Core Knowledge® SCIENCE

Plate Tectonics and Rock Cycling:

What causes Earth's surface to change?

Science Literacy

Science Literacy Student Reader

Hawaii volcano

Iceland rift

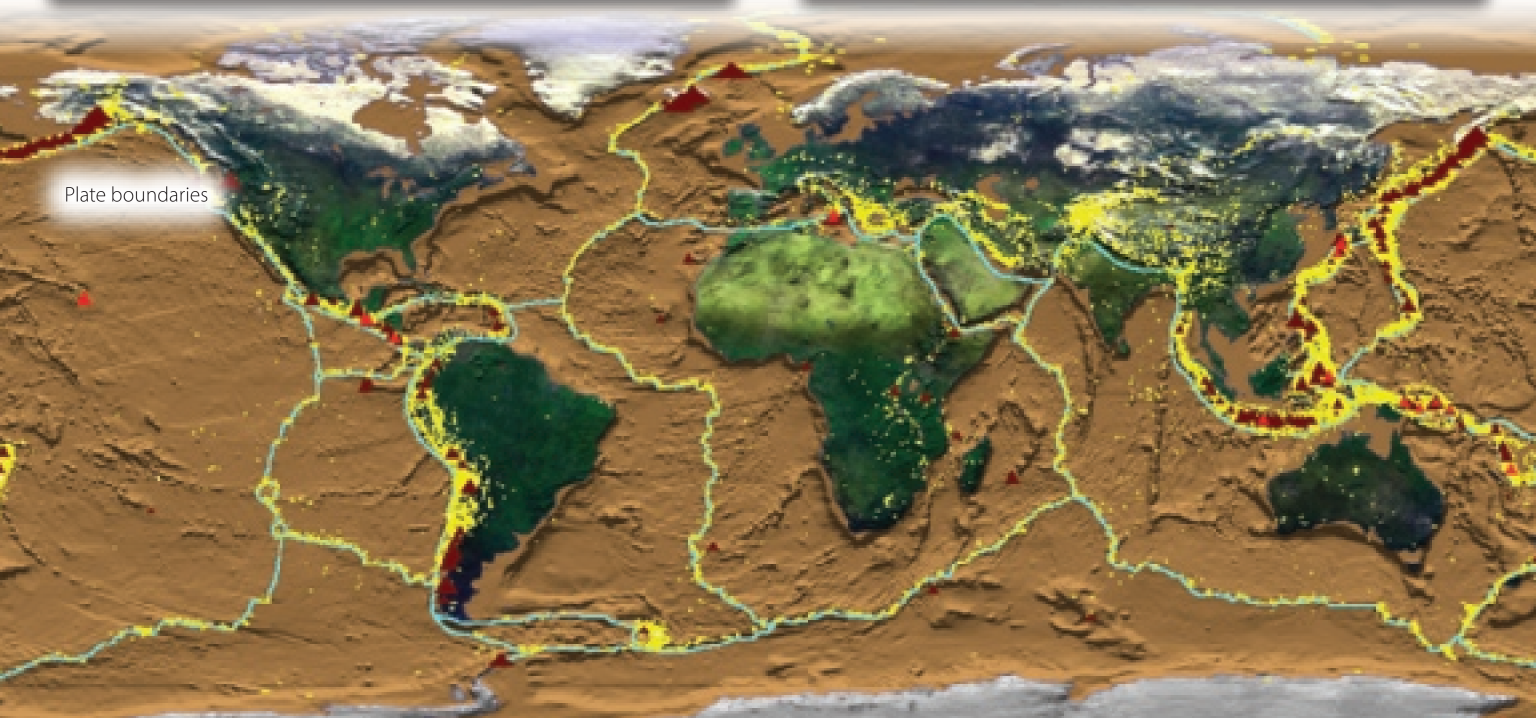

Plate boundaries

Plate Tectonics and Rock Cycling

Science Literacy Student Reader

Core Knowledge®

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Plate Tectonics and Rock Cycling

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Put Yourself in This Scene

It's the weekend, and you're scrolling through social media.
You see that your friend has shared a post.

OB **Olivia Brown**

I've just learned that there's going to be fracking in our state. This is extremely dangerous! Fracking deliberately causes earthquakes. And for what? Just to get a bit of oil? That's right; they drill deep into the ground and then push water in to break it apart so they can get the oil out. This changes the ground and will eventually break all North America apart. This is a very dangerous practice, which is why it's so controversial. I don't know about you, but I don't want people to go around making earthquakes and putting us all at risk. Let's organize a protest.

Wow, that sounds scary! You want to share your friend's post, but before you can do that, a reply pops up on the screen.

EA **Emily Austin**

Don't be ridiculous. I'm so tired of seeing outrage over fracking, when clearly none of you understand what fracking is. It's not going to break all North America apart. Yes, there are earthquakes associated with fracking because that's what fracking is. Water or sand is pushed into the ground to break it up in a controlled way, which technically is an earthquake. But it's not dangerous, it's entirely controlled, and they don't do this near where people live. They're not even very big earthquakes, because humans don't have the ability to cause major quakes. It just opens the ground up a little bit so oil and natural gas can be extracted. It's much less damaging to the ground and environment than digging oil wells. Everybody needs to just calm down and understand the facts. We still need oil and gas reserves until we can transition to renewable resources, and fracking is a good way to get them.

Well, that makes it sound like your friend doesn't know what she's talking about. But you know your friend is smart. If she's worried, she must have a good reason. You decide to research fracking and if it could really break North America into pieces. But as you start looking into it, you find more and more controversy. How can you tell who is right? That's what this book is about—scientific literacy, which means knowing how to think about science topics that you read or hear about. Our world has 24–7 news, social media, and too many websites to count. The amount of information we must sort through is overwhelming, and all the information is not reliable. In the internet age, sources of information are often obscure or not trustworthy. It is good to process information with a healthy degree of skepticism.

We will make our way back to the topic of fracking by the end of the book. Along the way, the series of reading selections and the writing exercises that go with them will help you flex your mental muscles and sharpen your science literacy skills. The ability to read about science, understand the information, and tell truth from fallacy or misrepresentation is important. Science literacy helps you as an individual and as a consumer, and it shapes the ways you affect the community in which you live.

Vivid Vacation Pics

Today we hiked the Rainbow Mountains in Zhangye Danxia park in China. Just beautiful!

SCIENCE IN HERE

The colorful stripes on these mountains are layers of sandstone that formed over millions of years. They were shifted sideways by changes in Earth's **crust**, then eroded away by wind and water to reveal these bright stripes.

We visited Bromo Tengger Semeru National Park in Indonesia to see the volcanoes. Some are active! You can see smoke rising from several of them in this picture.

SCIENCE IN HERE

Bromo Tengger Semeru National Park is home to many active volcanoes. Volcanoes within this park erupt frequently, changing the landscape of the park bit by bit. Indonesia sits in the Ring of Fire, a large path around the Pacific Ocean where numerous volcanic eruptions and earthquakes occur.

We traveled to Uluru in Australia to see this incredible formation. The landform is sacred to the Anangu people, so we didn't try to climb it.

SCIENCE IN HERE

The rocks that form Uluru were laid down on an ocean floor over 500 million years ago. The ocean receded, uplift and erosion occurred, and today we see this towering sandstone landform.

We ended our vacation in Crete. The rocks here are so weird! It looks like a giant crumpled them up.

SCIENCE IN HERE

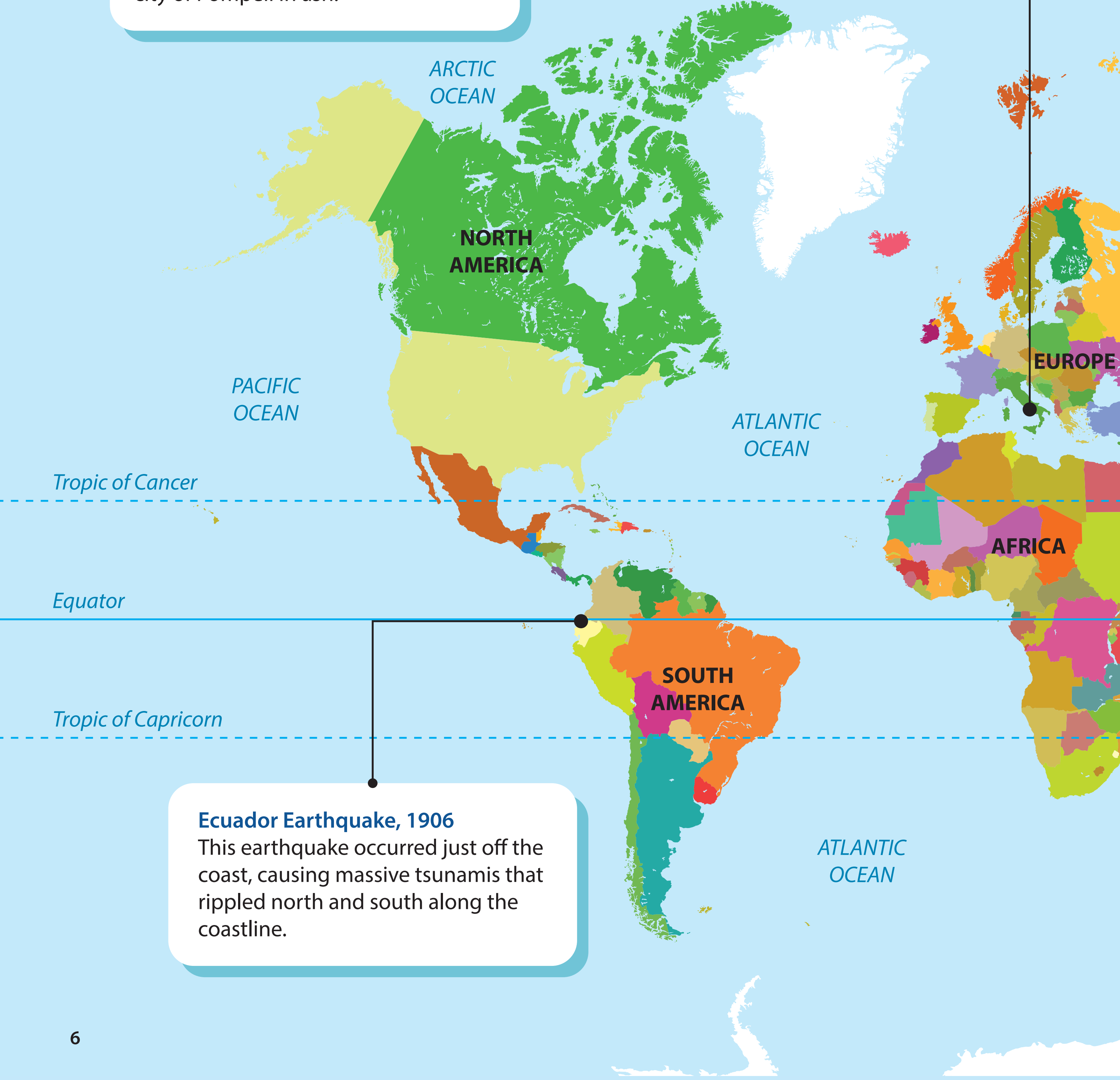
These geological formations show extreme folding, which occurred tens of kilometers below the surface. The strata in Crete are limestone, a relatively soft sedimentary rock. Their makeup makes them very pliable, which is how they were able to bend and fold into the interesting shapes you see here.

Vocabulary

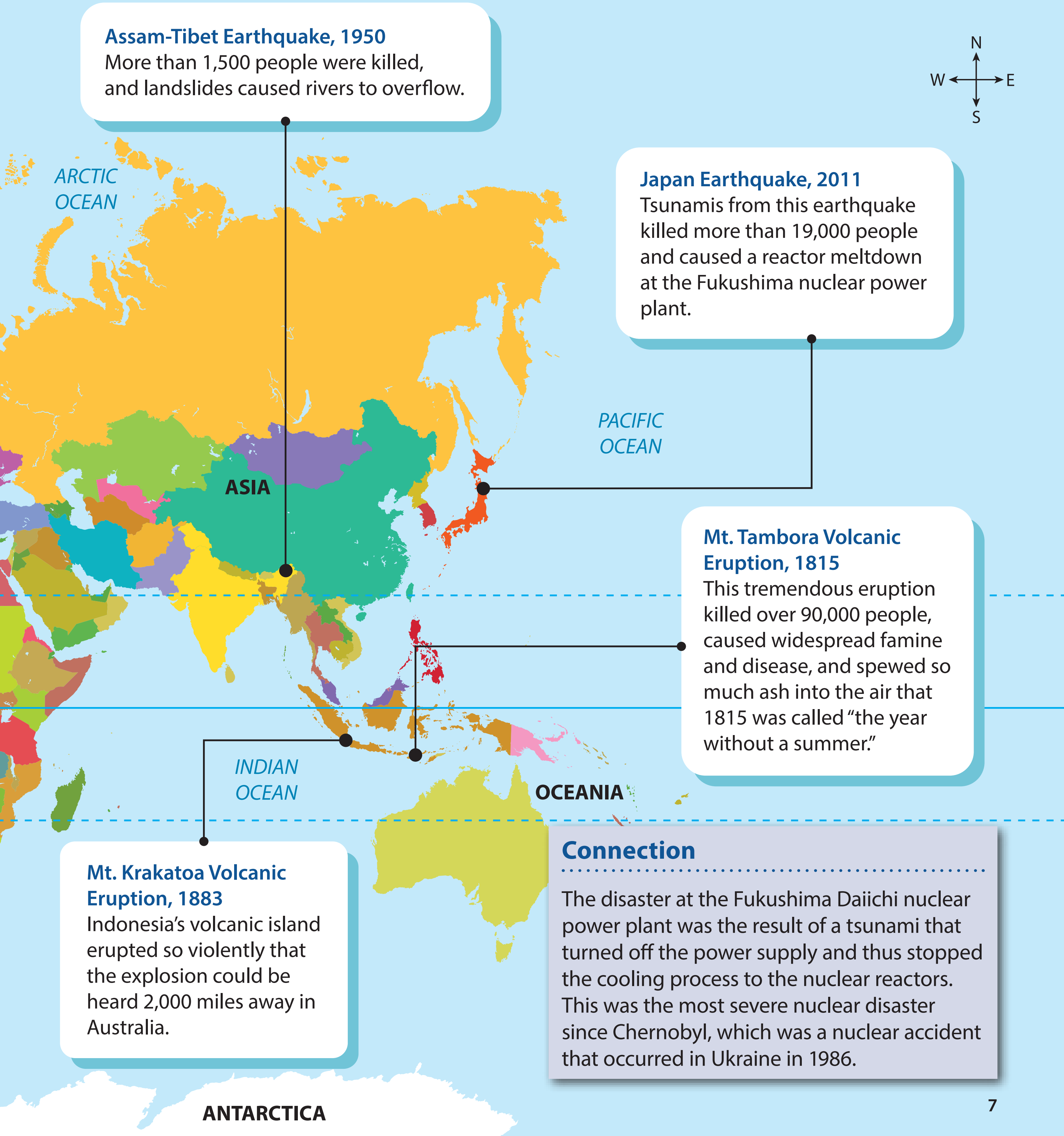
crust, n. Earth's rocky outer layer

Earth's Famous Events

Mt. Vesuvius Volcanic Eruption, 79 CE
This devastating eruption buried the city of Pompeii in ash.



Ecuador Earthquake, 1906
This earthquake occurred just off the coast, causing massive tsunamis that rippled north and south along the coastline.



Connection

The disaster at the Fukushima Daiichi nuclear power plant was the result of a tsunami that turned off the power supply and thus stopped the cooling process to the nuclear reactors. This was the most severe nuclear disaster since Chernobyl, which was a nuclear accident that occurred in Ukraine in 1986.

How Deep Can You Go?

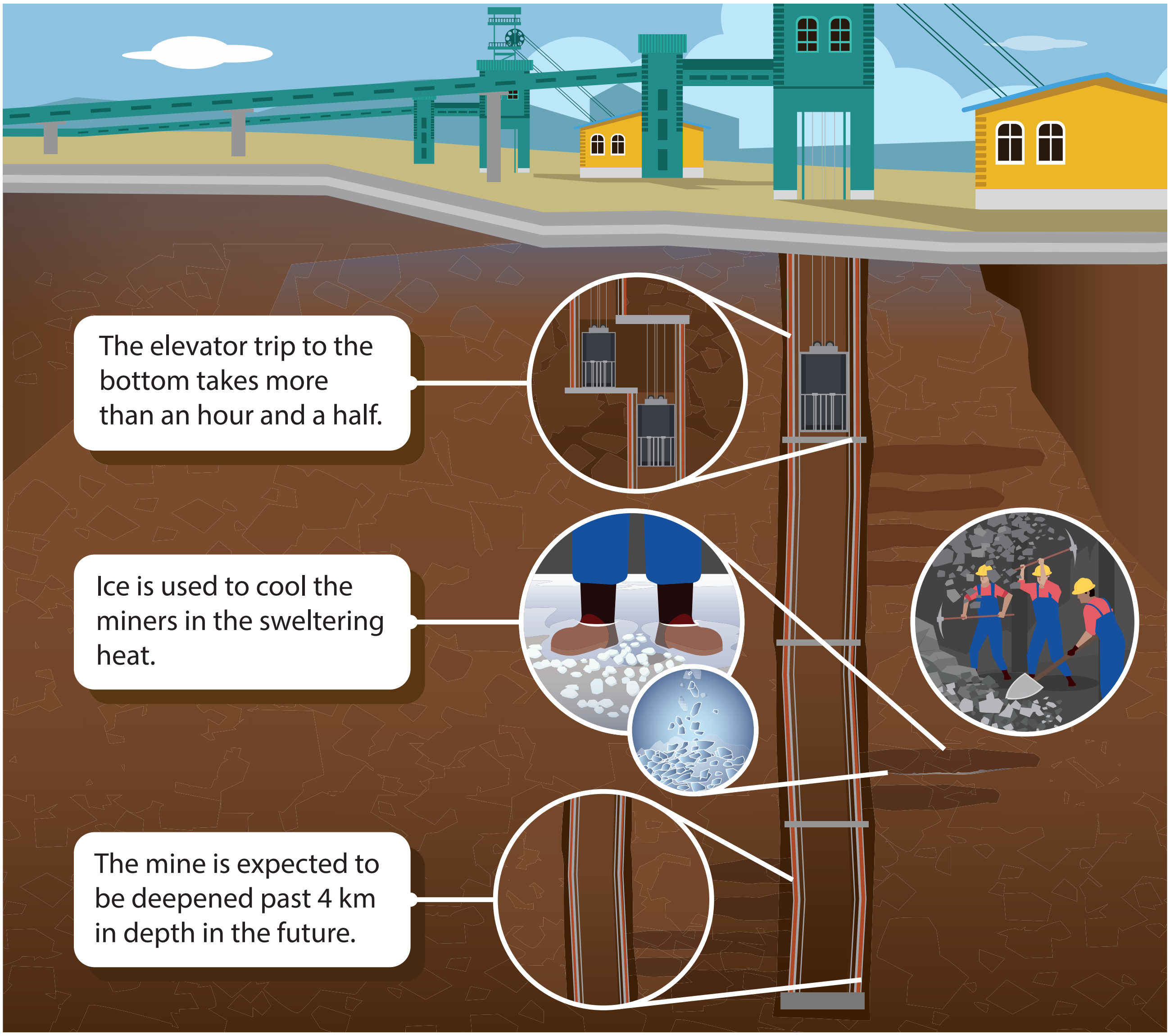
Have you ever wanted to dig a hole to the center of Earth? Have you ever visited a cave and journeyed deep underground? Does it make you wonder: How deep into Earth have humans gone?

The deepest humans have ever journeyed underground occurs in the Mponeng gold mine in South Africa. The mine is 3.48 kilometers (2.2 miles) deep—more than 10 times as deep as the Empire State Building is tall!

More than 4,000 workers per day travel into the mine, some going all the way to the bottom, which takes more than an hour and a half to reach. And it's no picnic. Temperatures in the mine can reach 60˚C (140˚F). The mine is so hot that ice slurry is pumped in to keep it cool enough for miners to work.

And the mine doesn't just produce gold. It also produces scientific discoveries! Bacteria were found there. There is no sunlight and no living matter to act upon. They derive their nutrition from the products that result when radioactivity interacts with the water and minerals that are present.

Miners work deep underground in the Mponeng mine.



The Mponeng mine is the deepest humans have ever traveled underground, but it's not the deepest we've ever dug. That honor belongs to the Kola Superdeep Borehole in Russia, which reaches 12,262 meters (7.6 miles) below the surface. The borehole is a scientific research endeavor to investigate the depths of Earth's crust. Discoveries at the borehole include fossilized plankton 6 km below the surface, pockets of hydrogen gas, and evidence of water saturation at 7 km deep.

This tower marks the top of the Kola Superdeep Borehole at the border of Russia and Norway.

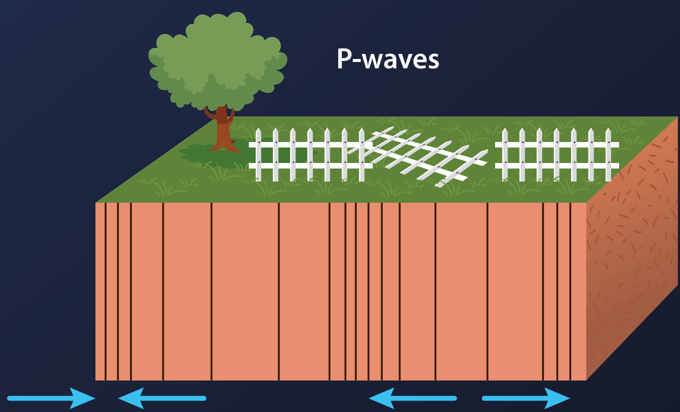
Seeing the Unseen

Humans can't dig into the layers of Earth to see what they're like. So how do scientists know anything about the layers?

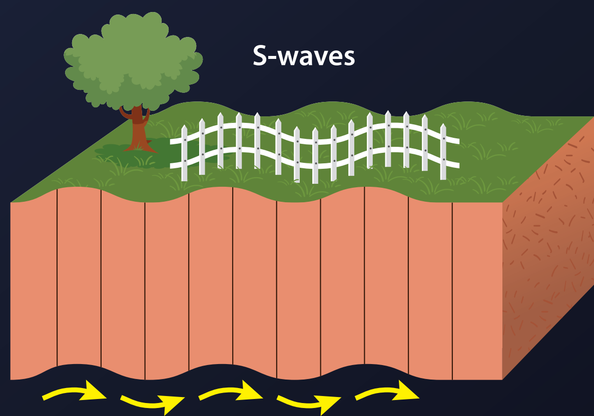
Scientists across the globe have to work together to gather information that gives evidence about Earth's layers. Stations are set up all over the world that record tremors using seismometers. When an earthquake happens, scientists can combine their data to see how the seismic waves tranfer energy through Earth.

Seismic waves move through Earth, causing readings to be recorded on seismometers as they reach Earth's surface once again. The type of wave, the time it takes to reach the seismometer, and the location of the seismometer all provide scientists with data about the material the wave passed through.

Scientists also use laboratories to study how different types of rock affect the waves that move through them, and they compare that data with the data gathered from seismometers. This tells them about the material of Earth's layers, in addition to the state of matter.



P-waves are seismic waves that cause compression and expansion of the material they move through. You can think of them like someone stretching and releasing a spring. P-waves can travel through solids, liquids, and gases.



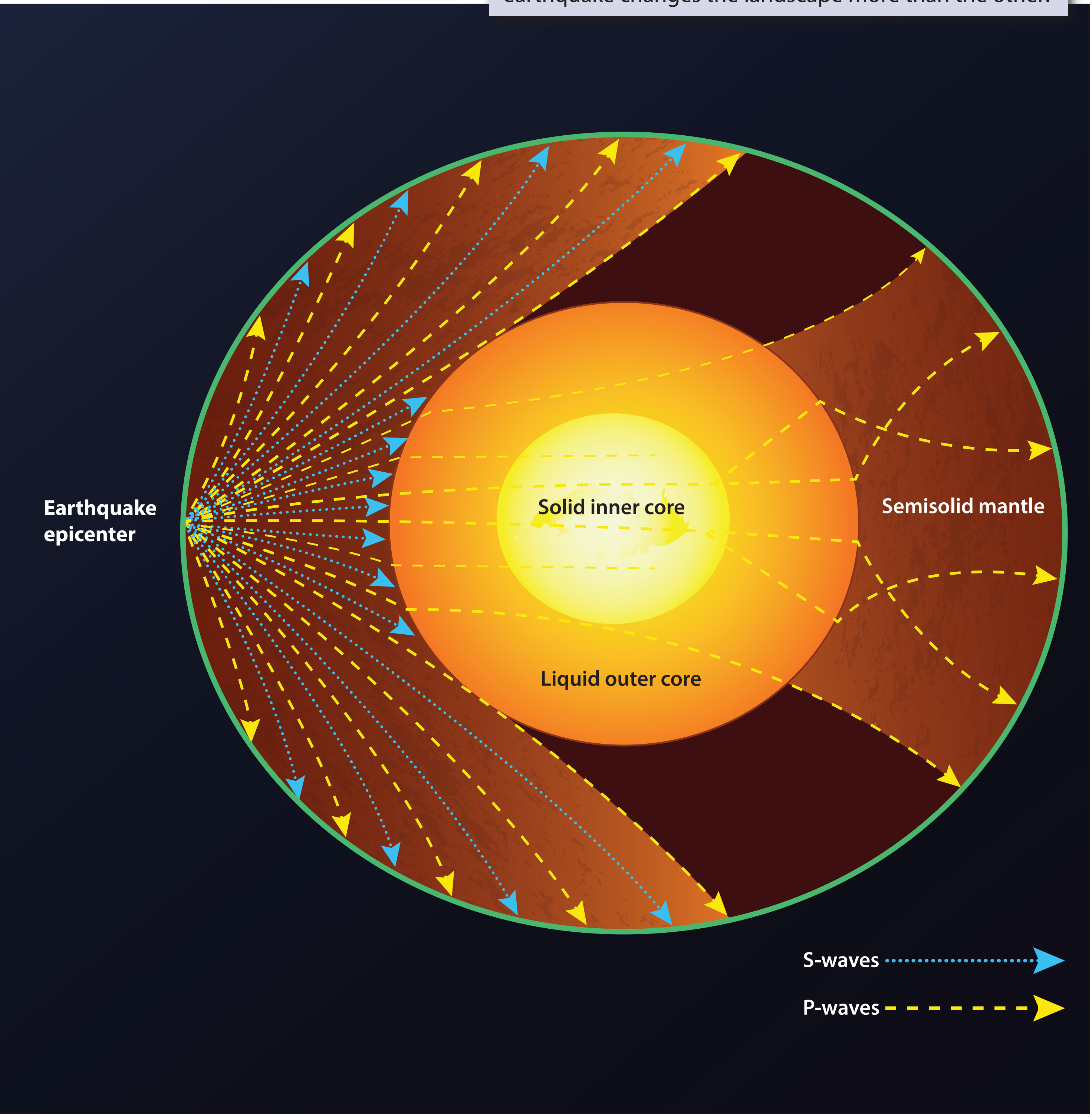
S-waves are seismic waves that cause objects on the surface to move at a right angle to the direction of the wave. You can think of them like someone shaking a jump rope back and forth. S-waves can travel through solid material but not liquid or gas.

Words to Know

A *seismometer* is an instrument used to detect waves from an earthquake, called *seismic waves*.

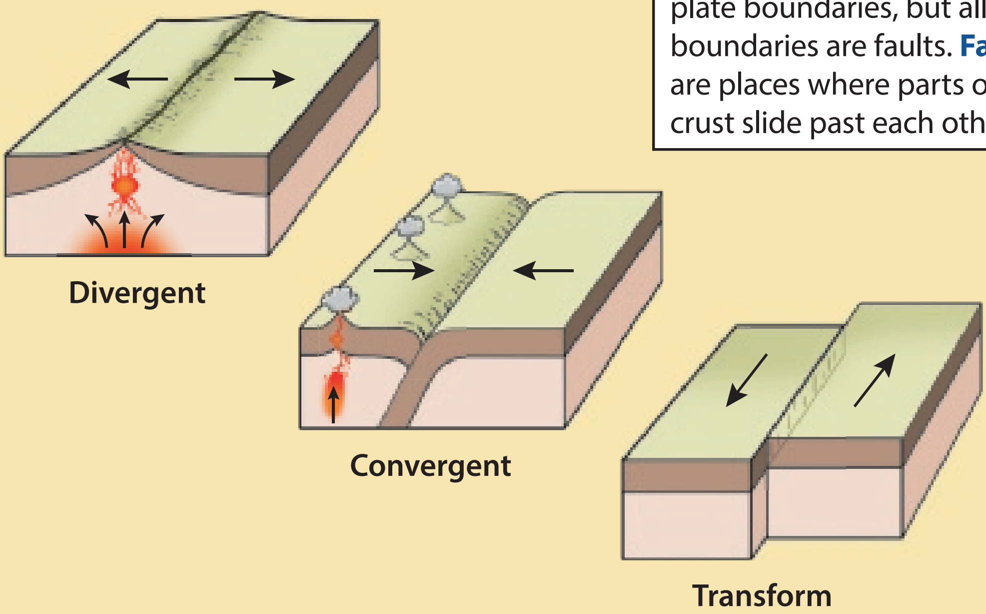
Connection

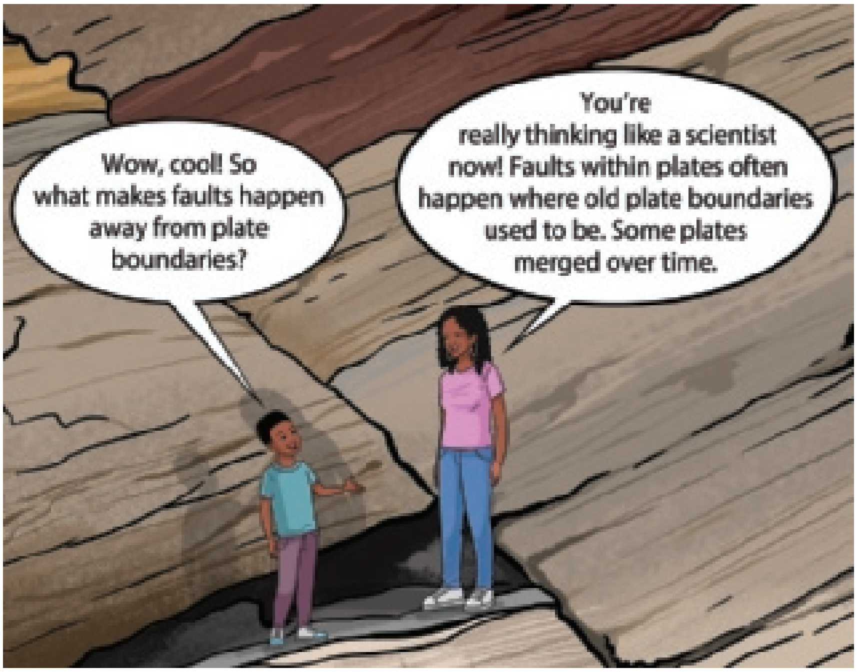
During an earthquake, P-waves travel the fastest and are the first to arrive at the seismometer, followed by S-waves. Do you think one type of wave from an earthquake changes the landscape more than the other?

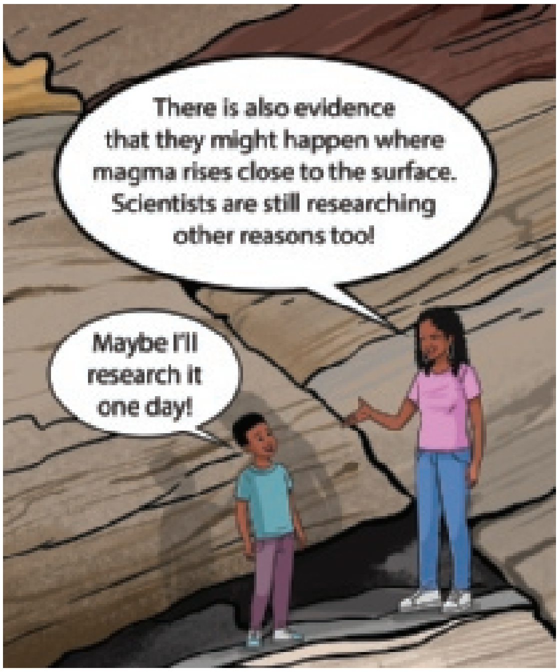


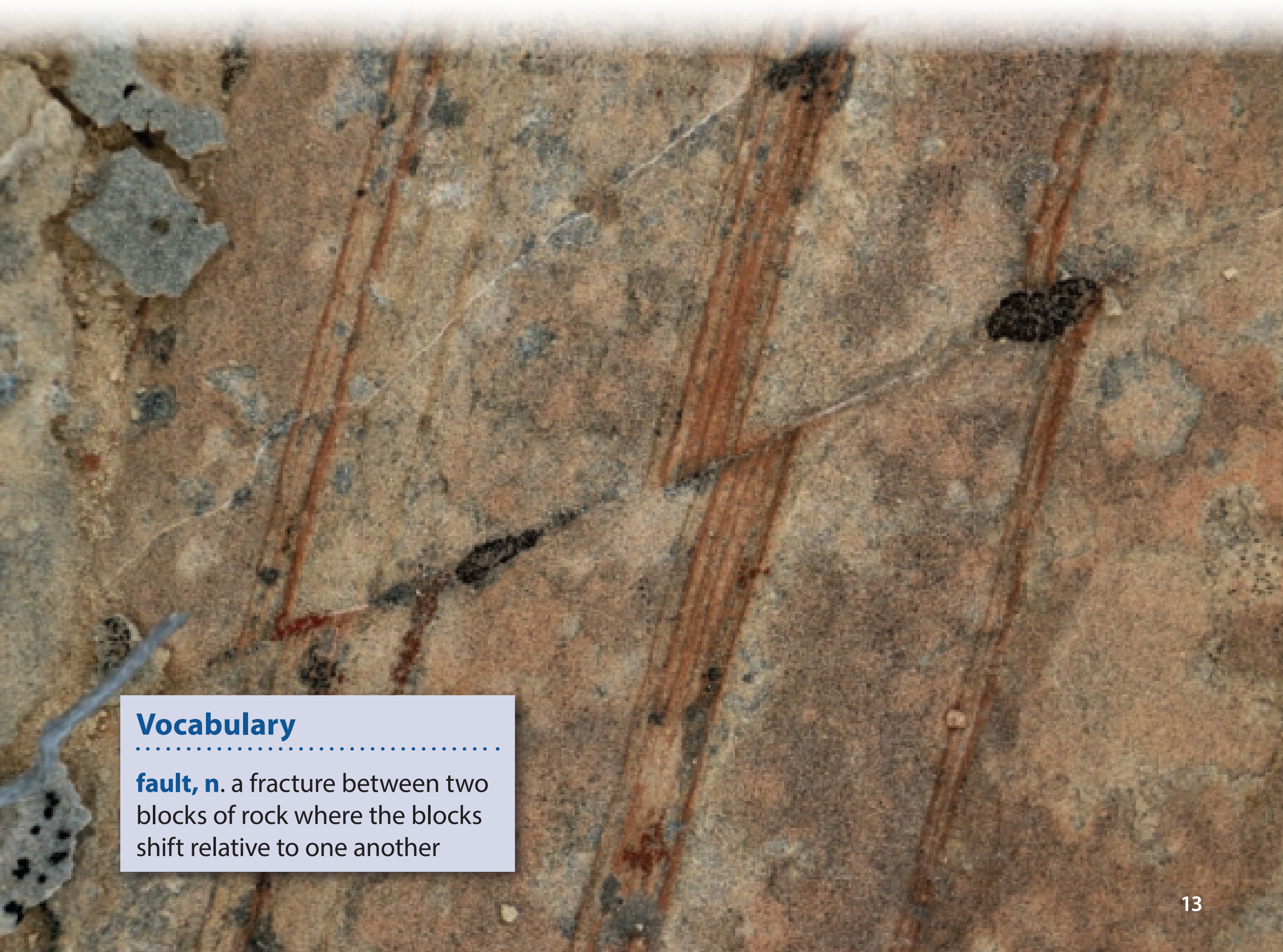
It's Not Their Fault

All faults do not occur at plate boundaries, but all plate boundaries are faults. **Faults** are places where parts of Earth's crust slide past each other.









Vocabulary

fault, n. a fracture between two blocks of rock where the blocks shift relative to one another

Wegener: A Science Outcast

The **theory of plate tectonics** is a relatively new one. In the early twentieth century, people didn't fully understand the changing nature of Earth's surface. Our current understanding of plate tectonics owes its beginnings to an unlikely source: a young German meteorologist named Alfred Wegener.

Wegener was born in 1880, and as a young man he studied physics, meteorology, and astronomy. Meteorology and climatology were new fields and drew his interest. He began joining expeditions to Greenland to both map its northern coasts and learn about polar weather and climate.

On these expeditions, Wegener became interested in paleoclimatology—the study of ancient climates. This, combined with his mapmaking endeavors, led him to notice that the coasts of the continents on either side of the Atlantic seemed to fit together like puzzle pieces. In addition, several fossils of identical species had been discovered in both South America and Africa. There was also evidence that the rock that made up the Appalachian Mountains in North America and the Caledonian Mountains in Scotland was the same rock.

Alfred Wegener proposed the idea of continental drift.

In 1915, Wegener proposed the idea of continental drift in a book that he published, stating that all the continents that exist today were once a single, large continent, which he called Urkontinent, which means *original continent*. However, World War I was by this

1922 – Wegener publishes his final version of his continental drift hypothesis.

1915 – Wegener first publishes his ideas about continental drift.

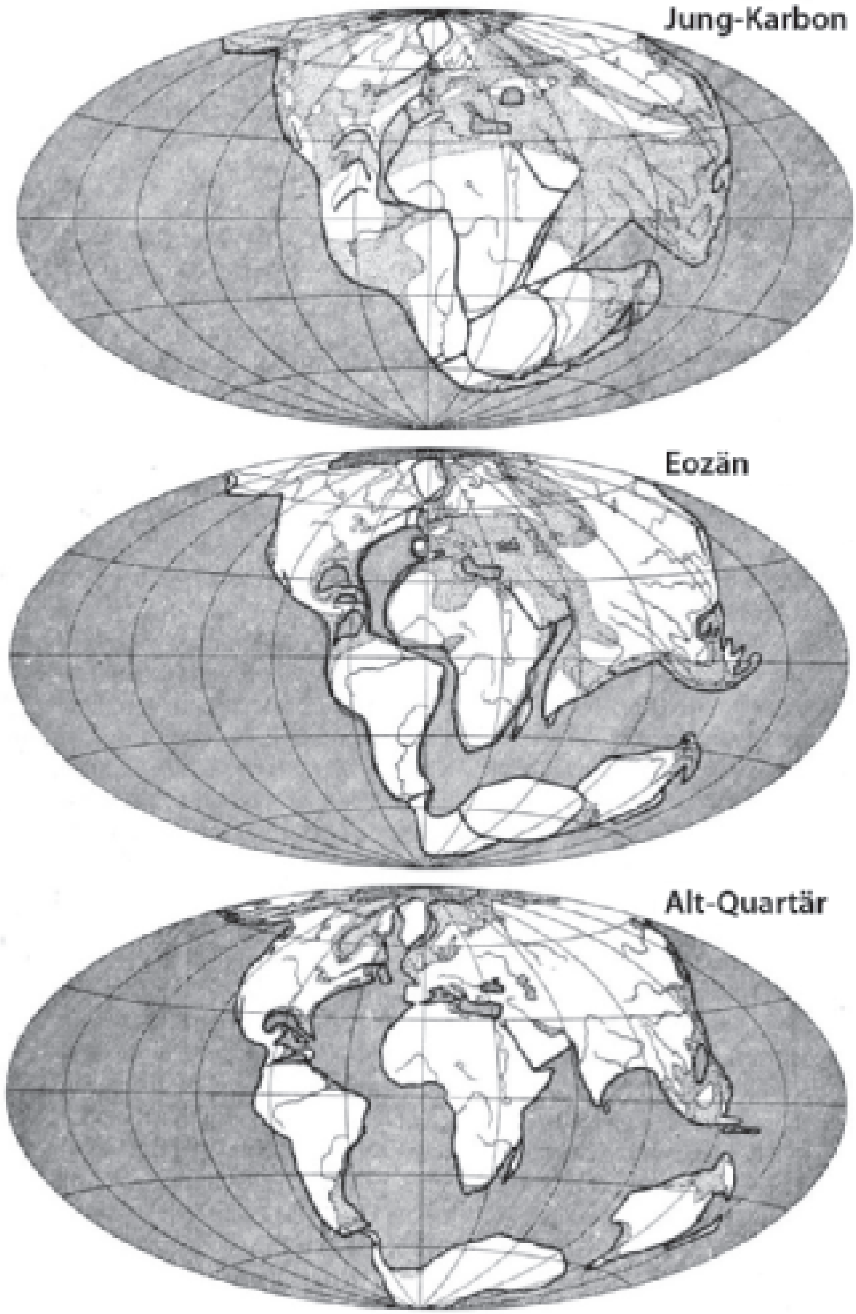
1926 – Wegener presents his research at a symposium in New York.

time well underway and would remain so for several more years, so the book was given little attention.

In 1922, Wegener published a revised version of his original book about continental drift, and in 1926, he presented his ideas to the American Association of Petroleum Geologists in New York City.

Yet Wegener's ideas were incredibly unpopular. Critics published papers tearing his book apart. Lecturers denounced his research. These people believed that Wegener had the right idea about movement of pieces of Earth's crust but very wrong ideas about the mechanisms for that movement. Wegener thought the continents plowed through the oceanic crust the way a ship plowed through ice. In fact, even the name he proposed, continental drift, betrays the heart of his misunderstanding—it's not just the continents that move; it's every portion of the crust both above and below the water.

Wegener died in 1930, and for years his ideas were ignored. However, in the 1950s, researchers began to consider Wegener's ideas once more, and developments in the next few decades showed the truth Wegener had been so close to uncovering. Today, Wegener is lauded as a pioneer in the work of tectonic theory.



This page from Wegener's book shows the positions of the continents as he hypothesized they once existed, as well as their movements over time.

Vocabulary

theory of plate tectonics, n. the generally accepted characterization of Earth's crust as large regions of rock slowly moving relative to each other

Journey to the Center of the Earth

Science Fiction

Fiction writers have told fantastic stories about Earth's mysteries, trying to make sense of the things that scientists had not yet discovered.

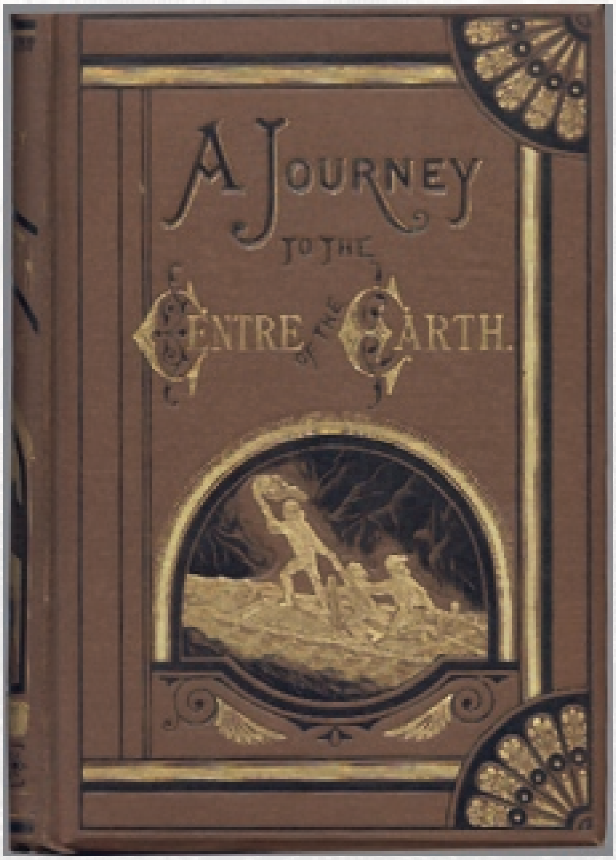
The excerpts here are from *Journey to the Center of the Earth* by Jules Verne, published in 1864. The story chronicles the adventures of an expedition miles underground, where they find plants, living animals thought to be extinct, and even human bones.

"And at this stage of our journey, according to all known laws on the increase of heat, there should be here a temperature of *fifteen hundred degrees of Reaumur.*"

"There should be—you say, my boy."

"In which case this granite would not exist, but be in a state of fusion."

"But you perceive, my boy, that it is not so, and that facts, as usual, are very stubborn things, overruling all theories."



"I am forced to yield to the evidence of my senses, but I am nevertheless very much surprised."

"What heat does the thermometer really indicate?" continued the philosopher.

"Twenty-seven six-tenths."

"So that science is wrong by fourteen hundred and seventy-four degrees and four-tenths. According to which, it is demonstrated that the proportional increase in temperature is an exploded error."

• • •

It was quite true. A vast, limitless expanse of water, the end of a lake if not of an ocean, spread before us, until it was lost in the distance. The shore, which was very much indented, consisted of a beautiful soft golden sand, mixed with small shells, the long-deserted home of some of the creatures of a past age. The waves broke incessantly—and with a peculiarly sonorous murmur, to be found in underground localities. A slight frothy flake arose as the wind blew along the pellucid waters; and many a dash of spray was blown into my face. The mighty superstructure of rock which rose above to an inconceivable height left only a narrow opening—but where we stood, there was a large margin of strand. On all sides were capes and promontories and enormous cliffs, partially worn by the eternal breaking of the waves, through countless ages! And as I gazed from side to side, the mighty rocks faded away like a fleecy film of cloud.

• • •

One thing startled and puzzled me greatly. How was it that I was able to look upon that vast sheet of water instead of being plunged in utter darkness? The vast landscape before me was lit up like day. But there was wanting the dazzling brilliancy, the splendid irradiation of the sun; the pale cold illumination of the moon; the brightness of the stars. The illuminating power in this subterranean region, from its trembling and Rickering character, its clear dry whiteness, the very slight elevation of its temperature, its great superiority to that of the moon, was evidently electric; something in the nature of the aurora borealis, only that its phenomena were constant, and able to light up the whole of the ocean cavern.

The tremendous vault above our heads, the sky, so to speak, appeared to be composed of a conglomeration of nebulous vapors, in constant motion. I should originally have supposed that, under such an atmospheric pressure as must exist in that place, the evaporation of water could not really take place, and yet from the action of some physical law, which escaped my memory, there were heavy and dense clouds rolling along that mighty vault, partially concealing the roof. Electric currents produced astonishing play of light and shade in the distance, especially around the heavier clouds. Deep shadows were cast beneath, and then suddenly, between two clouds, there would come a ray of unusual beauty, and remarkable intensity. And yet it was not like the sun, for it gave no heat.

1864 – Jules Verne publishes *Journey to the Center of the Earth.*

1936 – Inge Lehmann discovers the makeup of Earth's core.

Science Fact

At the time this story takes place, Earth's interior was a mystery.

It wasn't until 1936, 72 years after the publication of *Journey to the Center of the Earth*, that the makeup of Earth's interior became known. Inge Lehmann, a Danish geophysicist, examined readings from seismometers following a strong earthquake in New Zealand. She concluded that Earth's interior included a solid inner core and liquid outer core.

Inge Lehmann discovered the makeup of Earth's interior.

Of course, Verne's story was science fiction. However, the science fiction speculations of the past often lead to the scientific discoveries of the future. Human curiosity about the unknown abounds, and scientists use the scientific method to make new discoveries all the time. In this case, the fiction was shown to be merely that: fiction. Yet it is entirely possible that the curiosity that drove Verne to write his novel about Earth's interior was the same sort of curiosity that led Lehmann to discover the truth of it.

Wartime Discoveries

Important evidence supporting plate tectonics came from an unlikely source: the United States Navy.

As early as the mid-nineteenth century, devices called magnetometers had been used to measure the strength of Earth's magnetic field. In 1936, a pair of German scientists invented a magnetometer that could differentiate between Earth's magnetic field and ferromagnetic objects. In 1941, a Russian-born scientist working in a Pittsburgh lab developed a portable fluxgate magnetometer.

However, by 1941, the United States had not only built up a formidable navy, it was supplying Allied forces with ships. Additionally, U.S. fleets, both military and merchant, had a great interest in detecting and avoiding or disabling enemy submarines.

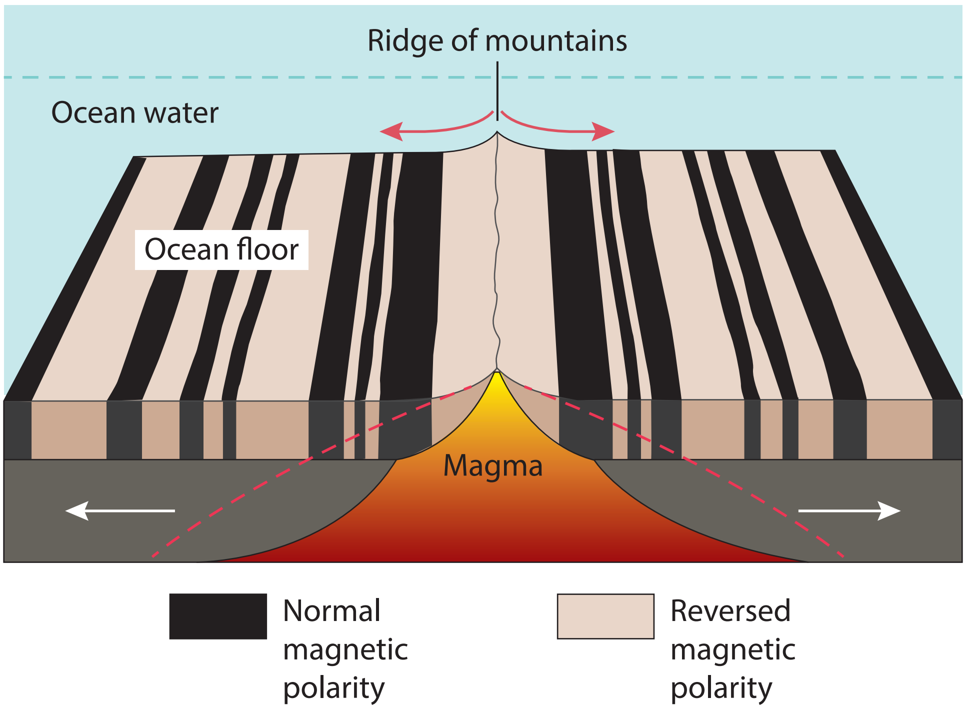
Word of the portable magnetometer reached naval command, and by 1942 the Navy was employing these devices in airplanes to spot enemy subs.

The device was so precise and accurate that researchers began using it to investigate the ocean floor. And they found something

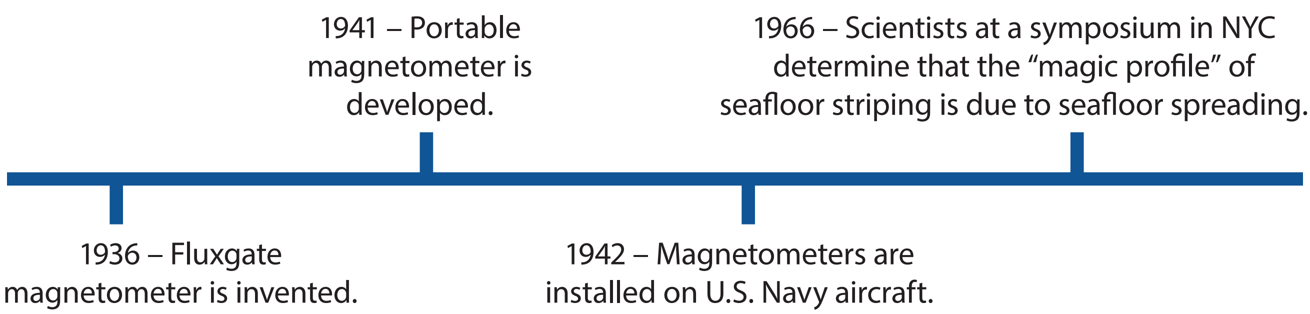
German U-boats, like this one, were widely used in both World War I and World War II.

remarkable. They found that the ocean floor had long bands in which the magnetism within them was oriented in opposite directions. Some long bands had magnetic fields oriented north to south, while others were south to north. What's more, the size and arrangement of the bands were the same to the left and right of a ridge of mountains on the ocean floor. We now know that the bands are caused by reversals in the polarity of Earth's magnetic field, which occur in frequent but irregular intervals.

In 1966, a symposium of Earth scientists met in New York City to investigate and understand measurements of what had been dubbed the "magic profile" of stripes on the floor of the Atlantic Ocean. This evidence, along with evidence of the movement of the continents gathered by Wegener and other researchers, led to our modern understanding of plate tectonics, including what is now called seafloor spreading.



Stripes of ferromagnetic material along the ocean floor show alternations in polarity, with identical stripes on either side of the mid-ocean ridge.



Tools of the Trade

Connection

NASA uses magnetometers on space satellites. These tools are more sophisticated now than when they were used to detect submarines in the early 1900s. NASA relies on fluxgate magnetometers to collect data about magnetic fields in space.

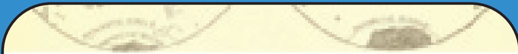
1880 – Modern seismometer is invented.

1900 – Maps provide early evidence for plate tectonics.

1941 – Portable fluxgate magnetometer is developed.

1987 – The U.S. Geological Survey (USGS) begins using GPS data to measure tectonic plate movement.

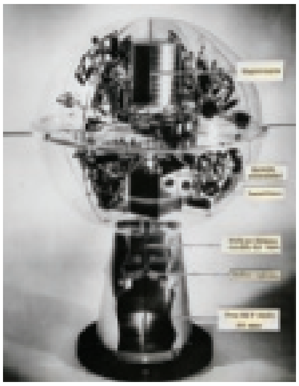
2004 – Computer modeling shows what Earth's surface looked like in the past.

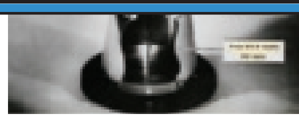


Most Recent Comments

Andrew Hyde

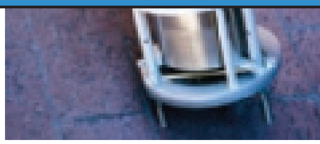
I looked up the fluxgate magnetometer. It sounds like something out of a Marvel movie! It works by sensing magnetic fields. People first used them to find submarines underwater. That was around the time of World War 2. Then they were used to help make maps of the seafloor.





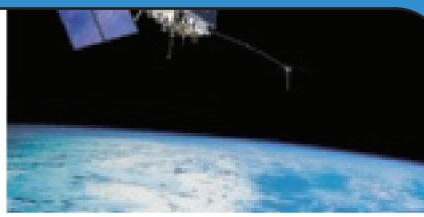
Faye Wellman

My tool is the seismometer. Seismometers are tools that can sense when the ground moves and shakes. They are put in the ground at different spots. If they detect shaking and noise in the earth, it could mean there is an earthquake or a volcano erupting somewhere!



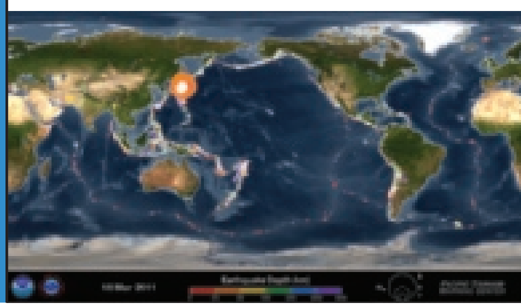
Jordan Kim

I picked GPS tools. There are GPS satellites orbiting Earth in space. They send signals down to scientists on Earth. Scientists use the data to see how much, and how fast, Earth's tectonic plates are moving.



Emma Huber

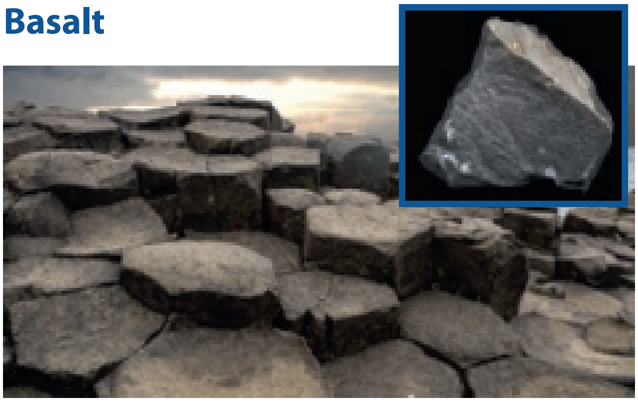
I looked up computer models. Scientists didn't start using computers until the 21st century. Computer models help scientists study how tectonic plates move. The models also help them see how plates looked in the past and predict how the plates will move in the future.



What's That Rock?

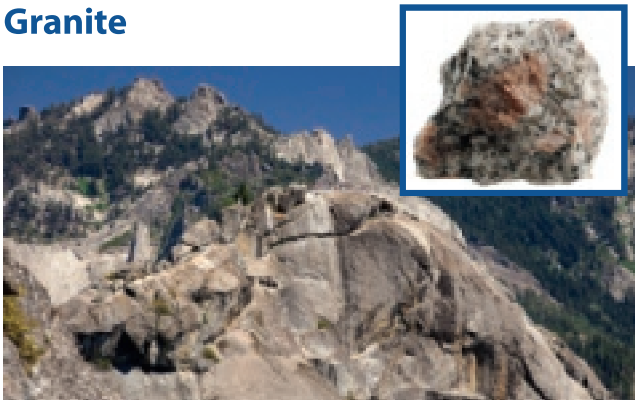
Do you know any of the kinds of rocks that are near where you live? Take a look at this collection, and see if any of your rocks are these types!

Basalt



Basalt is a type of igneous rock and in fact is the main type of volcanic rock in Earth's crust, making up more than 90% of all volcanic rock. Igneous rocks are formed when hot magma cools on or near Earth's surface. It is said that igneous rocks are "born in fire."

Granite



Granite is another common igneous rock. It forms only underground, the result of slow cooling of magma. This allows large crystals to form within the rock, which can vary in color depending on type. Granite is highly prized as a building material due to its hardness and impermeability.

Marble

Marble is a well-known metamorphic rock. Metamorphic rocks are those that are formed by heat and pressure acting on other rocks. It forms when limestone is subjected to heat and pressure underground. Marble's softness and gleaming surfaces make it a sought-after material in sculpture, both in modern and ancient cultures. However, it is particularly susceptible to acid rain, so many outdoor marble carvings have been badly degraded over time.

Slate

Slate is another kind of metamorphic rock. It forms when shale is subjected to heat and pressure underground. Unlike marble, slate is foliated, meaning it is composed of layers. This makes it very easy to split into thin slabs, which is why it is a common material for roofing tiles. Chalkboards and sidewalks were once made out of slate.

Limestone

Limestone is a sedimentary rock made mostly of calcium carbonate. It frequently forms in bodies of water, because dead organisms sink to the bottom of the body of water. This process continues over millions of years, forming layer after layer. The pressure of these layers pushing down, combined with chemical reactions within the rock, cement the sediments together, forming limestone. Limestone has often been used as a building material but is especially susceptible to damage from acid rain.

Sandstone

Sandstone is a sedimentary rock formed from deposition of sand eroded from other types of rocks and minerals. Layers of sand build up on top of each other until pressure from the layers pushing down—and chemical processes—cement the grains of sand together. Sandstone has long been used as a building material and to make tools and sculptures. Sandstone is porous, allowing water to seep through, so sandstone deposits are important for the formation of aquifers, which are natural underground water reservoirs.

Fossils

Fossil Science Fair Project

by Ellen Ashton, Cualli Hernandez Salazar, and Olivia Blanc

Ms. Chapa's 10th Grade Class, Whitestone H.S.

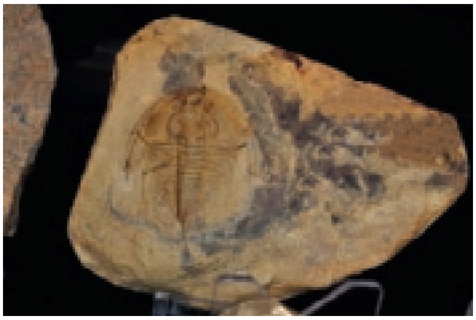
Introduction

Recently, on a class field trip to Mineral Wells Fossil Park, we found a fossil of a shell. We are not sure how old the fossil is, and we do not know what organism left the fossil. We found several other fossils as well.

Our hypothesis: We can determine the age of our fossil using the other fossils where it was found and use this age to find out what organism it is.

Unknown Fossil

Fossil A

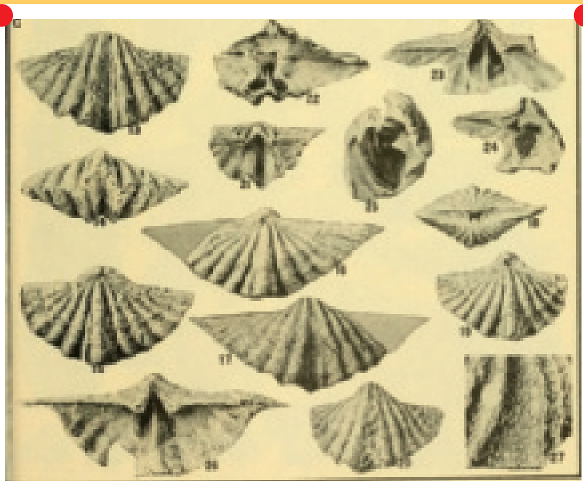


Fossil B

Materials and Methods

Our fossil, which we called Unknown Fossil, and three other fossils from the same area were used. We called the others Fossils A, B, and C. We found Fossils A and B on the same day and in the same general location where we found the Unknown Fossil. Fossil C is a fossil provided by staff at Mineral Wells Fossil Park, which was found in the same general location and the same rock layer where we found the Unknown Fossil.

We researched the fossils by asking experts on staff at Mineral Wells Fossil Park, looking up fossils in the book *National Audubon Society Field Guide to North American Fossils* by Ida Thompson and Townsend P. Dickinson, and searching online.



Fossil C

Results

The table contains information we found about each fossil.

Fossil	Organism	Time Range Organism Lived
Fossil A	*Petalodus* (shark tooth)	323–251 million years ago
Fossil B	*Ditomopyge* (trilobite)	360–230 million years ago
Fossil C	*Punctospirifer* (lamp shell brachiopod)	376–252 million years ago

The time ranges of all the fossils are very similar. We used these ranges to research organisms that lived during that time. We discovered that fossils from a family of animals called nautilus are common in North America. These organisms have cone-shaped, straight shells. They lived from 490 to 230 million years ago. Based on the data from other fossils and the description of this family, we identify our fossil as a species in the family Orthoceratidae.

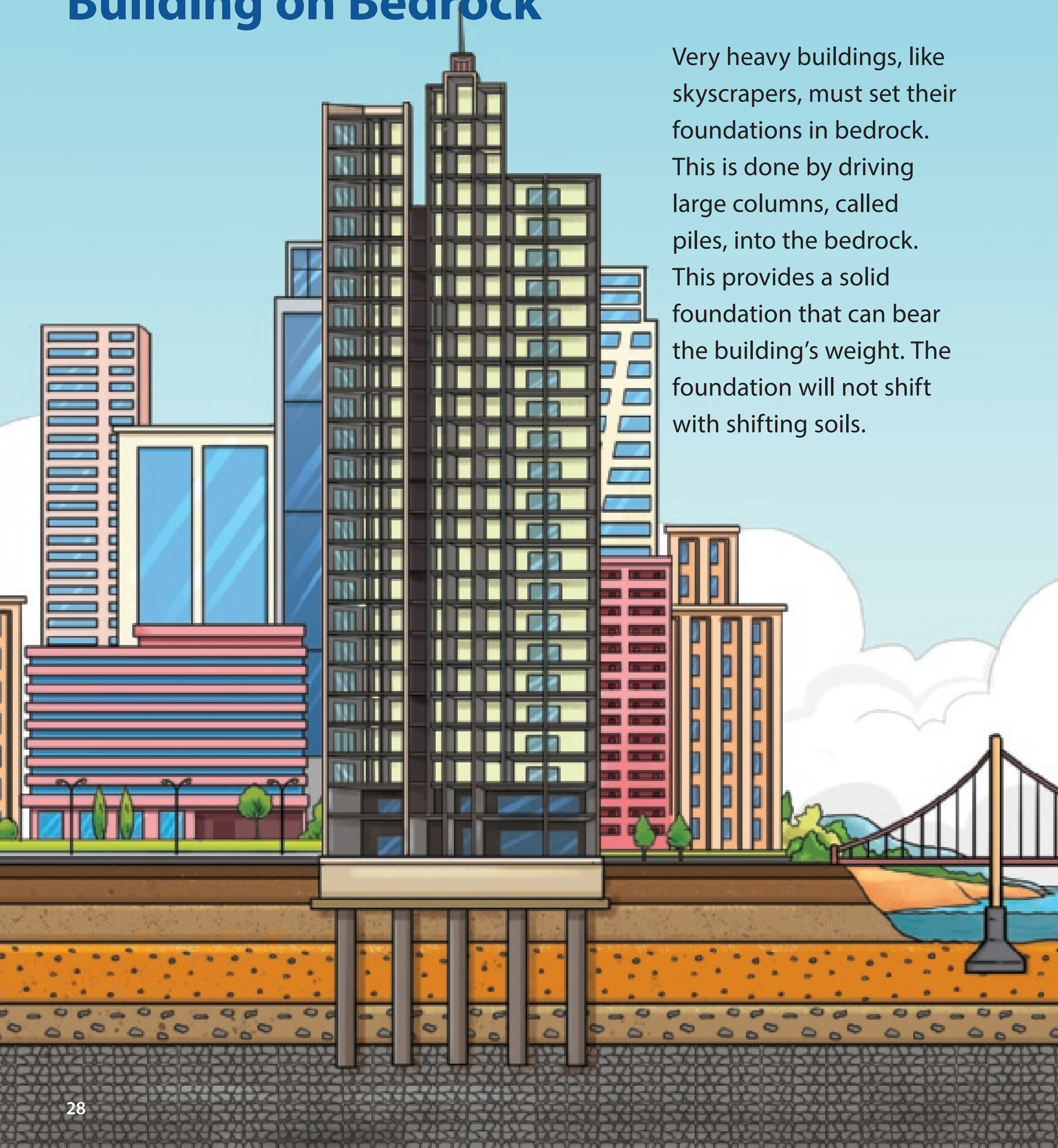
Discussion

Our results show our hypothesis is correct. We used different fossils with known ages that were found near our fossil to figure out the age of our fossil. We then looked up known organisms with straight, smooth shells that lived at that time and determined that our fossil was a kind of nautilus.

This technique is called relative dating. In our case, we used three other fossils, all with similar age ranges, to narrow down the age of our fossil. This helped us figure out in which time period our fossil lived, which helped us figure out which organism it was.

Building on Bedrock

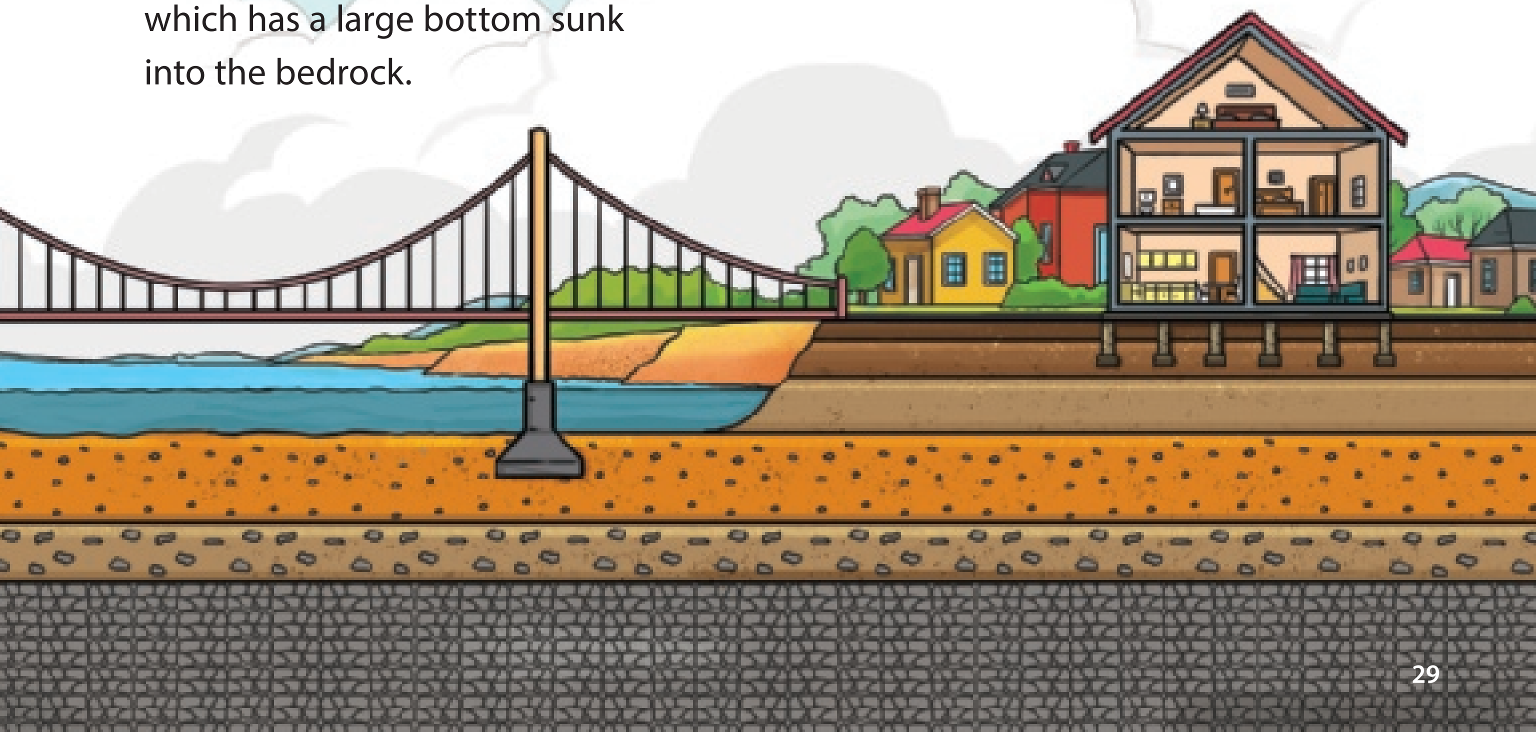
Very heavy buildings, like skyscrapers, must set their foundations in bedrock. This is done by driving large columns, called piles, into the bedrock. This provides a solid foundation that can bear the building's weight. The foundation will not shift with shifting soils.



Engineers must consider many factors when designing a building, not just which type of foundation to use. They must be aware of any underground water and note whether the bedrock is the same type of rock across all parts of the foundation. Engineers building on shallow foundations in soil should be certain that no part of the foundation overlaps bedrock, because this can cause cracks in the building if the soil shifts, since the part of the building on bedrock will remain in place.

Many large bridges also set foundations in bedrock, which provides stability for the bridge. Most bridges use a foundation called a caisson, which has a large bottom sunk into the bedrock.

Lighter buildings, such as homes and small stores, can set foundations in soil. These foundations may shift as soil shifts, resulting in small cracks, depending on how the foundation is set and the type of soil it rests on.



Volcano Lessons

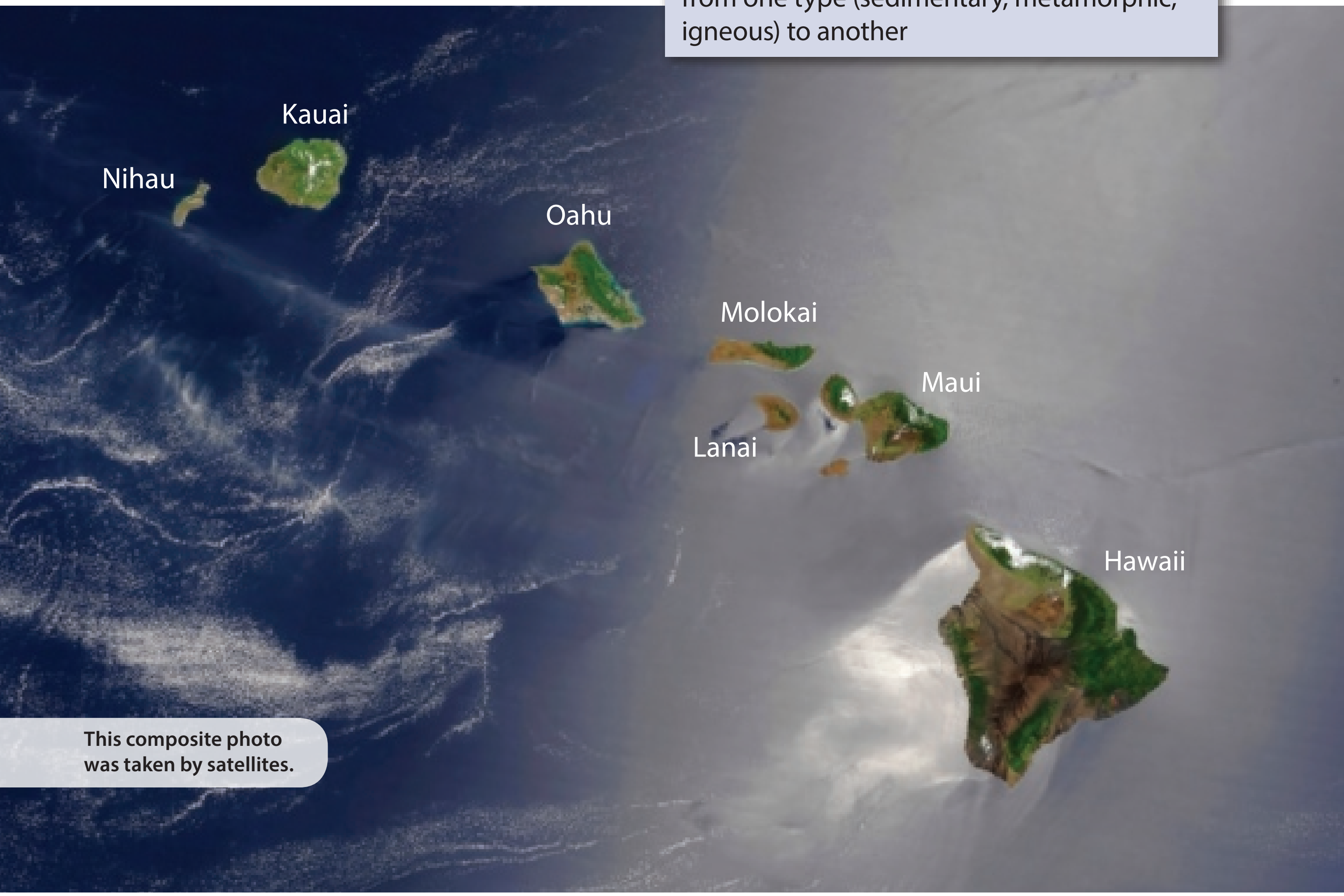
We can learn a lot from volcanoes. We can see the **rock cycle** in action with the formation of new igneous rock. We can tell how new ecosystems form even when there is no soil. We can even learn where the edges of tectonic plates are, because earthquakes occur most frequently here and volcanoes often spring up in those places.

But did you know volcanoes also provide a snapshot of how Earth's plates are moving?

Consider the Hawaiian Islands. This chain of islands sits in the middle of the Pacific Ocean, far from the edges of the Pacific Plate.

Vocabulary

rock cycle, n. the ongoing transition of rock from one type (sedimentary, metamorphic, igneous) to another



This composite photo was taken by satellites.

What do you see when you look at this photo of the Hawaiian Islands to the lower left? You might notice that they line up, arcing from one corner of the photo to the other.

This is no accident. The Hawaiian Islands are the result of a hot spot, which is a place where magma rises up and breaks through the crust. Kauai was formed from volcanic eruptions 4 million years ago. The biggest island, Hawaii, which is the easternmost island, is still forming! The same hot spot that formed Kauai (as well as the tiny islands to the west of Kauai) also formed the Big Island and all the other Hawaiian Islands.

This shows scientists that the Pacific Plate is moving west and slightly north. As the plate moves, it passes over the hot spot below, and new islands are formed in the chain. New lava flows from hot spots and down into the sea to cool, forming new land.

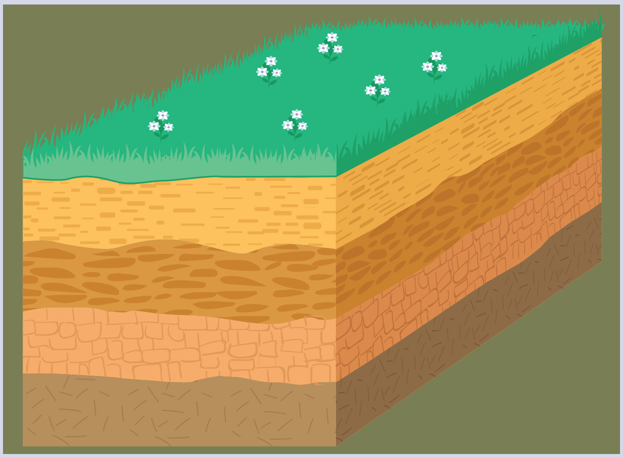
The dotted line of the Hawaiian Islands is a striking visual reminder that Earth's surface is constantly changing. And up close, the Hawaiian volcano Kilauea can change Earth's surface right before your eyes!

Maui's famous Black Sand Beach is the result of weathering of the black igneous rock that makes up much of the island. The soil formed from this rock is very rich, leading to the lush vegetation visible in the photo.

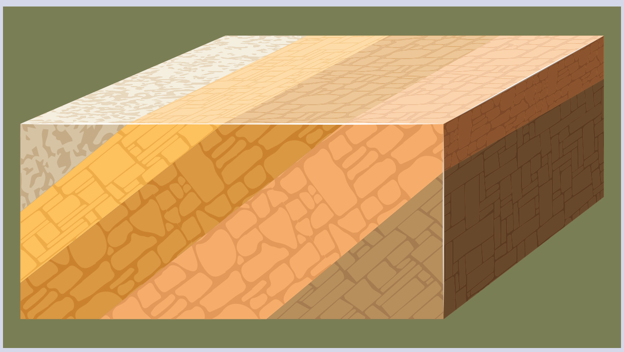
The Laws of Layers

The layering of rocks is not haphazard. How does it happen?

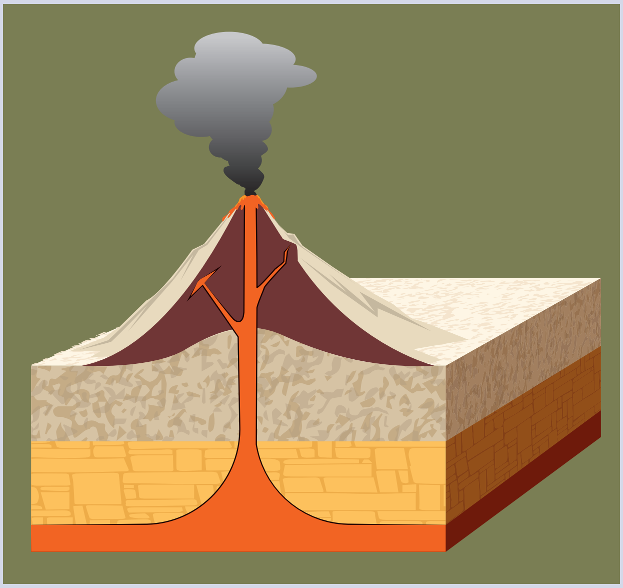
These rock layers in Canyonlands National Park in Utah have been laid down in a process geologists now understand and refer to as "laws."



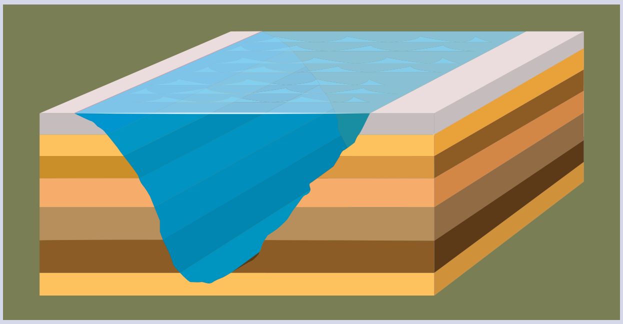
Geologists have developed a concept called the **law of superposition**, which states that if the rock layers have not been disturbed, older layers are lower, and newer layers are higher.



The **law of original horizontality** states that layers of sedimentary rock were originally flat, even though they might now be angled, which can happen due to events such as uplift and folding.



The **law of cross-cutting relationships** states that, if a layer cuts through other layers, the layer cutting through is the youngest layer. This layer is usually igneous rock, which forms when magma pushes through rock layers that already exist.

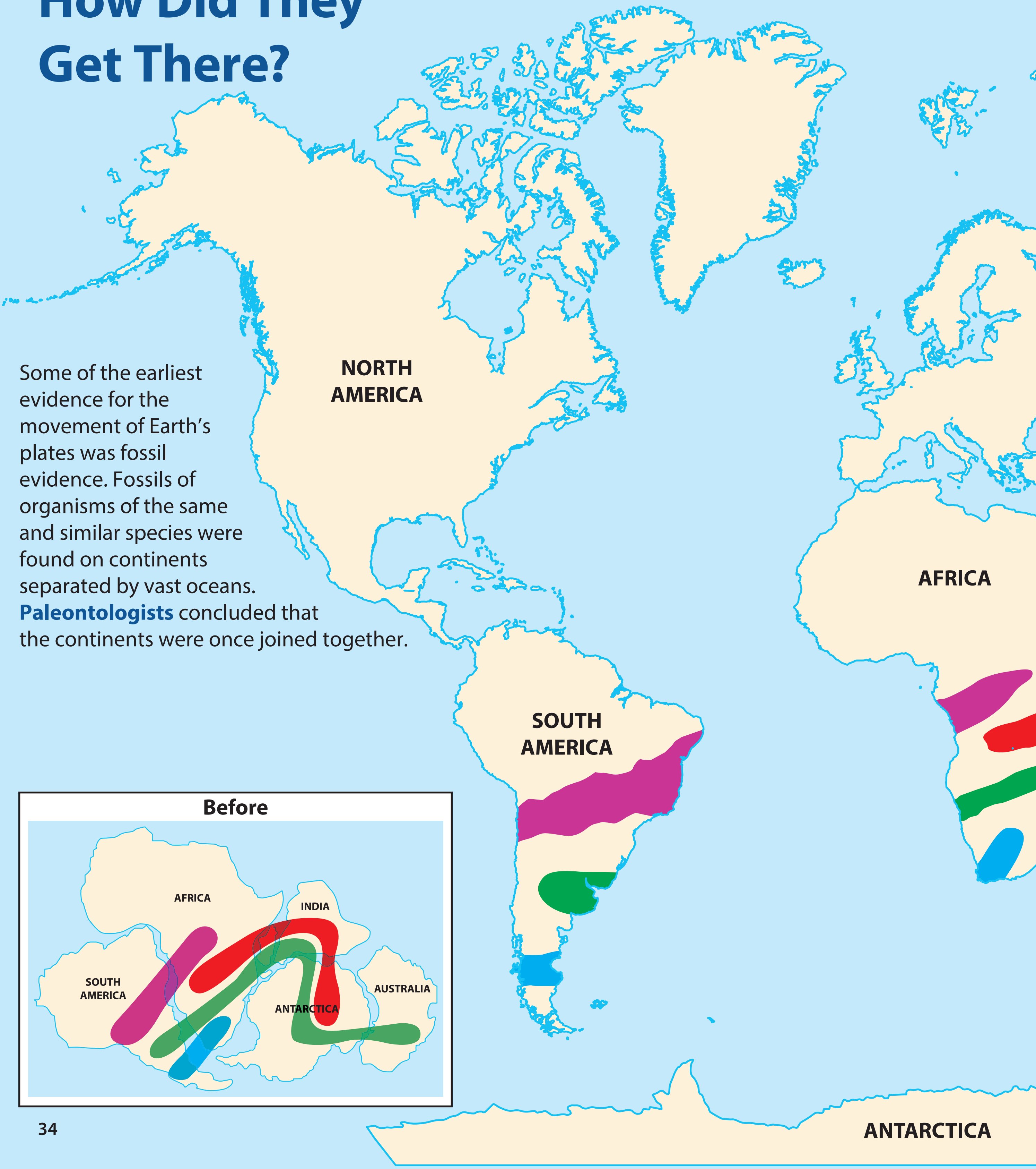


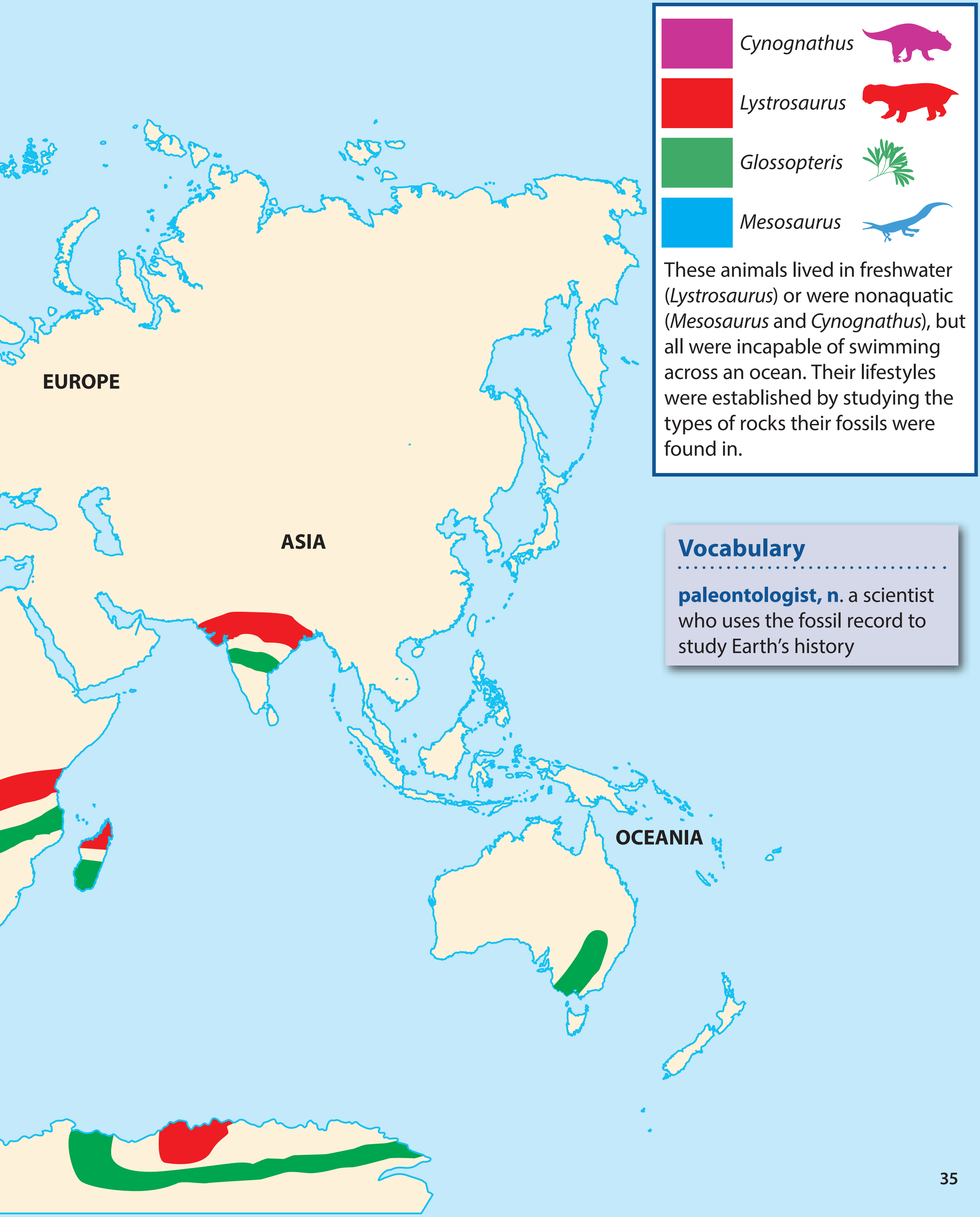
The **law of lateral continuity** states that rock layers are continuous in all directions until they meet an obstacle or are worn away by an eroding force, such as a body of water.

Geologists can use these laws as a guide to determine the relative ages of rock layers. They can also use radiometric dating to determine the absolute ages of rock layers. They combine these methods to construct a history of Earth's surface and predict how it might look in the future.

How Did They Get There?

Some of the earliest evidence for the movement of Earth's plates was fossil evidence. Fossils of organisms of the same and similar species were found on continents separated by vast oceans. **Paleontologists** concluded that the continents were once joined together.





These animals lived in freshwater (*Lystrosaurus*) or were nonaquatic (*Mesosaurus* and *Cynognathus*), but all were incapable of swimming across an ocean. Their lifestyles were established by studying the types of rocks their fossils were found in.

Vocabulary

paleontologist, n. a scientist who uses the fossil record to study Earth's history

Unsolved Mystery: The Marianas Trench

MysteryOfTheTrench.com

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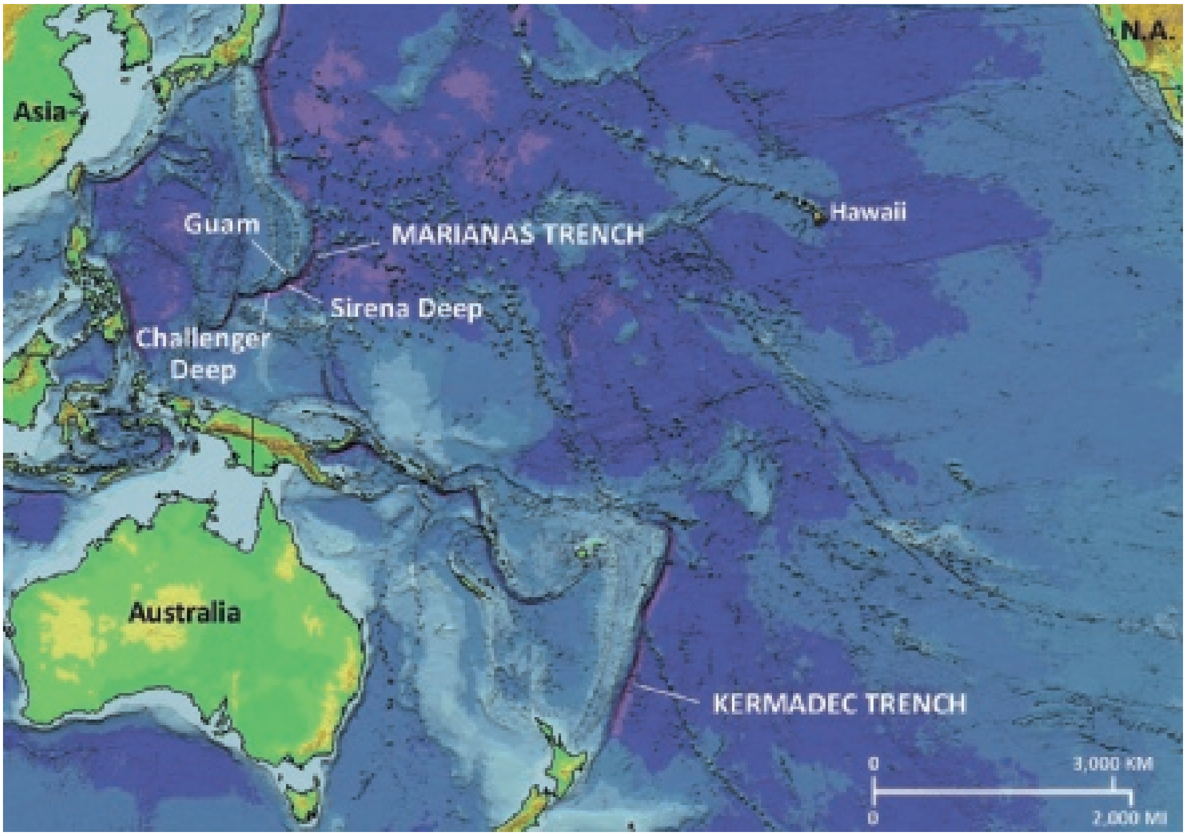
The Unfathomable Fathoms of the Marianas Trench

Humans are natural explorers, finding routes to go where no human has ever dared, from the coldest reaches of Antarctica to the tallest peaks of Mount Everest and even setting foot on the moon. But part of our own planet remains a mystery: the Marianas Trench.

The Marianas Trench is a crescent-shaped deep-ocean trench located in the Pacific Ocean. It is the deepest ocean trench in the world, known to be over 10,000 meters (6.2 miles) deep but believed to be more than 11,000 meters deep in some places. This deeper measurement is unverified, however, not because no one wants to know, but because exploring the trench is incredibly difficult.



The Marianas Trench is in the Pacific Ocean, near the Mariana Islands, for which it was named.

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Charting the Trench

The first measurements of the trench were taken in 1875 on the Challenger Expedition, which was a series of scientific oceanic expeditions conducted by British scientists. Measurements were made with a weighted rope and found the trench to be 8,184 meters deep.

This submersible was used by Victor Vescovo on his journey to Challenger Deep.

In 1951, more precise measurements were made using sonar, a technique known as echo sounding. Measurements showed the deepest parts of the trench to be 10,900 meters deep. This part of the trench was dubbed Challenger Deep in honor of the first expedition to measure the trench.

Since 1951, many other surveys of the trench have been made, all of which have used echo sounding to take measurements, although the devices that emit and record sonar waves have varied.

Deep Dives

Not content with merely taking sonar measurements from the water's surface, humans have also journeyed into the Marianas Trench. Several intrepid people have personally visited the depths of the trench in submersibles. American explorer Victor Vescovo holds the record for the deepest journey, reaching 10,927 meters in May 2019. Uncrewed submersibles have also been sent into the trench. These vessels help conduct scientific research.

The supergiant decapods found in the Marianas Trench can measure over 30 centimeters long.

Research is focused on both mapping the bottom and investigating organisms that live there. Life at such depths is incredibly difficult. Pressures reach 1,086 bars (15,750 psi), and light cannot penetrate. Yet life does exist there, from tiny organisms that inhabit the muddy bottom to supergiant decapods, a type of crustacean that looks similar to shrimp.

Connection

Filmmaker James Cameron, known for movies such as *Aliens*, *Titanic*, and *Avatar*, has a passion for underwater exploration. Cameron journeyed to Challenger Deep in a submersible, where he was able to explore the depths of the Marianas Trench for four hours. According to reports, Cameron found candy wrappers and sea creatures at the deepest part of the Marianas Trench.

Visit the Natural Wonders!

For your family vacation this year, Fortes Travel Agency recommends a tour of the Natural Wonders of the World, featuring wonders shaped by processes operating at Earth's changing surface.

Mount Everest

Nepal

Mount Everest, by some standards the tallest mountain on Earth, is a peak within the Himalayan Mountains. These mountains are still being uplifted! The Himalayas are thrust up where the Indian Plate collides with the Eurasian Plate. This mountain is beautiful to behold, but climbing it is only for well-trained, experienced climbers. The climb is so dangerous, it claims an average of five lives per year.

Parícutin

Michoacán, Mexico

Parícutin, a cinder cone volcano, sprang suddenly from the ground in 1943. Scientists have flocked to the volcano since then, as they are able to observe it during its geologic infancy. Parícutin, like other volcanoes in the region, owes its existence to the subduction of the Rivera and Cocos Plates beneath the North American Plate. Guided hiking tours are available for those who dare to get a close look at the volcano.

The Grand Canyon

United States

The Grand Canyon was formed by the Colorado River, which cuts into the rock that was once a plateau. The rock was uplifted by tectonic forces, allowing the river to flow quickly through it. The layers of rock exposed by this weathering and erosion give geologists a window into Earth's history. Rock at the bottom of the canyon is about 1.7 billion years old, while rock at the top is only about 6 million years old.

Victoria Falls

Zambia and Zimbabwe

The largest waterfall in the world, Victoria Falls is part of the Zambezi River. The river flows over a basalt plateau and spills into a gorge formed by a crack in the plateau. The basalt plateau began to break apart about 200 million years ago as the tectonic plates in the region pulled apart. Visitors to the region enjoy swimming in natural pools formed by the river, as well as observing the wildlife in the area on guided safaris.

Rio de Janeiro Harbor

Rio de Janeiro, Brazil

The harbor at Rio de Janeiro lies within Guanabara Bay. Flanking the bay are towering, pillar-like hills and steep cliffs. The bay itself is created by the erosion of sedimentary rock along the shore of the continent, while stronger metamorphic rock makes up the crags left behind. Rio de Janeiro is a very large city, with a population of over 6 million people, so visitors can find plenty to do during their stay.

Book your trip today!

Is Yellowstone About to Explode?

The Status and Potential Threat of the Yellowstone Volcano

Rachel Vargas, Ashton McInnis, and Emmanuel Moreno Cortes

Introduction

Yellowstone volcano is an active volcano in the northwest region of the United States. It is a hot spot. Magma rises through the crust here just as in Hawaii. It has magma just beneath its surface, which gives rise to the many geysers and hot springs in the area. Research has shown that an eruption of the Yellowstone volcano 2.1 million years ago caused ash to be blown high into the atmosphere. It spread across a large portion of North America, creating a layer of ash thousands of kilometers in area and as much as 30 centimeters deep. It also decreased temperatures across the globe. The most recent eruption occurred 70,000 years ago. Since that time, magma has been building beneath the surface, creating pressurized magma chambers that will explode violently during the next eruption. It is important for us to know the conditions of the volcano and evaluate whether it poses a risk to life in North America and around the globe.

Methods

We used data gathered by the Yellowstone Volcano Observatory (YVO). This is a monitoring group that observes and records data about volcanic activity in the Yellowstone Plateau. Data used in our models included observations of seismicity and ground deformations. We used both Swarm and Ash3D to determine the likelihood of an eruption and its effects, should one occur.

Results

Frequency of earthquakes was tracked both per quarter and cumulatively (Fig. 1).

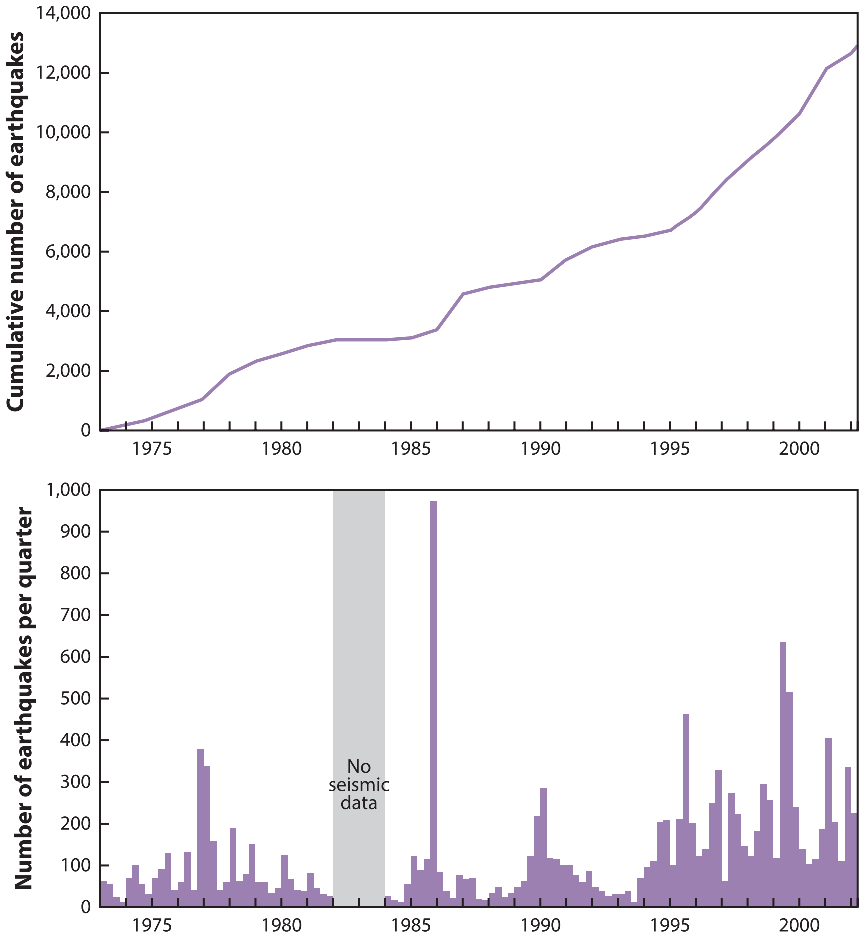


Figure 1. Earthquakes in the region have been monitored since 1973.

Ground deformations were gathered via satellite and confirmed by ground-level monitors, as shown in Fig. 2.

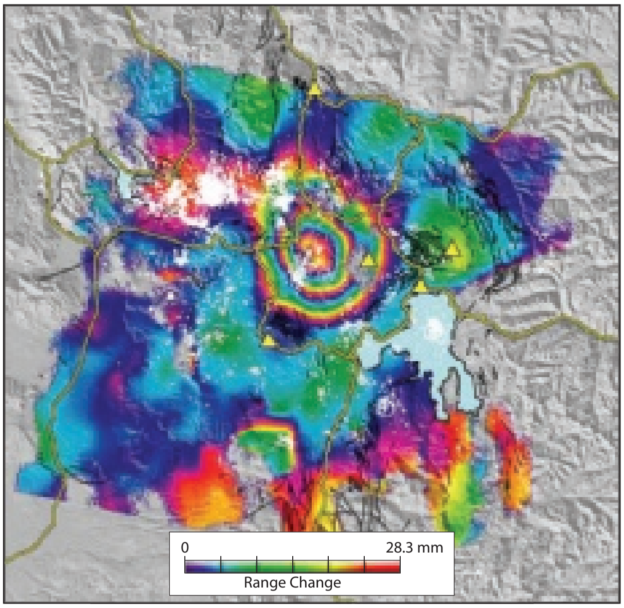


Figure 2. Elevation changes in the area were monitored by satellite between 1996 and 2000. Yellow triangles represent GPS stations, and white dots represent earthquakes.

Spread of the ash cloud in the event of an eruption was modeled using Ash3D, as shown in Fig. 3.

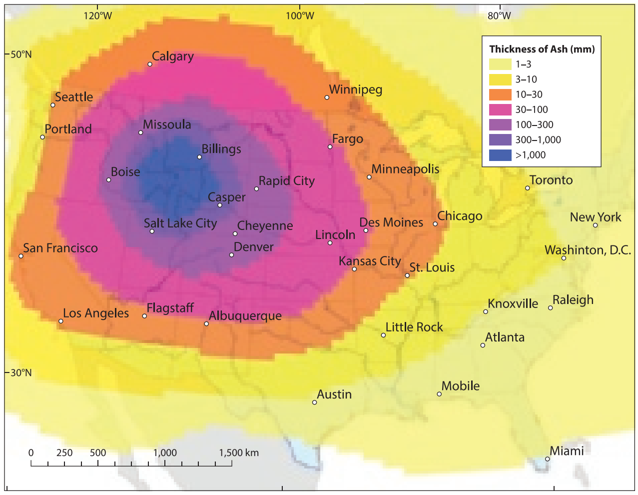


Figure 3. The map shows predicted ashfall for one month following an eruption.

Conclusion

Our results show that an eruption of the Yellowstone volcano would have devastating effects on the entire United States, with more mild effects worldwide. However, the behavior of the volcano has been similar over the past several decades of monitoring. It shows no signs of increasing, as we would expect if the volcano were nearing an eruption. Historically, the volcano has erupted about once every 600,000 to 800,000 years, with the last eruption occurring about 70,000 years ago. Therefore, it is not expected that the Yellowstone volcano will erupt anytime soon. It is advisable that monitoring of the area continues in case the situation in the region changes.

Word to Know

When something is added together over time, it is *cumulative*.

Dig into Data

What kinds of earthquake data trends do you notice from Figure 1?

Which city on the map would most likely have the thickest amount of ashfall after a volcanic eruption?

Consider the Source

This article is a simulation with made-up names, but it is based on real studies conducted by the USGS and other institutions tasked with monitoring the status of volcanoes and earthquakes in the United States. Data presented are real data gathered by the USGS and published in reports on its website.

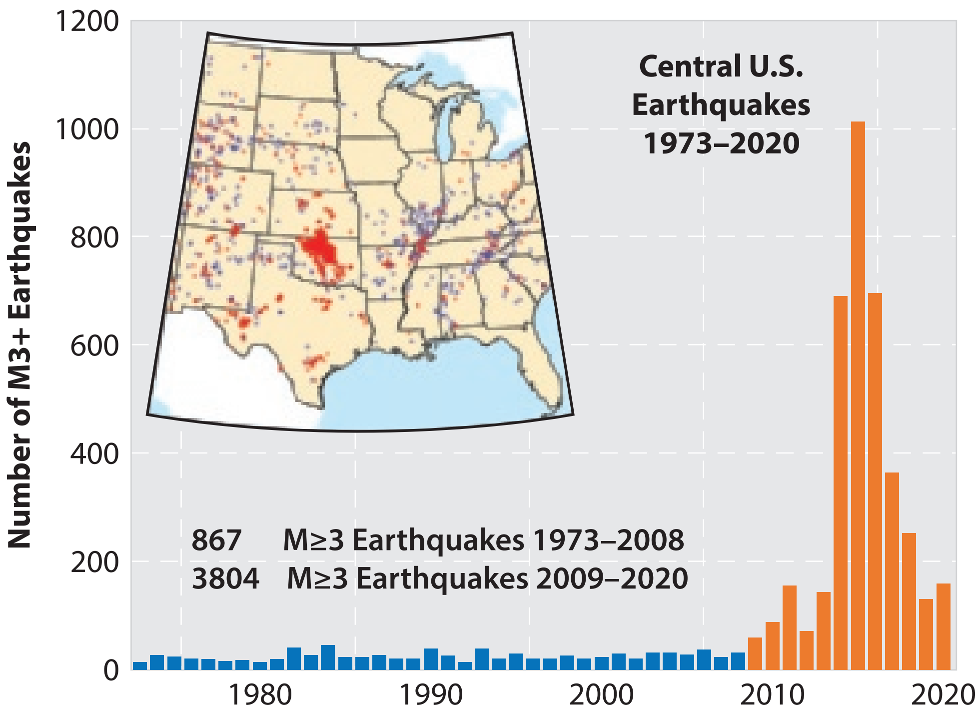
Induced Earthquakes

The frequency of earthquakes in the central United States rose sharply after 2008.

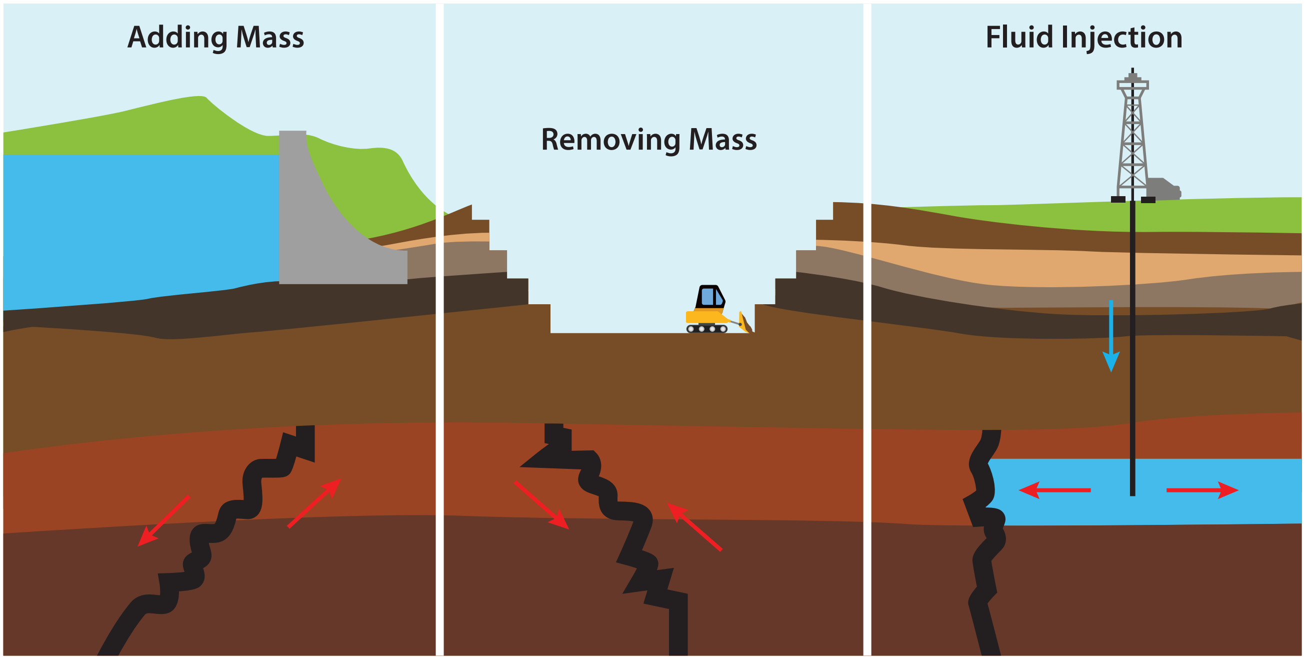
The increase is sudden and dramatic. It prompts questions about what could be causing the seismic activity. The increased earthquake frequency is not focused along a plate boundary, where high levels of seismic activity might be expected. And the increase in frequency contrasts sharply with the very slow movement of Earth's tectonic plates.

Consider the Source

The graph shows the numbers of earthquakes with magnitude 3.0 or greater each year in the central and eastern United States from 1973 through 2020. The map shows where the earthquakes occurred. These representations of data are from the U.S. Geological Survey, an agency created by Congress to monitor and analyze complex interactions between people and Earth's natural systems.



There are such things as induced earthquakes—earthquakes caused by human activity. Many are large enough that people can feel them, but most are small enough that they do not cause damage. A few, however, have been powerful enough to damage structures and present danger.



A dam holds a great deal of water in a reservoir. The water is heavy. If the added mass is over a fault, it can cause the rock along a fault to shift, inducing an earthquake.

Mining does the opposite. It removes heavy material that may be pressing down on a fault. The reduced pressure can allow the rock along a fault to shift, inducing an earthquake.

Extraction of oil and natural gas from Earth produces wastewater. The fluid is injected beneath the ground to dispose of it. This wastewater injection can prompt rock along a fault to shift, inducing an earthquake.

Glossary

absolute dating, n. determination of the age of material based on its physical properties

continental drift, n. the concept of gradual movement of Earth's continents over geologic time

correlated, adj. having a connection between factors that mutually affects the factors

crust, n. Earth's rocky outer layer

cumulative, adj. added together over time

fault, n. a fracture between two blocks of rock where the blocks shift relative to one another

ferromagnetic, adj. attracted to magnets

fracking, n. the shortened name for hydraulic fracturing, a process that uses pressurized liquid to break rock during the extraction of underground natural resource materials

hot spot, n. an area in Earth's crust prone to volcanic activity

igneous rock, n. rock formed through the cooling of lava or magma

magnetometer, n. a device that measures a magnetic field

paleontologist, n. a scientist who uses the fossil record to study Earth's history

relative dating, n. characterization of the age of material based on its occurrence related to other materials

rock cycle, n. the ongoing transition of rock from one type (sedimentary, metamorphic, igneous) to another

science literacy, n. the ability to read, hear, and comprehend information about scientific topics and demonstrate understanding in discussion and through writing

seafloor spreading, n. the process where new oceanic crust forms at and then pushes away from a ridge

seismic waves, n. energy waves that travel through Earth's layers

seismometer, n. an instrument used to detect waves from an earthquake

social media, n. websites and applications that allow users to participate in sharing content on the internet

theory, n. an idea that proposes an unproven or not fully provable explanation for a phenomenon

theory of plate tectonics, n. the generally accepted characterization of Earth's crust as large regions of rock slowly moving relative to each other

Key Sources

Gramling, Carolyn. *A WWII submarine-hunting device helped prove the theory of plate tectonics*. Science News, 2 July, 2021.
https://www.sciencenews.org/article/fluxgate-magnetometer-submarine-plate-tectonics

Golembiewski, Kate. *How We Know What's Deep Inside the Earth, Despite Never Traveling There*. Discover, 17 November, 2020.
https://www.discovermagazine.com/planet-earth/how-we-know-whats-deep-inside-the-earth-despite-never-traveling-there

Inge Lehmann: Discoverer of the Earth's Inner Core. American Museum of Natural History, n.d.
https://www.amnh.org/learn-teach/curriculum-collections/earth-inside-and-out/inge-lehmann-discoverer-of-the-earth-s-inner-core

Mastin, Larry. *Modeling the Ash Distribution of a Yellowstone Supereruption*. United States Geologic Survey, 27 August, 2014.
https://www.usgs.gov/center-news/modeling-ash-distribution-a-yellowstone-supereruption?qt-news_science_products=3#qt-news_science_products

Mponeng Gold Mine. NS Energy, n.d.
https://www.nsenergybusiness.com/projects/mponeng-gold-mine/

Street, Francesca. *Explorer Victor Vescovo completes mission to dive to deepest points in the world's oceans*. CNN, 8 October, 2019.
https://www.cnn.com/travel/article/victor-vescovo-historic-dive/index.html

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