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# THE EARTH HANDBOOK

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The Earth is changing all the time—right under our feet! We may not be able to see it happening, but landforms like mountains and beaches move. They weren't always where they are now and won't always be there in the future.

Some changes happen in an instant. We can see, hear, and feel them, like the movement of rocks and sediment in a landslide. Some changes, like the slide of a glacier or the formation of a volcano, occur slowly or deep inside the Earth so we can't see them.

*The Earth* is a model that lets you study and observe the geological forces that change our planet—above and below the surface, in a matter of minutes, and over millions of years.

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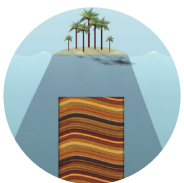
## IN THE APP

We encourage open play and discovery. Explore each view of the Earth: swipe, tap, and scroll to reveal surprises that support learning.



### DIG IN

Tap a magnifying glass to see detailed scenes of geological forces.



Tap a door to see detailed scenes of geological features.

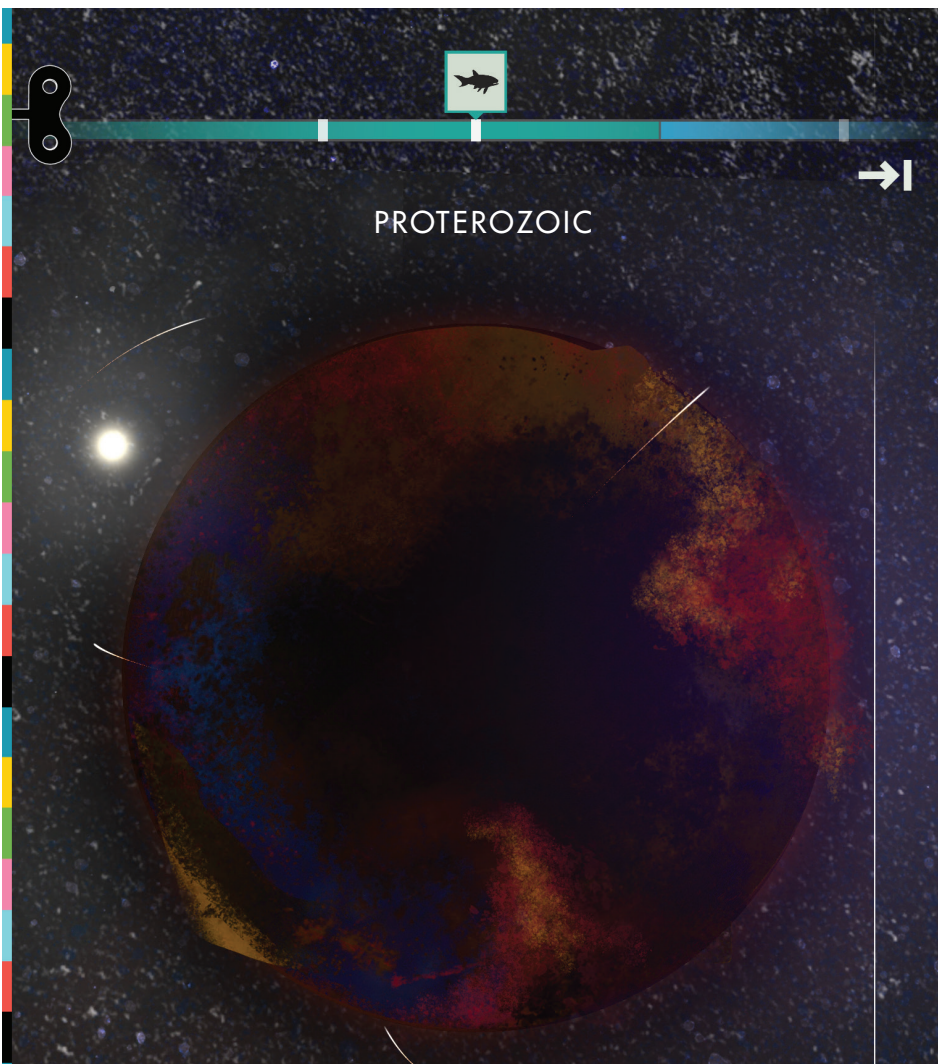
As you explore *The Earth*, think about how the planet is changing, what's causing these changes, and how forces working inside the Earth affect what happens on the outside.

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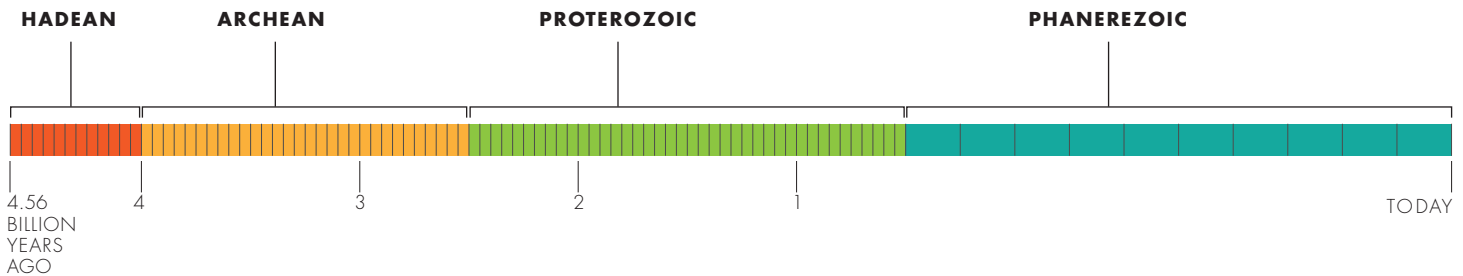
# Geological time

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Sometimes changes to the Earth happen during our lifetimes, and sometimes they happen quickly enough that we can see them before our eyes. But some changes take hundreds, thousands, or millions of years to occur. Here's a quick trip through the Earth's changes over time.



*Looking at the Earth from space, at the top of the screen, scroll left and right to travel through four eons and see how the Earth has been shaped over time.*



### **EARLY HADEAN EARTH**

During the Hadean Era, about 4.6 to 4 billion years ago, the Earth was a freshly formed sphere of boiling hot rock. As it cooled, it separated into layers. Its surface solidified into rocky land. Water condensed into early oceans.

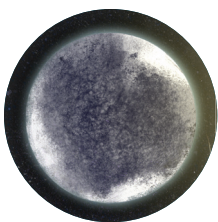
### **LATE HEAVY BOMBARDMENT**

During the Mid-Hadean Eon to Early Archean Eon, about 4 billion years ago, the Earth was hit by large asteroids. The asteroids heated the Earth's surface, melting and sinking portions of the young planet's crust.

### **PLATE TECTONICS**

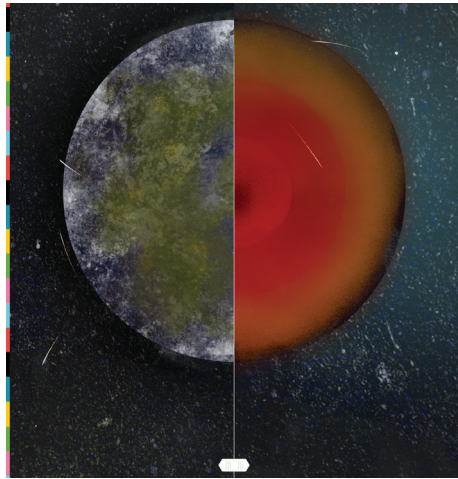
Land began forming as early as the Hadean Eon but the Earth's crust didn't split into plates until later. Beginning in the Archean Eon, about 4 to 2.5 billion years ago, and continuing through the present, the plates shift, moving continents toward and away from each other, joining them into supercontinents, and then pulling them apart again.

Pangea was the most recent supercontinent. It looked as if all the continents we know today were puzzled together. Continents are still moving today and will eventually form another supercontinent.



### **ICE AGES AND SNOWBALL EARTH**

During the Late Proterozoic Eon, about 2.5 billion to 500 million years ago, through the present, the Earth experiences long periods of colder temperatures. During these Ice Ages, polar ice sheets (glaciers) expand to cover the Earth's continents. When the ice sheets expand far enough to meet at the Earth's equator, the period is called a Snowball Earth. As these glaciers expand and then recede, they carve Earth's surface.



*Looking at the Earth from space, at the bottom of the screen, drag the slider left and right to explore inside the Earth.*

## INVESTIGATE THE EARTH'S LAYERS

Many changes to the Earth's surface start inside the planet. Here you can peek in and see that it's not just one solid mass.

The Earth is made up of different layers of rock. The crust is on the surface. Below that is the mantle. And below that, in the center, is the core. The deeper you go into the Earth, the hotter and denser the layers get.

### CRUST

The crust is the thin surface of the Earth. It's divided into plates that float on the mantle. There are two types of crust:

Continental crust is about 30 miles thick and mostly made of granite. It includes mountains and other landforms on the surface. The thin and finely layered top part that we can see is mostly sedimentary rock.

Oceanic crust is very thin compared to other layers. Made mostly of a dense volcanic rock called basalt, it's about 5 miles thick. A layer of sediment and rock sits on top. Oceanic crust covers the two-thirds of the surface of the Earth that lie beneath oceans.

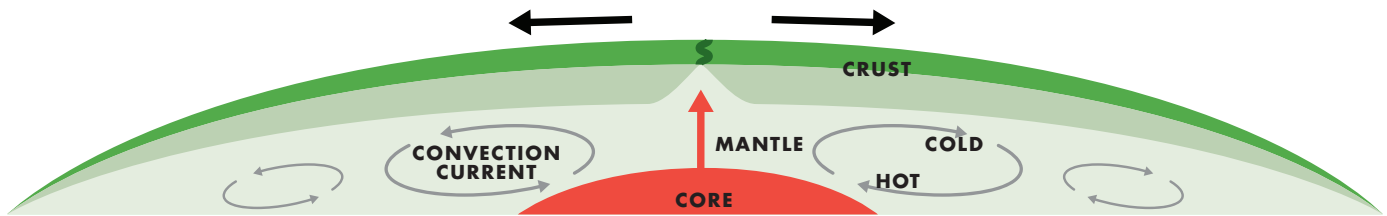
### MANTLE

The mantle is a layer of even more dense silicate rock that's about 1,802 miles thick. Approximately 80% of the volume of the Earth is contained in the mantle. It has an upper and lower layer. The upper mantle is cooler and brittle. The lower mantle is solid but hot and elastic.

### CORE

The core, the center of the Earth, is the densest and hottest part. It reaches temperatures between 9,000 and 13,000 degrees Fahrenheit. It also has two layers. The outer core is liquid. But the inner core is solid because it's under so much pressure from the mantle and the crust.





## **OBSERVE THE FORCES THAT CHANGE THE EARTH**

Forces working from both the inside and the outside of Earth change its surface. While the surface changes, the planet isn't getting any bigger or smaller. When rock and sediment disappear from one place, they reappear in another.

### **INSIDE**

Deep in the center, the core is like the Earth's engine. It sends out heat and radioactive energy, warming the lower mantle. As the lower mantle gets hot, it rises toward the crust and pushes rock from the cooler upper mantle down. That rock heats up, rises, and pushes down the cooler rock again. This cycle of heating, rising, cooling, and sinking is called a convection current.

The movement of convection currents in the mantle causes the plates floating above to shift, ultimately moving the continents and changing the outside of the Earth. The Earth's shifting, hot interior also pushes up mountains, creates new seafloors, and generates molten magma which creates volcanoes.

Though many of these processes occur too slowly for us to notice, we can sometimes feel them happening when shifting plates catch on each other and generate earthquakes.

### **OUTSIDE**

Water, wind, and ice, paired with gravity, move rocks and sediment across Earth's surface. These forces change the land by shaping and moving the crust in the processes of weathering, erosion, and deposition. These processes respectively break, move, and deposit rocks.

While the movement of plates pushes a mountain up, gravity, wind, water, and ice will sculpt that mountain over time.

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## **DISCUSSION QUESTIONS**

Has the Earth's surface always looked the same?

What are some of the forces that change the Earth over time?

How does activity inside the Earth affect changes on the surface of the planet?

Why do you think scientists call Earth a "living planet"?

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# Plate tectonics

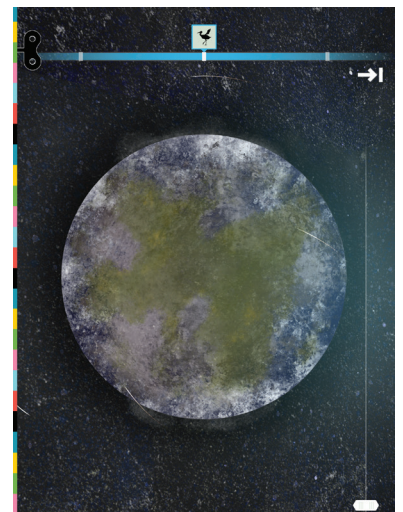
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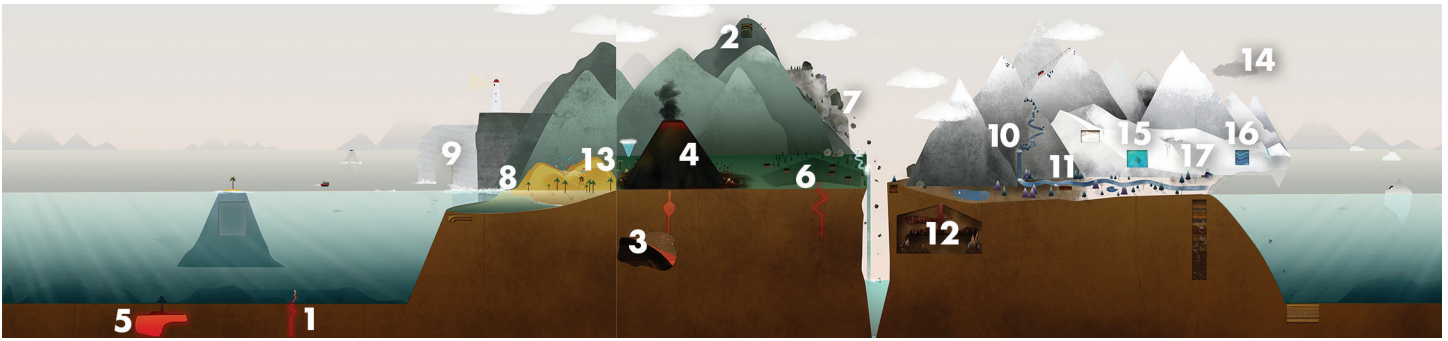
Long ago, the continents all fit together. Now it looks like only Africa and South American might have been next to each other. The appearance of those two continents inspired early plate tectonics research.

Plate tectonics is the idea that the Earth's crust is broken into individual tectonic plates that are constantly moving and changing shape over time. The convection currents inside the Earth move the plates about  $1\frac{1}{3}$  inches a year (about the same amount as your fingernails grow). That's not very much but over a million years, they'll move 22 miles.

There are three different tectonic boundaries: divergent, convergent, and transform. The movement of plates along these boundaries causes volcanoes and earthquakes and builds mountains and oceanic trenches.

*Looking at the Earth from space, at the top of the screen, scroll left and right to travel through four eons and see how the Earth has been shaped over time.*





At DIVERGENT BOUNDARIES, plates move away from each other. As they move, they create mountain ranges, volcanoes, rifts (areas where the crust pulls away from the upper mantle), and new ocean floors.

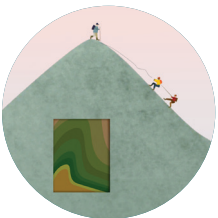


### (1) Tap the mid-ocean ridge on the seafloor. What happens?

As the plates move away from each other, magma (molten rock) rises from Earth's interior to fill the gap, creating new ocean floor (oceanic crust). These mini volcanoes continuously erupt forming a raised mid-ocean ridge along the seafloor. Eighty percent of volcano eruptions take place under water.

At CONVERGENT BOUNDARIES, plates push into each other. If one plate is oceanic and one is continental, the oceanic plate slides under the continental plate. This process is called subduction. Volcanoes and mountains may rise along a subduction zone.

If both plates are continental plates, the land masses crumple and fold, eventually forming a mountain. This can take millions of years. As an example, Mt. Everest, the tallest peak in the Himalayas, grows about 1/8 of an inch each year.



### (2) Tap the door to look inside a mountain formed on a convergent boundary.

You'll see the layers of crust folded over each other and piled up into a mountain.

At TRANSFORM BOUNDARIES, plates slide against each other, usually on the ocean floor. New landforms aren't created, but tension builds up between the two plates. The tension eventually releases as an earthquake.

## VOLCANOES

A volcano is a vent in the Earth that lava, rock debris, and gases erupt out of. They can be many different shapes and sizes.

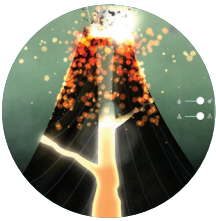


### (3) Find an oceanic plate subducting beneath a continental plate.

Here's a hint: look for a volcano! In this volcano, as the oceanic plate subducts beneath the continental plate, it heats up and melts into magma. This process releases water and causes more magma to melt, rise, and pool in a magma chamber. Eventually, this results in volcanic eruptions.

Volcanos on subduction zones include Mt. St. Helens, Mt. Rainier, Pinatubo, Mt. Fuji, Merapi, Galeras, and Cotopaxi. They account for the largest number of Earth's volcanoes. The explosive eruptions of these volcanoes have caused the most casualties of any type of volcano.





#### (4) Toggle through four different volcanoes. Tap each volcano to make it erupt.

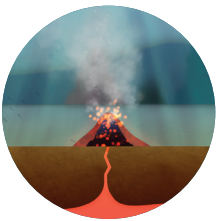
Volcanoes come in different shapes and have different eruptions. The shape of a volcano and the strength of its eruptions result from the type of magma it releases. When magma reaches the surface of the Earth, it is lava.

A SHIELD VOLCANO does not produce explosive eruptions. Its magma is runny and has little gas in it.

A CINDER CONE VOLCANO does not produce explosive eruptions. Its magma is runny but has lots of gas in it.

A PLUG DOME VOLCANO does not usually produce explosive eruptions. Its magma is thicker and sticky and has little gas in it.

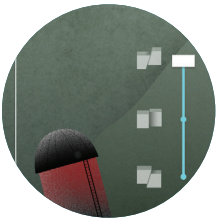
A STRATOVOLCANO produces explosive eruptions with thick, sticky, and gassy magma.



#### (5) Tap the hotspot volcano. What happens?

Hotspots are extremely hot areas under the plates that produce lots of magma, which erupts through cracks in the crust. These small eruptions create underwater mountains known as seamounts. Seamounts grow, eventually rising above sea level and becoming volcanic islands.

Over time, the plate over the hotspot moves, moving the island with it. Once it's no longer over the hotspot, the island volcano becomes extinct. But a new one starts forming in its place over the hotspot. Eventually, a chain of islands forms, like the Hawaiian Islands.



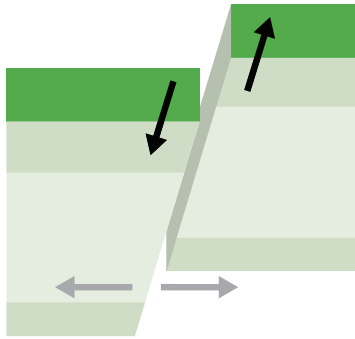
## EARTHQUAKES

#### (6) Toggle through three different earthquakes. Tap to trigger each earthquake.

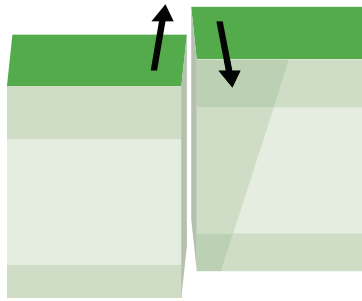
The boundaries, or edges, of plates aren't smooth. They have faults (breaks in the rock). As plates move, their edges slide next to each other. Sometimes, edges get stuck at faults while the rest of the plate keeps moving. Tension and energy build up until the stuck pieces slip, releasing all the energy outward in seismic waves (like ripples on a pond), causing an earthquake.

Earthquakes are measured by the Richter Scale which assigns a number to the energy released by an earthquake. The higher the number, the bigger the earthquake.

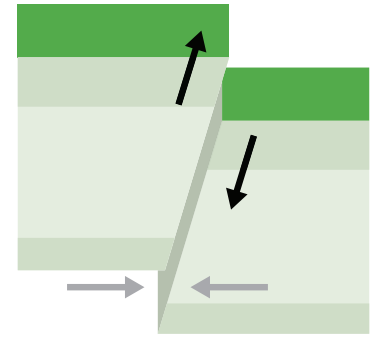
The focus of an earthquake is the location below the Earth's surface where an earthquake starts. Earthquakes can begin as deep as 500 miles below the surface of the Earth in the crust and upper mantle. Earthquakes become less intense as they travel through the ground. So, the farther away you are from the focus, the less likely you are to feel it. And, the deeper an earthquake is, the less we feel it on the surface. The epicenter is the location on the Earth's surface directly above the focus.



**NORMAL FAULT**



**STRIKE-SLIP FAULT**



**REVERSE FAULT**

There are three types of earthquakes. They differ depending on the direction the plates move in relationship to each other.

At a **NORMAL FAULT**, the plates or chunks of rock move away from each other and one drops below the other extending the crust and creating a basin. Landforms called ranges rise on either side of the basin. These faults usually happen at divergent plate boundaries and produce weaker earthquakes.

At a **STRIKE-SLIP FAULT**, the plates or chunks of rock slide past each other, causing the crust to slide or shift its location. These occur at transform plate boundaries and produce medium to intense earthquakes.

At a **REVERSE FAULT** the plates or rocks move into each other, pushing one up, compressing the crust, and forming mountains or causing tsunamis. These usually happen at convergent plate boundaries and create intense earthquakes.

## **DISCUSSION QUESTIONS**

What causes volcanoes and earthquakes?

Why are volcanoes different shapes?

How does what happens inside the Earth affect what happens on the surface in an earthquake? How does what happens inside the Earth affect what happens on the surface in a volcano?

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# Weathering, erosion & deposition

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Weathering, erosion, and deposition transform the surface of the Earth. As an example, mountains may be tall and jagged when they first form, like the young Rocky Mountains of the American West. Over time, they become shorter and smoother, like the Appalachians of the American East. There are three processes responsible for these changes: weathering, erosion, and deposition.

**WEATHERING** breaks, cracks, crumbles, or otherwise changes rocks. Water, wind, ice, plants, and animals can all break rocks and turn them into sediment.

**EROSION** moves rocks and sediment. Water, ice, and wind can loosen, pick up, and carry rocks. Gravity helps move them along.

In **DEPOSITION** rocks are dropped off in a new location. Icy glaciers and streams can leave rocks in new places as they melt and move. As rocks and sediment gather in new places, they can create new landforms.

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## FORCES OF CHANGE

Wind, water, and ice, combined with gravity, are the forces that weather, erode, and deposit rocks and sediment. Gravity moves everything down, toward the center of the Earth. It pulls heavy particles to the ground when wind slows. It drives water in streams and glaciers from mountaintops down. And gravity pulls rocks and sediment down—quickly!—in a landslide.

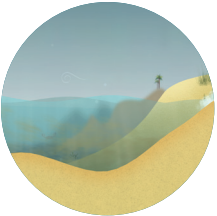


### (7) Tap rocks to trigger a rockslide.

Because whole rocks fall, this type of landslide is called a rockslide. Weathering breaks down the rocks. A change in weather (usually warming temperatures) or a sudden disturbance loosens the broken rocks. As rocks begin to fall, they knock other rocks down, too. Gravity pulls more and more rocks down. The resulting pile of rocks at the bottom of the rockfall is called a talus.

## WATER

Water, in the form of waves, rivers, and groundwater is the main force of erosion. On a coast, waves carrying rocks and sand hit the land, causing erosion and creating cliffs, arches, and caves.



### (8) Tap the water to see how it moves sand and changes beaches.

Beaches are always changing; sand is constantly added and removed from them. Especially stormy beaches can change more visibly or frequently.

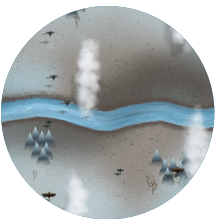
Small summer waves deposit sediment on the beach and make it grow bigger. Heavy winter waves carry sand away, eroding the beach and making it smaller.

### (9) Tap the water to create waves. What happens?

Waves weather the cliffs, breaking them down into sand. Waves can create all kinds of wildly shaped landforms: terraces, platforms, notches, arches, and sea stacks.

### (10) Tap rocks to drop them into the river. Follow them as they travel to the ocean.

As rivers carve through Earth's surface, carrying water according to gravity from higher to lower ground, they pick up and transport rocks and sediment. This first causes erosion and eventually deposition, when the rivers drop the rocks in the sea or in river beds.



### (11) Tap the river to speed it up. What happens?

A young stream's path may be a direct line from a high elevation to low elevation, but over time, it meanders. As it floods and dries over the course of years, it alters the land through which it runs. When it floods, the force of the river erodes the land along its sides. When it dries, rocks and sediment are deposited in river beds. Through many cycles of flooding and drying, the shape of the river itself changes.

### (12) Find the underground cave.

Underground caves can form when water chemically weathers limestone rock. It seeps into the ground and combines with carbon dioxide in the air, making an acidic solution that dissolves the limestone from the ground up.

In a cave, stalactites can form as water drips mineral deposits from the top. Stalagmites form from the ground up as those mineral deposits drip all the way down. It can take a stalactite 100 years to grow one inch.

## WIND

Wind weathers rock, erodes rock and sediment, and deposits rock and sediment. Fast winds pick up sediments. As winds slow down, they deposit what they've picked up. Big particles creep along the ground, medium ones skip along, and fine ones travel with the wind.

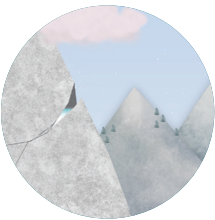


### (13) Tap the dunes to create wind. What happens?

Wind deposits sand into dunes. Sand dunes can change shape and size depending on which way the wind blows. New dunes can shift and move within decades—before our eyes.

## ICE

Ice weathers rock, breaking it up as water freezes and expands in cracks. Ice, in the form of a glacier, also erodes and deposits rock as it slowly moves along.



### (14) Tap the cloud to make it rain and fill the crack with water. What happens?

When water falls into cracks in rocks and freezes, it expands, pushing against the rock and eventually breaking it apart. This is frost wedging. When frost wedging occurs over and over, it can turn solid rocks into rubble.

When frost wedging occurs high up on a mountaintop, gravity eventually moves the weathered and broken rock down—in a rockslide.

### (15 or 16) Tap the door to see layers of ice in a glacier.

Glaciers are large ice masses that form over time. Snow piles up year over year, compressing into interlocking ice crystals that eventually become a huge sheet of solid, bright blue ice.

Eventually, like all water, the solid mass of ice begins to move downhill, usually just a few inches each day, or about 1000 feet per year. Glaciers pull rocks and sediment from land, scrape across land and reshape its surface, and deposit sediment, rocks, and boulders when they melt. Glaciers from past ice ages shaped many landscape features we see today—lakes, hills, valleys.



### (17) Swipe to the right to make the glacier advance. Swipe to the left to make the glacier recede.

Glaciers advance if the climate cools and more ice and snow accumulate than melt away.

When a glacier advances, it picks up rocks and sediment in its path underneath it.

If the climate warms and less new snow and ice accumulate than melt, a glacier will shrink and retreat. When a glacier retreats, it reveals the materials it has picked up and the land it has transformed underneath it.



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## DISCUSSION QUESTIONS

How can water transform a mountain?

How does gravity transform the Earth's surface?

How does a glacier act like a river?

How does wind shape the desert?

What are some changes to the Earth's surface that can we see in a minute? During our lives?

What are some changes to the Earth's surface that happen too slowly for us to see?

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Thanks for playing **THE EARTH**.

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