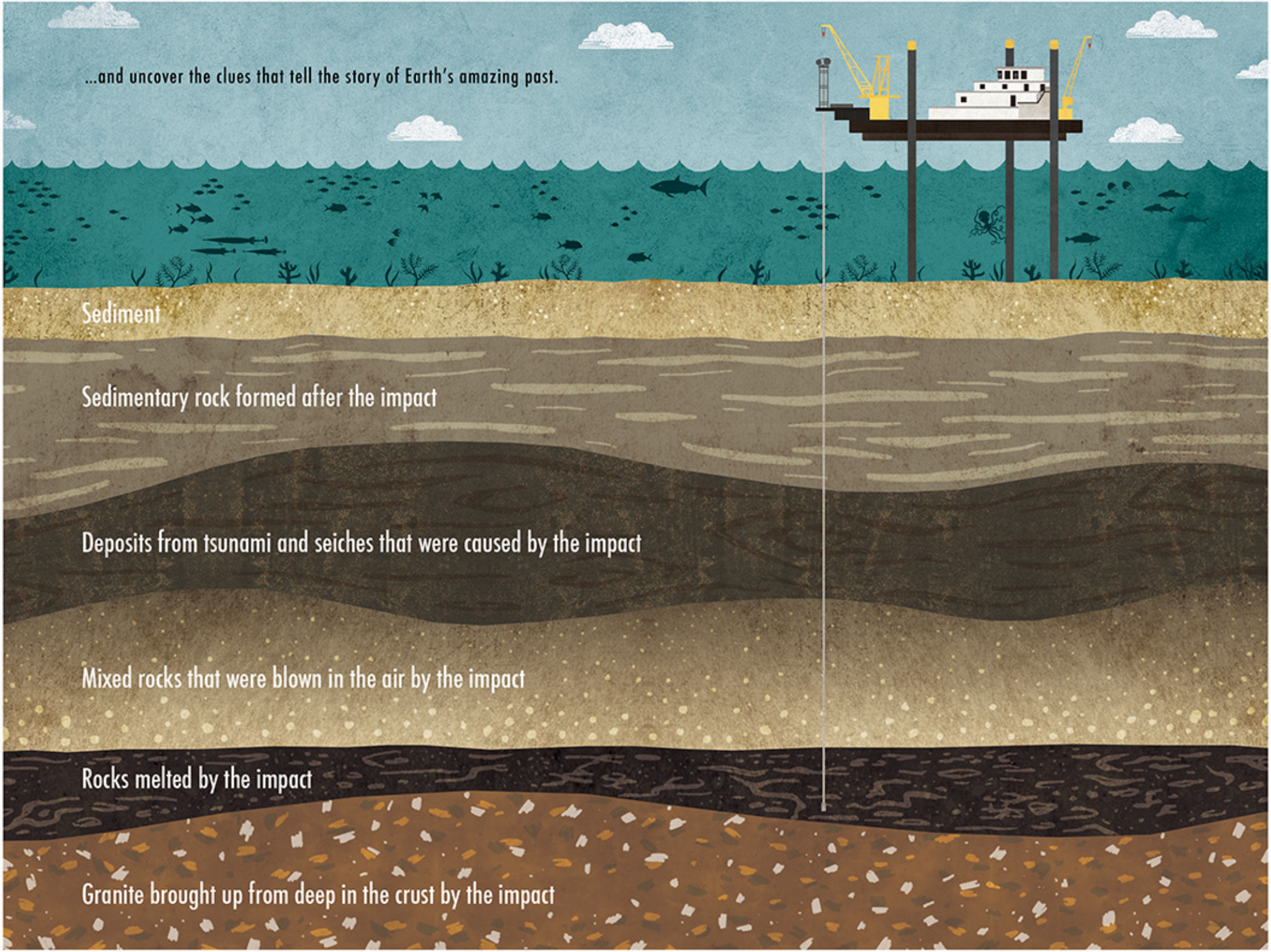



This series of devastating natural disasters affected animals and plants around the world. 75% of species went extinct at this time.

But not everything went extinct. Some species survived and slowly filled empty habitats around the world. Even the Chicxulub Crater eventually filled with life. Over time, some of these animals gradually changed and became new species.


The animals that survived are the ancestors of the animals we see today, including humans.
The Chicxulub impact led to our rise, the first inhabitants of Earth who can ask questions and find answers...
chicxulub crater

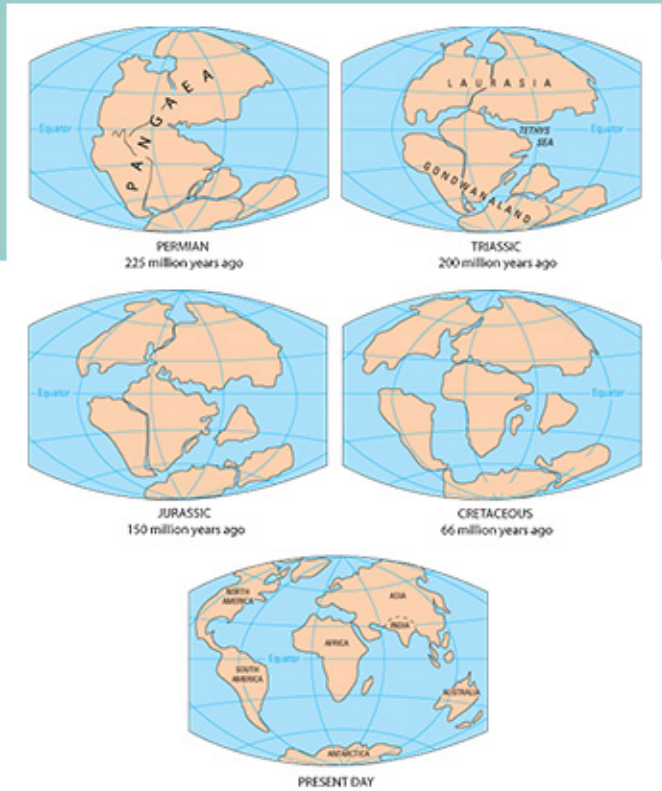

...and uncover the clues that tell the story of Earth's amazing past.
Sediment
Sedimentary rock formed after the impact
Deposits from tsunami and seiches that were caused by the impact
Mixed rocks that were blown in the air by the impact
Rocks melted by the impact
Granite brought up from deep in the crust by the impact

PAGE 1

Mass Extinctions

Extinction happens when all the individuals in a species die and none are left. This usually happens because something changes in the species' habitat that the species cannot adapt to. A mass extinction is the name for an event when the vast majority of species on Earth go extinct in a relatively short time. Mass extinctions are caused by changes that are so big, they affect the entire planet. They have happened five times in Earth's past.

1. The End-Ordovician Extinction; 444 million years ago; 86% of species went extinct
2. The Late Devonian Extinction; 375 million years ago; 75% of species went extinct
3. The End-Permian Extinction; 251 million years ago; 96% of species went extinct
4. The End-Triassic Extinction; 200 million years ago; 80% of species went extinct
5. The End-Cretaceous Extinction; 66 million years ago; 75% of species went extinct



Asteroids and Comets

The Chixculub Crater was created by the impact of an asteroid or a comet, though most scientists think it was an asteroid.

This is asteroid 243 Ida. It is found in the asteroid belt between Mars and Jupiter. 243 Ida is about ten miles (sixteen kilometers) wide. It is slightly bigger than the asteroid that created the Chicxulub Crater.

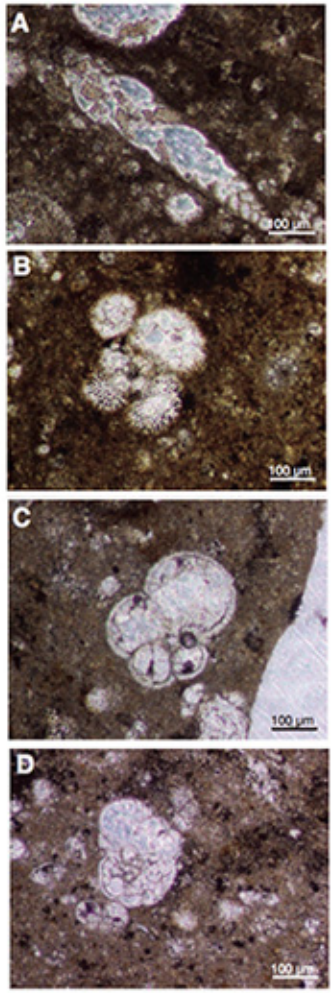
Asteroids are rocky objects in our Solar System that orbit the sun. They are smaller than planets and tend to be irregularly shaped. Most asteroids in the Solar System orbit between Mars and Jupiter in an area called the asteroid belt.

Shifting Continents

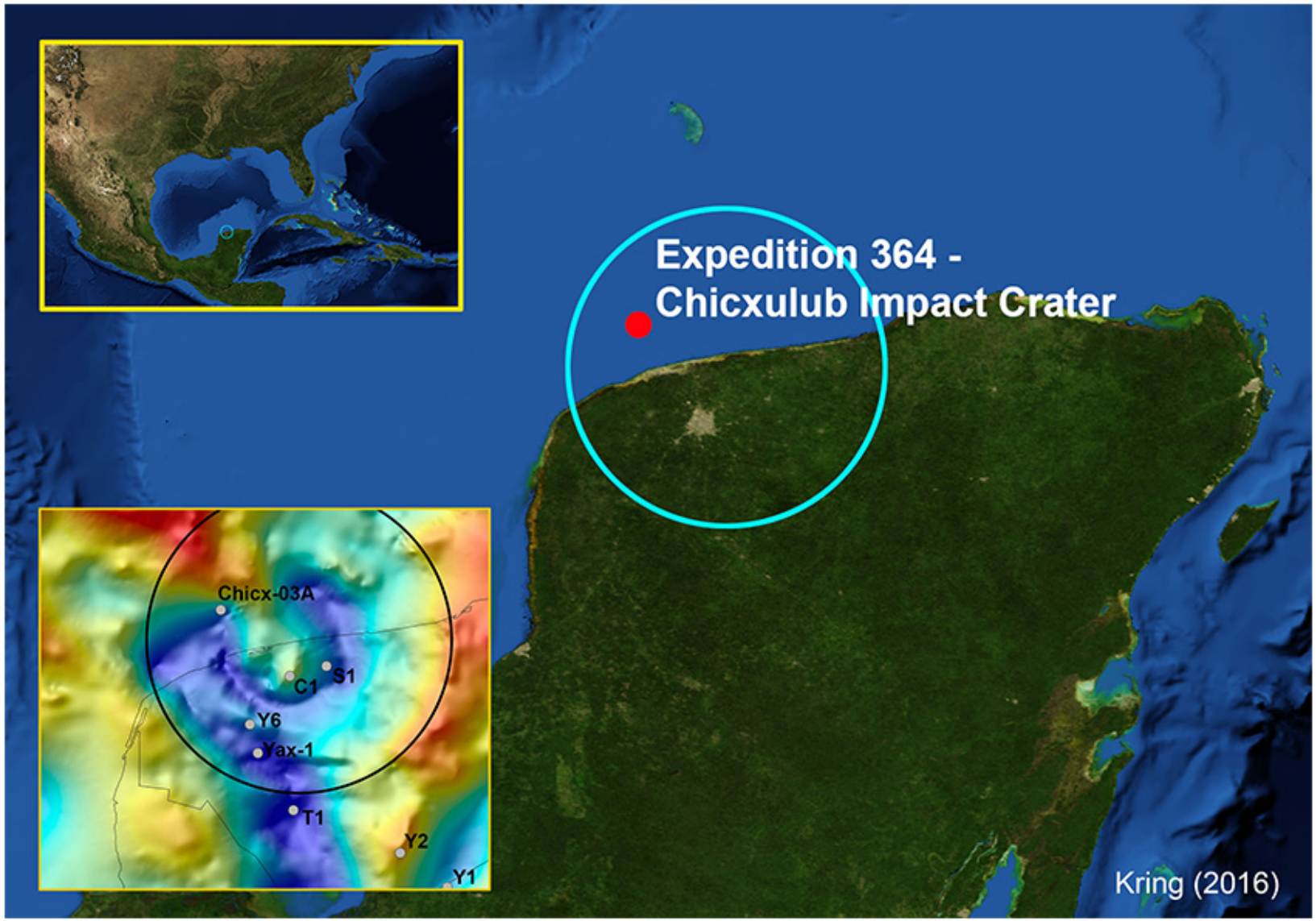
Even though we can't see it happening, the Earth has been changing its look. Sixty-six million years ago, North and South America were separated from each other and the Atlantic Ocean was much smaller. At other earlier times, all of the continents have been joined together to form a single supercontinent. These changes occur because of plate tectonics.

Hidden Crater

Because it was buried so quickly, the Chicxulub Crater is one of the best-preserved craters on Earth. The Chicxulub Crater is now covered in 66 million years of sediment and rock. When the Liftboat Myrtle drilled into the Gulf of Mexico, they had to go through about 2,350 feet (620 meters) of sediment and limestone to reach the impact layer.



These are some of the microscopic shell fossils that covered the Chicxulub Crater.



What is the K/Pg Boundary?

The K/Pg boundary is a thin clay layer (clay meaning made of tiny particles of sediment) found in rocks around the world. It has been found both on land and under the seafloor. The fallout from the Chicxulub impact created the K/Pg boundary layer. The impact ejected over 12.5 trillion tons (12 trillion metric tons) of rock and dust into the air. The dust spread through the atmosphere around the world. Eventually, it blanketed the entire planet, creating the K/Pg boundary layer. The K/Pg boundary also represents a boundary in time between the Cretaceous Period (145-66 million years ago) and the Paleogene Period (66-23 million years ago) (the K stands for Cretaceous and the Pg for Paleogene).

The K/Pg boundary layer in rocks in Colorado.

Walter Alvarez and his son Luis next to a rocky outcrop that contains the K/Pg boundary. This photo was taken near Gubbio, Italy.

An Earth-Shattering Idea

The first scientists to find significant evidence that the Cretaceous mass extinction was caused by an asteroid impact was a father and son team named Walter and Luis Alavarez. Working together, they realized that the K/Pg layer had a lot more iridium in it than was normal. Since iridium is much more common in asteroids and comets than it is on Earth, they hypothesized that maybe the layer was the fallout of a massive asteroid or comet impact. Since the layer was right above the dinosaur fossils, and therefore happened at the end of the age of the dinosaurs, they also hypothesized that this impact could have cause the extinction of the dinosaurs. They published their findings in 1980.

How to Find a Hidden Crater

When Walter and Luis Alvarez released their hypothesis in 1980 that a giant asteroid or comet impact had caused the extinction of the dinosaurs, scientists started looking around the world to see if they could find the crater from this impact. Scientists became aware that geologists working for the Mexican oil company Pemex had found evidence in the 1950s, 60s, and 70s that there was a huge crater underneath the Yucatan Peninsula. Because the Pemex geologists' job was to find oil and not make scientific discoveries, information about their discovery was at first not made public. Scientists studied the Pemex cores and found the crater's size and age were exactly what they were expecting for the K/Pg boundary crater. In 1990, scientists announced the discovery of the Chicxulub Impact Crater.

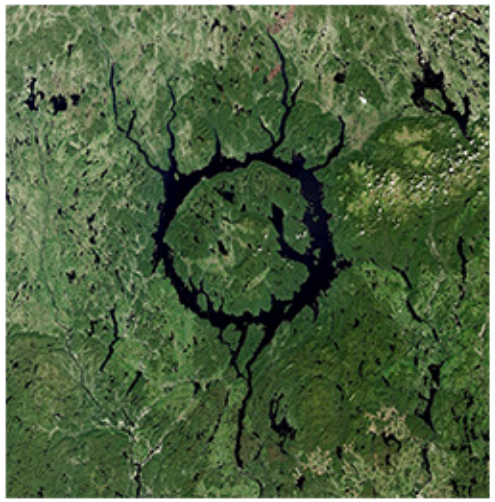
Other Large Impact Craters in North America

There is a 53 mile (85 kilometer) wide impact crater buried under the Chesapeake Bay in the United States.

Barringer Crater, which is also inaccurately named Meteor Crater, is in Arizona, United States.

The Sudbury Basin Impact crater is in Quebec, Canada.

The Manson Crater is in Iowa, United States.



The Manicougan Reservoir Impact crater is in Quebec, Canada.

The Chicxulub K/Pg Impact Crater Expedition

The research expedition that drilled into Chicxulub Crater in 2016 was titled the Chicxulub K/Pg Impact Crater Expedition. It was expedition 364 for the International Ocean Discovery Program (IODP). The IODP is an international collaboration that conducts expeditions to drill the seafloor and collect rock and sediment samples for scientific research. The Chicxulub expedition was overseen by the European Consortium for Ocean Research Drilling (ECORD).

Photo by Kevin Kurtz

IODP EXPEDITION 364
CHICXULUB K-Pg IMPACT CRATER

ECORD
EUROPEAN CONSORTIUM FOR OCEAN RESEARCH DRILLING

The Liftboat Myrtle

The at-sea part of the expedition lasted fifty-seven days, from April 5 to May 31, 2016. The Chicxulub expedition scientists used the Liftboat Myrtle, a boat that can stand on the seafloor, to drill into the Chicxulub Crater. It has three "legs" that lift the ship above the water so it doesn't get rocked by the waves. The ocean at the Chicxulub drilling site was only about sixty feet (eighteen meters) deep. This is too shallow for the International Ocean Discovery Program's (IODP) regular drilling ships, the JOIDES Resolution and the Chikyu. The IODP leased the Liftboat Myrtle to use just for this expedition.

Why Germany?

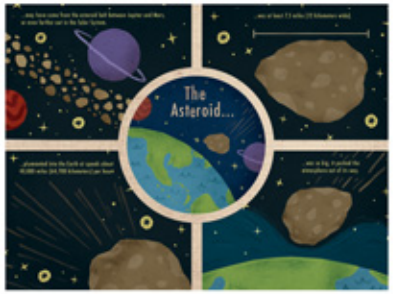
The Chicxulub scientists did the first major work of observing and measuring the Chicxulub cores in Bremen, Germany. One of the reasons they went there is because Bremen is one of three places in the world that has a repository for the cores drilled by the International Ocean Discovery Program (IODP). It is located at the MARUM research facility at the University of Bremen. This large, refrigerated warehouse, seen in the photo on the right, preserves thousands of ocean cores for future research.

Photo by Kevin Kurtz

Image courtesy of Volker Diekamp@ECORD_IODP

The Chicxulub Science Team

After the drilling occurred, this group of people came together in Bremen, Germany to observe measure and study the Chicxulub cores. From September 21 to October 16, 2016, they worked twelve-hour shifts each day at the MARUM Research Facility in Bremen. The team included thirty-three scientists from eleven different countries, as well as lab techs and many other people to assist them. The scientists included geologists, chemists, physicists, paleontologists, and microbiologists. Each used their expertise to study and describe different aspects of the cores.



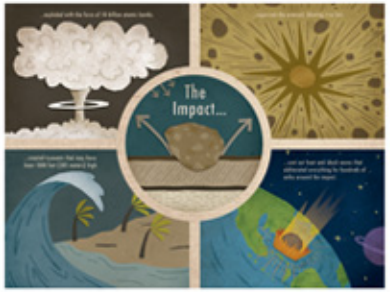
Ginormous

The Chicxulub asteroid was at least 7.5 miles (12 km) wide. That distance is about two miles (3.2 kilometers) longer than the height of Mount Everest, which is 5.5 miles (8.8 km) above sea level.

A Hole in the Sky

The Chicxulub asteroid pushed all the air in front of it out of its way. The emptiness of space briefly followed the asteroid down to Earth's surface. It basically created a hole in the sky. It only took two seconds for the Chicxulub asteroid to travel through the atmosphere and strike the Earth. When the impact occurred, the asteroid and the rock beneath it were compressed (basically squeezed into a tinier space) very quickly. The impact released so much energy that the impact site temporarily became hotter than the Sun!

If the Chicxulub asteroid was placed on flat land next to Mount Everest, the top of it would be at least two miles (3.2 km) above the top of the mountain.

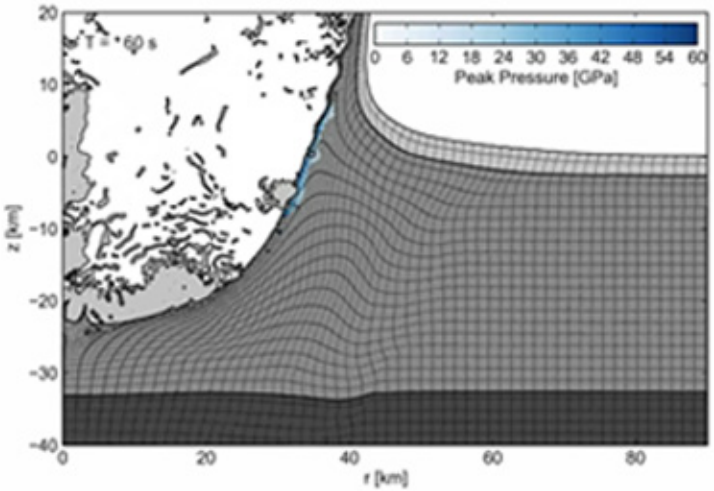


What Does "10 Billion Atomic Bombs" Mean?

Atomic bombs are humans' most destructive invention, but some, like the hydrogen bomb, are more destructive than others. The atomic bombs we are referring to here are the ones used during World War II. Just one of those bombs could obliterate everything within a one-mile (1.6 kilometers) diameter.

Monster Tsunami

Tsunami are huge waves in the ocean that are caused by cataclysmic events such as earthquakes and massive landslides. Sixty-six million years ago, the area where the Chicxulub asteroid hit was completely underwater. The tsunami set off by the Chicxulub impact may have been well over one thousand feet tall. According to one computer simulation, it is possible that some of the Chicxulub tsunami waves may even have been five thousand feet (1,500 meters) tall. The tsunami likely hit coastlines around the world, though the waves became smaller the farther they were from the impact.



A Giant Rock Became Gas

The asteroid collided with so much force that most of it was instantaneously vaporized. What that means is much of this solid rock was turned into a gas. The vaporized asteroid and target rock formed a rapidly expanding impact plume. The plume ejected material around the world at speeds of up to 6.5 miles (11 km) per second.

This image shows the movement of rock in the Chicxulub Crater at 60 seconds after the asteroid impact. The left edge of the chart is at ground zero for the impact. The numbers along the edges measure distances in kilometers.

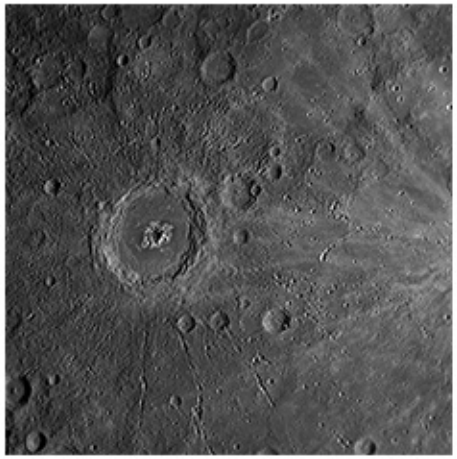
Inside the Blast Zone

The Chicxulub impact blasted out heat and shock waves. Air temperatures nearby may have reached over 10,000 degrees Fahrenheit (5,540 degrees Celsius) for a few minutes. Everything alive within a 625 miles (1,000 kilometers) radius would have been burned to death. The shock waves pushed the air all around them, creating winds that may have blown over 625 miles (1,000 kilometers) per hour. This air blast may have reached 935 miles (1,500 kilometers) from the impact.

Instant Mountains

The Chicxulub Crater has the only intact peak ring on Earth. When the scientists drilled into the Chicxulub Crater in 2016, they purposely drilled into the peak ring to learn more about how they form. A peak ring is the inner ring of mountains found in many large craters.

When the asteroid smashed into the Earth, it sent out shock waves into the rock below that caused them to fracture and flow like a fluid. The asteroid pushed the earth down forming a great big hole. The fluid-like rocks rebounded causing millions of tons of rocks to rise up to from the center to possibly 12 miles (20 kilometers) high. When the geyser of rock collapsed, it formed the mountains that are the Chicxulub peak ring. They rise about 1,300 feet (400 meters) above the floor of the crater.



You can see the inner peak ring of mountains inside the Eminescu Crater on Mars.

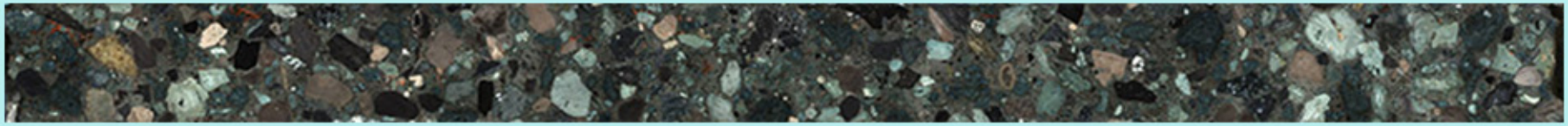
A Literal Earth-Quake

The Chicxulub asteroid hit with such force that it shook our entire planet. The areas around ground zero likely experienced a magnitude 12 earthquake. The impact also sent seismic waves throughout the planet. Even the opposite side of the Earth from the Chicxulub impact likely experienced an earthquake that was magnitude 9.

Asteroids and Volcanoes

The Chicxulub impact set-off massive earthquakes around the world. Huge earthquakes can cause volcanoes to erupt. Volcanoes are places where magma from deep in the Earth is close to the surface. Magma has lots of bubbles of gas in it. Just like how shaking up a can of soda releases the gas in the soda, a big earthquakes shakes up a volcano and releases the gas in the magma. The released gas puts pressure on the rock holding back the magma and can cause the rock to break, leading to an eruption. It's likely the Chicxulub earthquake shook volcanoes and caused eruptions around the world.

Raining Rocks



The Chicxulub Crater ranges in diameter from 118 miles (190 kilometers) to 130 miles (210 kilometers) wide and about 12 miles (20 kilometers) deep. The crater's total area is bigger than the entire state of Massachusetts in the USA. It is estimated that 26.5 quadrillion pounds (26,500,000,000,000,000 pounds) (12 quadrillion kilograms) of rock were blasted into the air by the impact. Some of the chunks of rock that were blasted from the ground eventually fell back into the crater. Some rocks were blasted far away from the crater, including into space. It's possible there are chunks of rock from the Chicxulub impact on the Moon.

The Sky was Falling

When the asteroid impact blasted quadrillion of pounds of rock out of the ground, some of this rock was blown above the Earth's atmosphere and then pulled back to Earth by gravity. As the rock fragments plummeted down though air, they heated up, creating a deluge of shooting stars. Heat from these glowing fragments was hot enough to set-off forest fires in multiple places.

This illustration of a meteor shower in 1833 is like a sprinkle compared to the downpour of shooting stars after the Chicxulub impact.

This is sulfur. In olden days, sulfur minerals were called brimstone.

Fire and Brimstone

It was very unlucky for the dinosaurs that the Chicxulub asteroid struck where it did. The rock under the Yucatán Peninsula area contained a lot of sulfur locked in a rock called anhydrite. The impact blasted the rocks and released more than 358 billion tons (325 billion metric tons) of the sulfur into the atmosphere. Sulfur is an element that can combine with oxygen to form a colorless gas or combine with water vapor to form sulfate aerosols. Both of these sulfur compounds can float in the atmosphere for a long time. So much sulfur, aerosols, and dust were released by the impact that, they, along with ash from the fires, may have blocked the sun's light and heat for ten years. The decade long winter without light was the main cause of the mass extinction that happened at the time.

A Dark Ocean

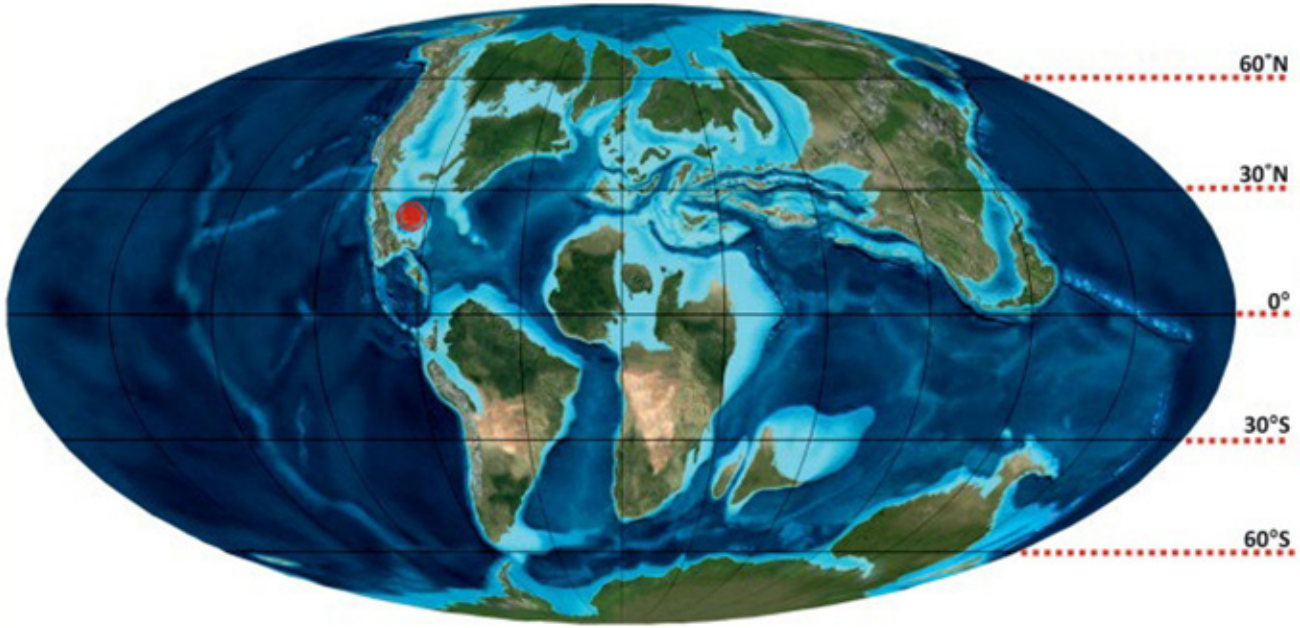
Water covers 71% of our planet and most of life is in the ocean. The impact also wiped out a huge number of marine species. Animals in the ocean are highly dependent on phytoplankton, the microscopic organisms that use sunlight to make food. Without sunlight, almost all of the phytoplankton died. About 99% of plankton species went extinct at that time. Since plankton is the base of most ocean food webs, many other ocean species also went extinct as they ran out of food.

Extreme Cold and Then Extreme Heat

The Chicxulub impact also released 425 billion tons of carbon dioxide into the atmosphere from the limestone in the Gulf of Mexico. After the sulfur blocked the sun for about ten years, the carbon dioxide made it unusually warm for possibly 100,000 years. Carbon dioxide is a greenhouse gas. This means it traps and holds heat and makes the air feel warmer. The more carbon dioxide there is in the atmosphere, the warmer the world becomes.

Really, Really Bad Luck

The dinosaurs might still be here if the Chicxulub Asteroid had struck just about anywhere else on Earth besides the Yucatán Peninsula.



This is what the Earth looked like at the time of the Chicxulub impact. The Yucatán Peninsula was the place you didn't want the asteroid to hit.

Other large impact craters have been found on Earth. The Chesapeake Bay impact crater that was created 35 million years ago is 53 miles (85 kilometers) wide. The Manicougan impact crater that was created 215 million years ago is 62 miles (100 kilometers) wide. Neither of these impacts caused global devastation. As far as we know, the Chicxulub impact 66 million years ago was the only asteroid or comet impact to cause a mass extinction.

Those other impacts likely set off a series of natural disasters, but their effects were mainly regional. What made the Chicxulub impact devastating was the size of the impact combined with the many layers of porous, sulfur-rich rocks in the Yucatán Peninsula. Most rocks on Earth do not have as much sulfur in them as the Yucatan rocks do. The impact released billions of tons of sulfur from the rock into the air, which blocked the Sun around the world for years. This was probably the main cause of extinctions. Had the asteroid struck somewhere else, the Sun may have kept shining.

What Are These Animals?

The asteroid impact 66 million years ago caused both dinosaurs and non-dinosaur species to go extinct.

Tyrannosaurus Rex (a dinosaur)

Many species of Foraminifera (a type of microscopic plankton)

Xiphactinus (a fish)

Anzu (a dinosaur)

Arambourgiania (a pterosaur)

Cycadeoidea (a tree)

Hybodus (a shark)

Scaphites (an ammonite)

Life Returns to Ground Zero

The scientists expected it to take many thousands of years for life to recover in the Chicxulub crater. When they examined the cores from the crater, they found fossil burrows that indicated marine worms were living in the crater just a few years after the impact. They also found evidence that ecosystems in the crater had recovered within 30,000 years. That may seem like a long time, but some ecosystems in the Gulf of Mexico took 300,000 years to recover like that! Scientists were surprised to discover that life recovered and evolved within the Chicxulub impact crater as fast as anywhere else on Earth.

Survivors

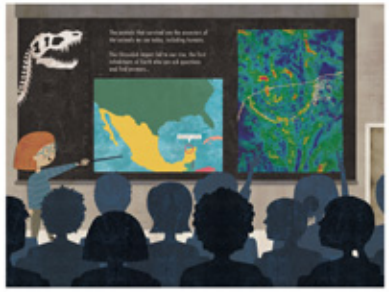
Even though 75% of species went extinct after the Chicxulub impact, 25% of species did not. Many scientists think one of the things that determined survival was size. The smaller animals had a better chance of survival than big animals. They could get into holes in the ground to escape the deadly heat and fires. They also needed less food. The animals with the best chance of survival were animals that ate seeds and/or insects (which both were still available, even after all the disasters) or opportunistic feeders (animals that eat just about anything).

Small, ground-dwelling, bug- and seed-eating animals had the best chance of surviving the K/Pg mass extinction. This is a drawing of a species that lived at the time called Purgatorius.

Palm trees are a type of plant that survived the Chicxulub impact.

Saved by Seeds

The Chicxulub impact and its aftermath may have killed every plant on Earth that was alive 66 million years ago. But even though about 75% of species went extinct overall, only about 57% of plant species went extinct. Plant species were able to survive because even though plants died, many of their seeds did not. Some seeds are hardy enough to last years. They may have sprouted when the sun came back out a decade later.



Not All Dinosaurs Went Extinct

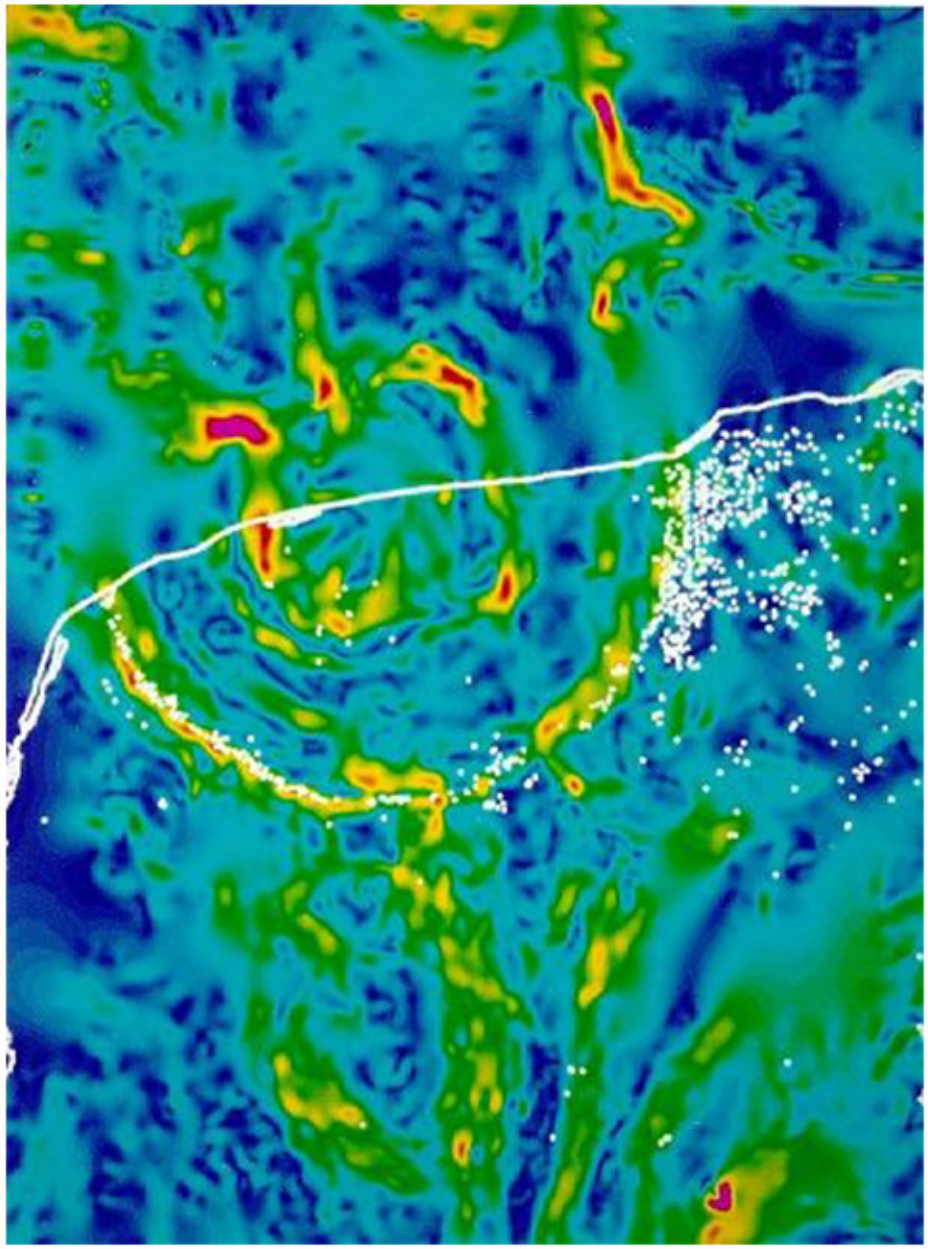
There are over 10,000 species of dinosaurs alive today. We now know that birds are dinosaurs. They were the one group of dinosaurs not completely wiped out by the Chicxulub asteroid impact disasters.

We Wouldn't be Here if Not for the Chicxulub Impact

Early mammals lived side-by-side with dinosaurs for 134 million years. They tended to be small and to only come out at night, when it was safer. The mass extinction left a world filled with empty habitats. Over time, the mammals spread to fill these habitats while changing to adapt to new opportunities. About 66 million years after the impact, descendants of some of these mammals evolved into us, modern humans. We would not be here if the non-avian dinosaurs had not gone extinct so that mammals could flourish.

An "X-ray" of the Chicxulub Crater

This image shows how the force of gravity changes in the Chicxulub crater. In doing so, it shows the crater features that are hidden underground. Scientists can measure the forces of gravity and create images that show where there is more gravity and where there is less. The red and yellow areas in this image indicate the places where the gravity changes very rapidly. The differences in gravity create an image that is kind of like an x-ray of the Earth. The red and yellow circular areas show the rim and peak ring of the Chicxulub Crater, which have more mass and more gravity than the places around them, causing the gravity to rapidly change.



The Starting Point

The Chicxulub expedition began collecting cores about 1,660 feet (506 meters) below the seafloor. The drill had to go through layers and layers of sediment and sedimentary rock to reach that point. They chose to skip the first 1,660 feet (506 meters) because cores drilled there would not be useful to answer the research questions of the expedition. The expedition had limited time and resources, so they couldn't collect everything.

Fossils, Clays, and Sand

Ocean sediment is made up of tiny fossil shells and tiny grains of rock. The shells come from microscopic organisms like foraminifera and diatoms. Because it was close enough, the sediment also included tiny grains of rocks from land.

Ocean sediment mainly consists of shells like these. Each of these shells is less than 1 millimeter wide.

Squeezed Fossils

The cores that were drilled 1,660 feet (506 meters) to 2,024 feet (617 meters) below seafloor contain sedimentary rocks that formed after the impact. Sedimentary rock starts as sediment. If the sediment is put under great pressure, or experiences a change in chemistry, the grains and shells can bond together to form rock. If the sediment is mainly made up of fossil shells, it forms limestone. If it is mainly made up of tiny grains of rock, it forms rocks like claystone and sandstone.

Bouncing Waves

The cores drilled 2,023 feet (616.5 meters) below the seafloor contained the first layers of rock created by the asteroid impact. The top layer of the actual crater rock is mainly the result of the asteroid crashing in the ocean and setting off a tsunami that spread out from the impact across the ocean. When the tsunami returned, it deposited sediment to create this uppermost layer of the crater. Waves within the crater bounced back and forth for a while depositing sediment. This type of wave is called a seiche.

Rock Salad

The Chicxulub impact blasted quadrillions of pounds of rock out of the ground. Some of these rocks were blown far away, but some were mixed together and then deposited into the crater. Pieces of all sorts of different rocks were mixed together. As they piled up in the crater, they made what was basically a rock salad. Overtime, these chunks of rock cemented together to form a type of rock called breccia or suevite. This layer of mixed rocks in the Chicxulub cores was about 341 feet (104 meters) thick!

A Giant Pool of Liquid Rock

When the asteroid struck, it blasted a lot of rock out of the ground. It also released extreme heat and pressure that melted the rocks that weren't blown in the air. The extreme pressures and temperatures at the impact site melted enough rock to cover the crater floor with a pool of liquid rock that was about 85 ft (26 m) thick at the drill site, and up to 1.8 miles (3 km) thick in the crater centre. This melt slowly cools to form impact melt rock.

Granite

When the drill reached 2,450 feet (747 meters) below the seafloor, it began collecting rocks that, when the asteroid struck, may have originally been 6 to 20 miles (10 to 30 kilometers) below the seafloor. The energy released by the asteroid caused rock to violently rise out of the Earth. This type of rock is called granite. Once the expedition hit granite, almost everything drilled down to 4,379 feet (1,335 meters) below the seafloor is granite.

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Kevin Kurtz is an award-winning author of nonfiction children's books, including *A Day in the Deep*, *A Day in the Salt Marsh*, and *Living Things and Nonliving Things*. He is also the author of the free children's eBooks *Uncovering Earth's Secrets* and *Where Wild Microbes Grow*, both of which were illustrated by Alice Feagan. Kevin was able to be part of the Chicxulub Impact Crater Expedition, both during the drilling in the Gulf of Mexico and in the science labs in Bremen, Germany. To learn more about Kevin's books and school visit programs, visit his website www.kevkurtz.com.

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Alice Feagan specializes in traditional and digital cut paper illustration. She has illustrated picture books, chapter books, children's wall art, and products for clients such as National Geographic Kids Magazine, Kids Can Press, and World Book Encyclopedia. She was onboard the JR for a School of Rock educator workshop as the ship traveled from Curacao to Bermuda. To view Alice's portfolio visit http://alicefeagan.com.