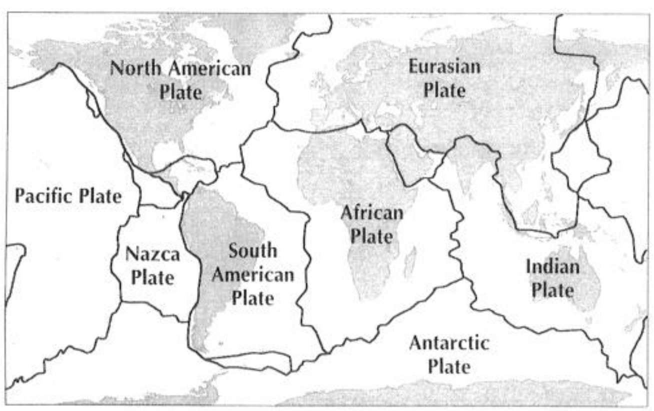
How does uplift change Earth's surface?

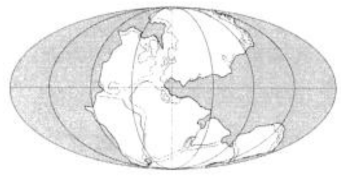
Plate Tectonics

When you walk down the street it seems as though the ground beneath your feet isn't moving — but it is. The ground you're walking on is like a giant raft, a huge piece of Earth's surface crust that's floating on top of a layer of hot, dense rock material called the **mantle**.

Earth's crust is divided into gigantic pieces, called **plates**. Over time, these crustal plates move around on top of the mantle. Some plates are pulling away from each other, some are pushing toward each other, and some are sliding past each other. Have you ever noticed that the coastlines of South America and Africa look like they fit together? Scientists think they were connected about 200 million years ago, along with what is now North America, Asia, and Australia, in one huge continent called Pangaea (pan-GEE-ah). Over millions of years, the land that made up Pangaea slowly drifted apart to form the continents and ocean basins we know today. And the continents are still drifting! In another 200 million years, the map of the world will probably look very different. This slow movement of Earth's crustal plates over millions of years is called **plate tectonics**.



Earth's crust is divided into plates.

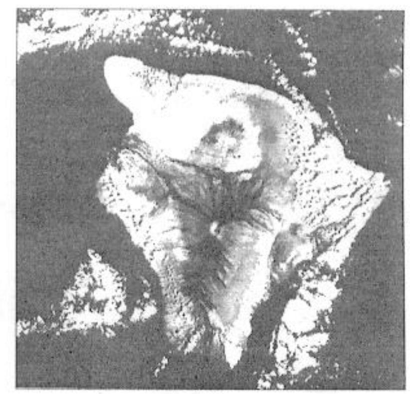


Earth's continents 200 million years ago.

Mountain ranges like the ones in Vastland show that plate tectonics is happening. Mountains form when two crustal plates push toward each other. The rock at the front edge of one or both plates crumples up, creating mountains and hills of broken and folded rock. This is called **uplift** because it creates landforms that are raised up from the surface. It can take millions of years for a mountain range to form since Earth's crustal plates move only a few inches each year.

Volcanoes are another type of landform created by the movement of Earth's crustal plates. When the edge of one plate is forced under the edge of another plate, rock deep beneath the surface where the two plates are coming together begins to melt. This forms hot liquid rock which sometimes forces its way upward through cracks in the overlying plate and finally erupts from a volcano.

Satellite Tip



Satellites can show us what Earth looks like from above. In this satellite image of Hawaii's biggest volcano, Mauna Loa, you can see the circular opening (caldera) at the top of the volcano and the dark lava that has flowed out of it.

How does uplift change Earth's surface?

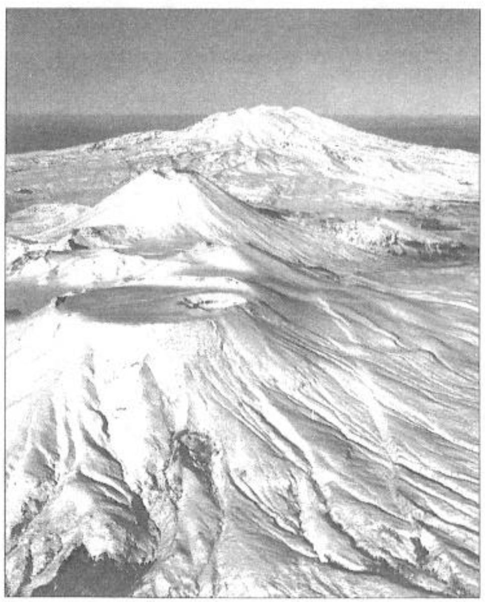
Volcanoes

The Center for Science Seekers believes that one of the satellite images of Vastland may show evidence of ancient volcanoes.

Volcanoes are formed from hot liquid rock (called **magma** when it's underground and **lava** when it reaches the surface). Deep underground in Earth's upper mantle, rock melts to form liquid rock which then pushes upward, breaking through the crust.

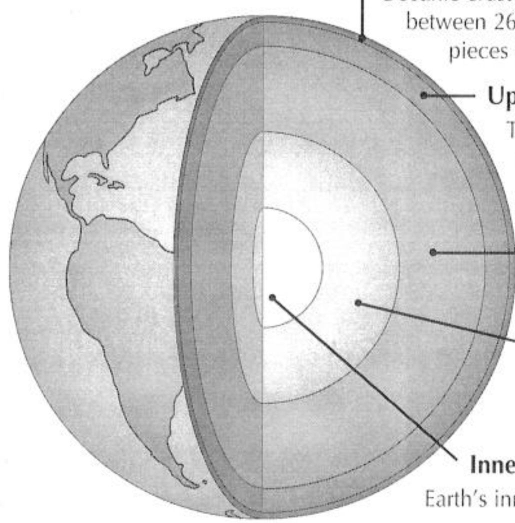
Lava can erupt violently, shooting hundreds of feet into the air, or it can slowly ooze out from a crack in the surface. Once it reaches the surface, the liquid rock spreads out over the land. As it cools down, it hardens into solid rock. Over thousands of years, a volcano can erupt many times, building up layer after layer of solid rock and forming a volcanic mountain.

Volcanoes can form on land, or at the bottom of the ocean, and where there's one there are usually more. They most often form along the edges of crustal plates — huge pieces of Earth's crust that float around on the mantle. These groups of volcanoes are called **volcanic zones**. Volcanic zones form in places where one crustal plate is ramming into and being pulled under another. They also form at the bottom of the ocean where crustal plates are pulling apart.



These volcanoes in New Zealand are still active.

Earth's Interior

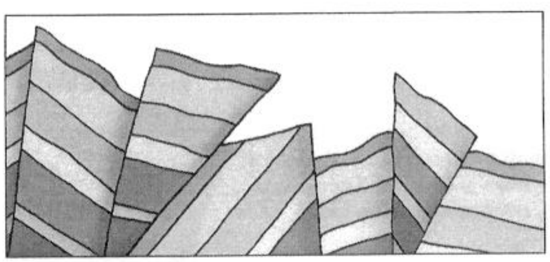


How does uplift change Earth's surface?

Faulting and Folding

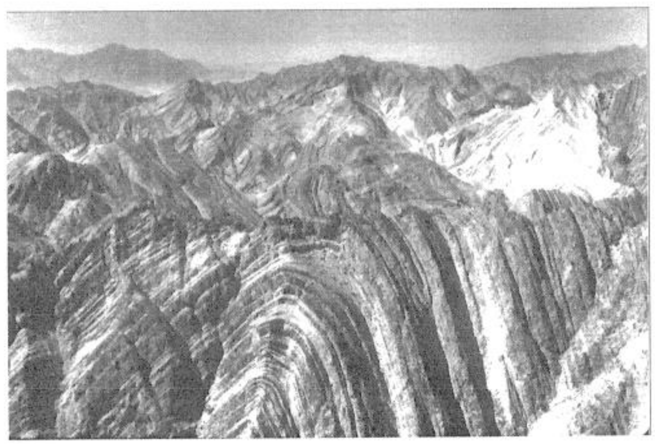
Although Earth might seem to be a solid ball, the ground that we stand on is like a shell that covers the planet's surface. Underneath the solid crust is a layer of hot, dense rock. Giant pieces of the outer crust, called **plates**, float around on this hot rock below. As they slide around, the crustal plates can bump into each other, pull away from each other, or slide alongside each other.

All this pushing and pulling puts a lot of stress on the rock that makes up Earth's surface. Sometimes the force is so great that large pieces of rock break apart. The place where rock breaks is called a **fault**. As large chunks of rock break off, they begin to move in different directions — up, down, or side to side along the fault. Over thousands of years, the chunks can pile up on top of each other like a huge pile of blocks, forming hills and mountains.



Pressure from Earth's moving plates can cause large blocks of rock to break apart and pile up into mountain ranges.

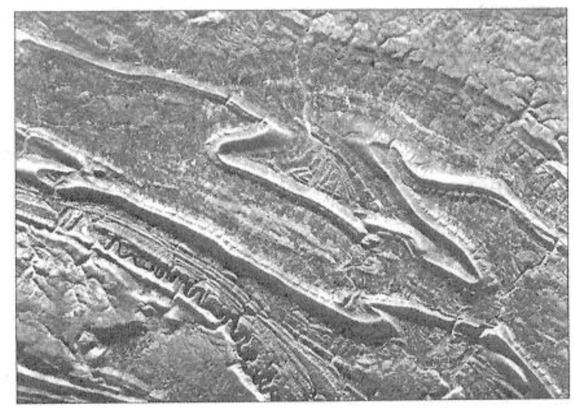
Rock doesn't always break under pressure, though. Solid rock buried deep underground is sometimes so hot and under so much pressure that it actually begins to bend and fold like clay as it's squeezed by Earth's moving crustal plates. Folding creates wavy-looking layers of rock, and over thousands of years can build up mountain ranges of folded rock. The Center for Science Seekers believes some of the mountains in Vastland may be made of folded rock.



Sometimes rock folds in response to pressure, creating mountain ranges of folded rock.

The movement of Earth's crustal plates causes **uplift** of Earth's surface by folding and faulting rock into hills and mountain ranges. Uplift can sometimes help make fossils easier to find. For example, when a block of rock moves upward along a fault, fossils within the rock that were buried deep underground are brought closer to the surface. On the other hand, uplift can sometimes destroy fossils. Folded rock isn't a great place to find fossils since they can get squashed as the rock bends.

Satellite Tip



Satellites give us a bird's-eye view of Earth's surface. This image shows large folds of rock in the Appalachian mountain range. From far above, a mountain range sometimes looks like rumpled bedsheets. The giant folds in the Appalachians happened long ago when Europe and North America were pushing toward each other. Today, the two continents are pulling away from each other and the Atlantic Ocean is getting bigger.

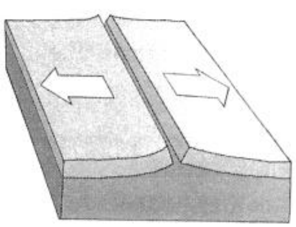
How does uplift change Earth's surface?

Plate Boundaries

Earth's surface is like a giant, very crowded bumper car ride. The solid crust that we stand on is divided into huge pieces called **plates**. These crustal plates move around, sometimes crashing into each other, sometimes pulling away from each other, and sometimes sliding alongside each other.

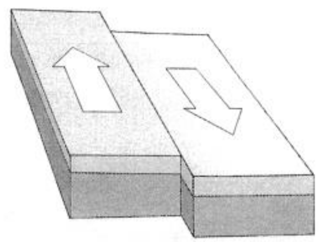
The reason we don't all have whiplash is because the crustal plates move very, very slowly—usually only a few inches each year. Each year on Earth there are over 10,000 earthquakes caused by movement of the crust. Most of them are so small that humans can't really feel them. But occasionally a "big one" happens in a populated area, causing major damage to buildings and roads. One earthquake in Alaska in 1899 lifted huge sections of the coast 46 feet higher than before.

A plate boundary is a place where two crustal plates meet, like two pieces of a giant jigsaw puzzle fitting together. A place where two crustal plates are pulling away from each other (or diverging) is called a **divergent boundary**. These are usually formed deep in the ocean. That's lucky for us, because hot melted rock from deep inside Earth comes up to fill the space between the two plates, forming a long chain of volcanoes.



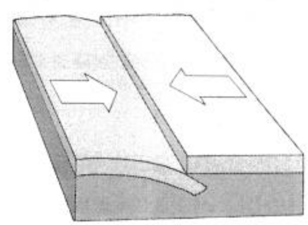
Divergent Boundary

At other places, crustal plates are sliding past each other like two trains moving on opposite tracks. This is called a **transform-fault boundary**. The two plates usually don't slide along smoothly but get locked together, then move with a sudden jolt as they break apart. The San Andreas fault in California is one example of this type of boundary.



Transform-Fault Boundary

A third type of plate boundary is called a **convergent boundary**, because two plates are converging or coming together. Mountain ranges and chains of volcanic mountains tend to form at convergent boundaries.



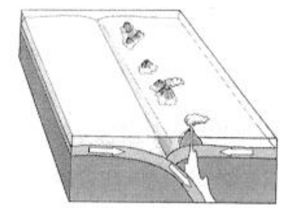
Convergent Boundary

Three Types of Convergent Boundaries

Exactly what happens at a convergent boundary depends on what type of crust each plate is made of. **Oceanic crust** (the ocean floor) is heavier and denser than **continental crust** (the land).

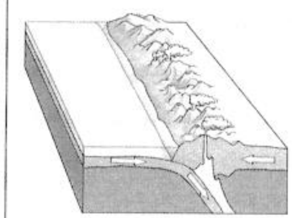
Oceanic vs. Oceanic

The edge of the older plate, which is heavier, sinks under the younger plate, causing rock deep beneath the surface to melt. The melted rock forces its way to the surface and erupts from volcanoes.



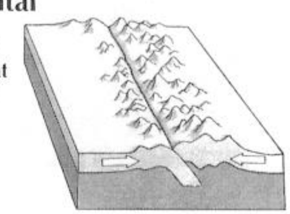
Continental vs. Oceanic

The denser oceanic crust sinks under the lighter continental crust, and the edge of the continental crust crumples up into mountains. The sinking oceanic crust can also cause rock deep underground to melt, forming magma which then erupts from volcanoes.



Continental vs. Continental

The force of the two plates pushing against each other causes the rock at the edges of both plates to crumple up, creating a mountain range.



How does uplift change Earth's surface?

What You Need

2 pieces blue foam

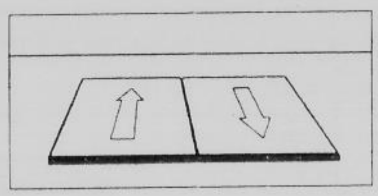
2 pieces red foam

Plate Boundaries

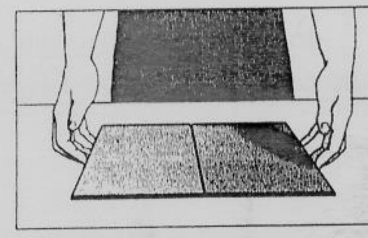
Forces within the Earth are strong enough to bend, fold, break, bury, and uplift the solid rock in Earth's crust. In this Science Lab you'll model what happens at different plate boundaries — the place where two of Earth's crustal plates meet. Your observations of these models can help you answer some of the questions on your Memorandum.

What To Do

1. On Earth's surface, oceanic crust (the ocean floor) is denser and heavier than continental crust (the land). In your models, blue foam represents oceanic crust. The red foam represents continental crust.
2. First you'll model a boundary where two plates are moving side by side in opposite directions. This is called a **transform-fault** boundary. Lay the two pieces of red foam side by side with the long sides touching. Place one hand on each piece of foam. Slowly slide one piece away from you, and the other toward you. Return to the beginning and repeat 2 or 3 times. Watch what happens at the edges of the foam as the pieces slide past each other. Describe the movement of the two plates in the "Plate Movement Observations" chart (use words or sketches).



3. A **divergent** boundary is a place where two plates are pulling away from each other. This usually happens on the ocean floor, so use the two blue pieces of foam to model a divergent boundary. Place the long sides of the blue foam pieces side by side, with the long sides touching. Pull them apart, leaving a gap in the middle. Describe this movement in the chart.
4. Lay the two blue foam pieces side by side again, as you did in Step 3. This time, put your fingers on the edges (as shown) and use a light, steady pressure to slowly push the two pieces together. Keep pushing until one of the pieces dives under the other. Return to the beginning and repeat 2 or 3 times. This is a model of a **convergent** boundary — a place where two plates are pushing toward each other. In the chart, draw your model and describe its movements.



5. Repeat Step 4, using one red and one blue piece of foam to model a convergent boundary between an oceanic plate and a continental plate. The red foam should bend as you push it against the blue foam. Repeat 2 or 3 times. Draw and describe your observations.
6. Use two red pieces of foam to model a convergent boundary between two continental plates. The edges of both foam pieces should rise upward. Repeat 2 or 3 times. Draw and describe your observations.

How does uplift change Earth's surface?

Plate Movement Observations

Model	Description or Sketch of Movement
Transform-Fault boundary ↑↓	
Divergent boundary ←→	
Convergent boundary (ocean-ocean) →←	
Convergent boundary (ocean-continent) →←	
Convergent boundary (continent-continent) →←	

What It Means

Which of the plate movements you observed could help bring fossils from deep underground to the surface? Which would not help reveal fossils? Why?

Advising the Team

Look at your group's Satellite Imagery poster and see if you can observe any areas in Vastland that look like they've been uplifted into mountain ranges.

Which rocks contain fossils?

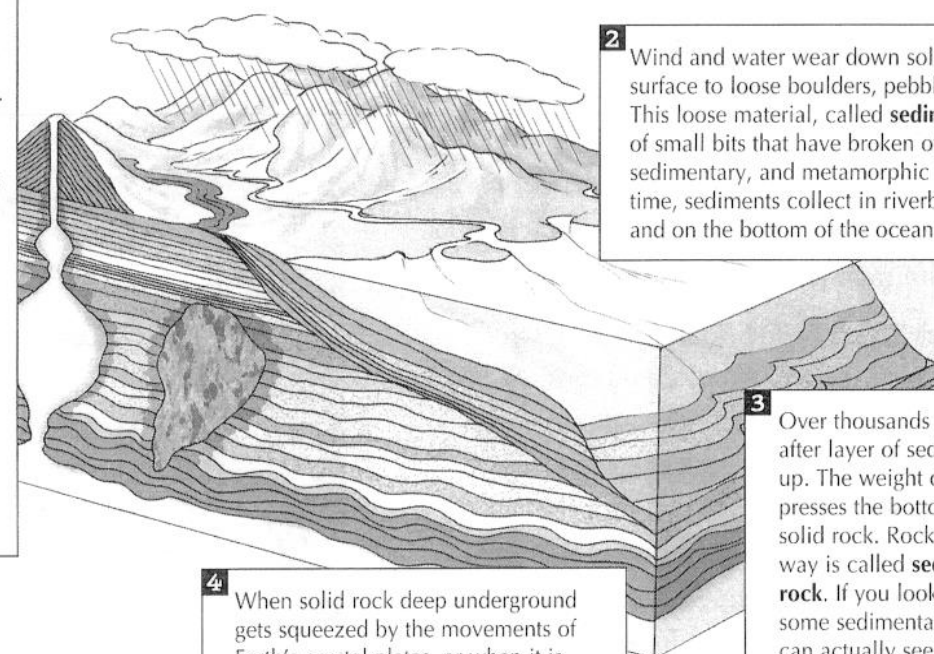
The Rock Cycle

Earth's surface is like a permanent construction site — landforms and rocks are constantly being built up and torn down again. Some changes, like a volcanic eruption or an earthquake, can happen so fast that they can be dangerous for humans nearby. Other times the changes happen so slowly that we hardly notice them.

All the thousands of different rocks on Earth's surface can be grouped into three categories based on how they were formed: **igneous, sedimentary,** and **metamorphic**. But a lot can happen to a rock as it sits on Earth's surface for millions of years. Deep underground, rocks get squeezed by pressure from plate tectonics, and can get melted in the mantle. On the surface, solid rock can get worn down into small pieces by wind, water, and other elements. These forces can cause rocks to change from one of the three types to another. This slow, endless process of rock changing form is called the **rock cycle**. While some rocks sit around for millions of years and never change, any rock can change over time to become any other type of rock. The possibilities are endless.

How Rocks Change Form

1 Rocks that are deep underground in Earth's lower crust and mantle can melt. New rock forms when hot melted rock (**magma**) comes bubbling up toward the surface. The liquid rock hardens into solid rock as it cools. It can cool underground, or it can break through the surface out of a volcano. Rocks formed from cooled magma are called **igneous rocks**.



2 Wind and water wear down solid rock on the surface to loose boulders, pebbles, and sand. This loose material, called **sediment**,is made of small bits that have broken off of igneous, sedimentary, and metamorphic rocks. Over time, sediments collect in riverbeds, in lakes, and on the bottom of the ocean.

3 Over thousands of years, layer after layer of sediments pile up. The weight on top compresses the bottom layers into solid rock. Rock formed this way is called **sedimentary rock**. If you look closely at some sedimentary rocks, you can actually see the tiny bits of other rocks contained in them.

4 When solid rock deep underground gets squeezed by the movements of Earth's crustal plates, or when it is exposed to heat from nearby magma, it sometimes goes through a process of chemical change. New minerals form inside the rock. The new rock is called **metamorphic rock** because its internal structure has changed.

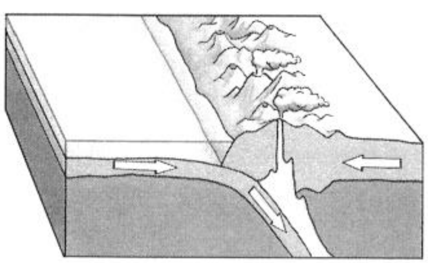
Which rocks contain fossils?

Igneous Rock

The Center for Science Seekers believes that Vastland contains one or more ancient volcanic zones. These are places where, long ago, hot liquid rock from deep underground erupted at the surface and cooled to form solid rock.

Fossil-hunting in a volcanic zone isn't a great idea because igneous rock is unlikely to contain fossils. Fossils buried inside rock deep underground would melt along with the rock that melts to form magma.

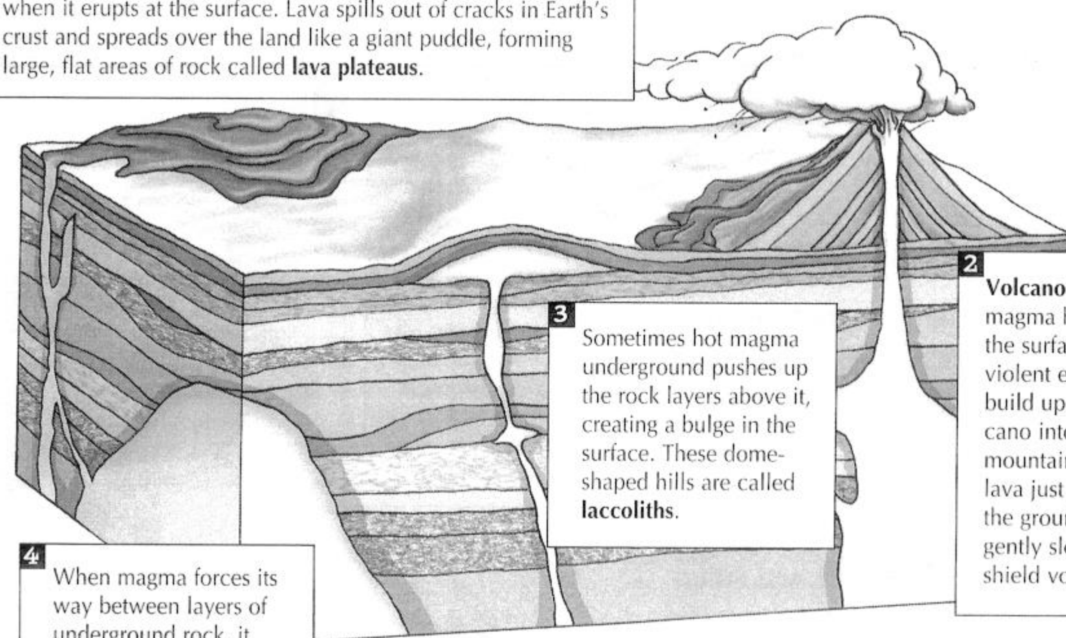
So where does magma come from? Any rock on Earth can get recycled to become liquid rock. As Earth's crustal plates move around, rocks that were once close to the surface can sink deep underground. There, intense heat and pressure can sometimes melt solid rock. This is part of the **rock cycle**, the process through which all rocks on Earth are constantly changing from one form to another.



The movement of Earth's crustal plates can pull rock from the surface deep underground, where it might melt to form magma.

How Igneous Rock Forms

Igneous rock forms when hot melted rock from deep inside Earth rises into Earth's crust, cooling and hardening into solid rock.



1 Melted rock is called **magma** when it's underground, and **lava** when it erupts at the surface. Lava spills out of cracks in Earth's crust and spreads over the land like a giant puddle, forming large, flat areas of rock called **lava plateaus**.

2 **Volcanoes** are places where magma has broken through the surface. In some places, violent eruptions of hot lava build up the sides of the volcano into a steep cone-shaped mountain. In other places, the lava just gently oozes out of the ground. This creates more gently sloped volcanoes called shield volcanoes.

3 Sometimes hot magma underground pushes up the rock layers above it, creating a bulge in the surface. These dome-shaped hills are called **laccoliths**.

4 When magma forces its way between layers of underground rock, it forms a **batholith**. Batholiths can be ten or fifteen football fields in size, or even bigger.

Which rocks contain fossils?

Metamorphic Rock

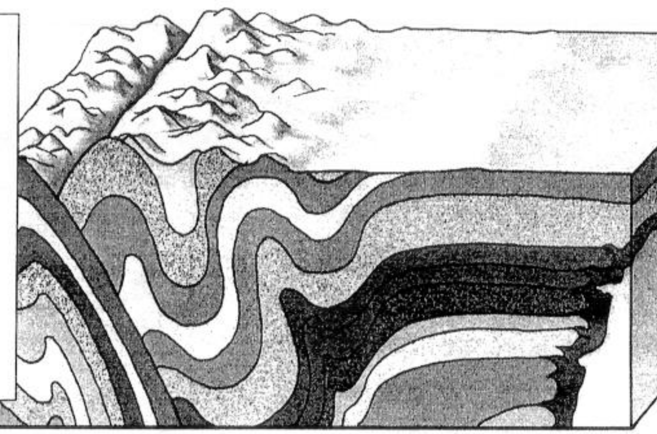
A caterpillar that changes into a butterfly has gone through a **metamorphosis**. Rocks can also undergo a metamorphosis (although they don't turn into butterflies, of course). When a rock is exposed to great heat or pressure deep underground, new minerals and crystals start to form within the rock. It's transformed into something completely different from what it was. Since the rock has gone through a metamorphosis, or change, it's called metamorphic rock.

Although metamorphic rock can exist anywhere, it's often found in areas where there's evidence that layers of rock have been folded by pressure from plate tectonics. It's also found around igneous rocks that have formed from hot melted rock. Areas of metamorphic rock are unlikely to contain good fossil samples. The heat and pressure that create metamorphic rock is so intense that any fossils contained within the original rock are likely to be destroyed.

Not all folded rock is metamorphic. Sometimes rock folds only a little bit, and doesn't change form. But rock that's been folded over and over again, was probably exposed to extreme heat and pressure deep underground which caused it to fold and change into metamorphic rock.

How Metamorphic Rock Forms

Metamorphic rock forms under extreme conditions, when high pressure, high temperature, or both change the minerals and internal structure of the rock.



1 When Earth's crustal plates push toward each other creating mountain ranges, the rock at the edge of each plate is under tremendous pressure. The pressure causes the minerals and internal structure of the rock to change as the rock folds, forming metamorphic rock. This is called **regional metamorphism**, because large regions of rock at the edge of each plate change to metamorphic rock.

2 When hot melted rock from deep inside the Earth bubbles up toward the surface, such as in a volcanic eruption, the tremendous heat of the liquid rock can change the solid rock nearby into metamorphic rock. This is called **contact metamorphism**, because any rock that comes into contact with heat from melted rock will change form.

The amazing thing is, any rock can change into a metamorphic rock if it is exposed to enough heat or pressure. This is part of the **rock cycle**, the process through which all rocks on Earth are constantly changing from one form to another.

Which rocks contain fossils?

Sedimentary Rock

A day at the beach means playing in the water, and relaxing in the sun on nice comfortable rocks. Wait a minute...no one goes to the beach to lie on rocks, do they? Well, as a matter of fact, the sand that you dig your toes into at the beach is actually made of tiny bits of rock and minerals. In fact, most of Earth's surface is covered with loose bits of rock and other material called **sediment**, which includes sand and pebbles, mud, clay, dust, and soil.

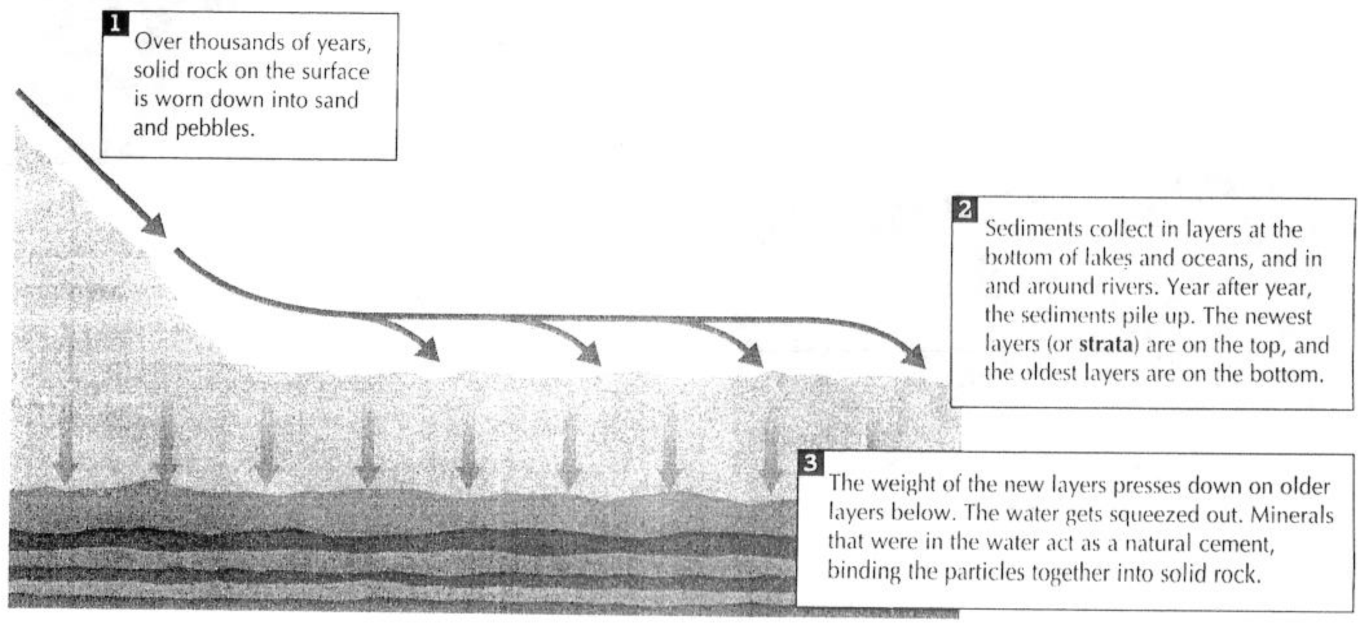
As water flows over the land, it picks up sediments and carries them along, eventually depositing them at the bottom of rivers, lakes, or oceans. Over thousands of years, sediments pile up until the pile is so huge and heavy that the sediment near the bottom (now deep underground) gets squeezed together into solid rock.

Now, imagine you're a dinosaur roaming the Earth 100 million years ago. When you're thirsty, you'll find a lake or a river to drink from. All dinosaurs visited lakes and rivers to find water and food, and some of them died there. Most probably became a snack for some other dinosaur. But if a dinosaur's body sank to the bottom of the lake or river, it was quickly covered up by sediment, which protected it from scavenging animals. The flesh and soft parts of the body quickly rotted away, but the hard skeleton remained, buried in sand and dirt. As sediments piled up over thousands of years, the skeleton was buried deeper and deeper underground. While the sediments around the dinosaur bones were slowly being squeezed together into solid sedimentary rock, minerals in the water around the skeleton replaced the original bone material. Eventually, a rock copy of the bone formed inside the sedimentary rock.

A fossil skeleton can remain inside sedimentary rock deep underground for millions of years, as long as the rock isn't exposed to too much heat or pressure. If it is, the fossils within it can get crushed or melted.

How Sedimentary Rock Forms

Sedimentary rock forms from pebbles, sand, mud, and other particles that are pressed together deep underground.



Which rocks contain fossils?

What You Need

- black crayon
- scissors
- reclosable plastic bag
- wax flakes (2 colors)
- plastic spoon
- hot water (75°C/168°F)
- beaker or metal can
- shallow pan or tub
- clock or watch that times seconds
- paper towels
- hot mitt
- samples of sedimentary, igneous, and metamorphic rock
- fossil specimen

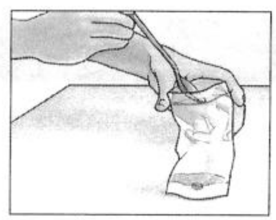
Caution: Be careful handling the hot water and melted wax. Do not open a bag containing melted wax.

Rock Recipes

What kinds of rocks might have fossils in them? It depends in part on how the rock formed. In this Science Lab, you'll demonstrate the three ways that rock can form, and then analyze your results to determine which of the three rock types is best for fossil-hunting.

What To Do

1. Use scissors to cut a piece of crayon about the thickness of a dime.
2. First, you'll make a model of sedimentary rock. Put 1 spoonful of one color of wax flakes into the plastic bag. The wax flakes represent sediment (such as sand) in your model.
3. Drop the crayon piece into the bag. The crayon represents a fossil.
4. Carefully put 1 spoonful of the other color of wax flakes on top of the "fossil" in the bag. Avoid shaking the bag to keep the two colors of wax from mixing. Squeeze any air out of the bag and close it by sealing the top.



5. Place the bag flat on a table. Make sure the fossil is buried in the wax. Sedimentary rock forms when loose sediments (like sand) are pressed together deep underground. To model this, put your hand on top of the bag and gently press down. Keep pressing until the wax flakes stick together (about 2 minutes).
6. Examine the sedimentary rock model and answer questions 1–3 in the What It Means section. Record your answers in the sedimentary rock column of the "Rock Model Observations" chart.
7. You'll now model how a sedimentary rock could become a metamorphic rock. Metamorphic rock forms when great heat and/or pressure changes the internal structure of a rock. Place a beaker or metal can in a sink or shallow tub. Carefully pour hot water (75ºC/168ºF) into the can until it is about 2/3 full.
8. Hold the bag containing the sedimentary rock model by the upper edge and lower it into the water, as shown. Hold it in the hot water until the wax flakes are partially melted (about 30 seconds). You may need to use the plastic spoon to keep the bag underwater. Take the bag out and wrap it in a paper towel. Knead the bag through the towel to mash the wax beads and fossil for about 20–30 seconds.

9. Let the wax cool for about 5 minutes and then complete the What It Means section with your observations of the metamorphic rock model.
10. Last, you'll make a model of igneous rock. Igneous rock forms from hot melted rock (magma) that comes from deep underground into Earth's crust and then cools, hardening into solid rock. Make sure the temperature of the water in the can is still 75ºC (you may need to pour out the water and add new hot water to the can). Hold the bag in the hot water again until all the wax is completely melted (about 2 minutes). Take the bag out, and shake it to mix the melted wax. Set it on a paper towel to cool (about 10 minutes).
11. When the melted wax has hardened, complete the What It Means section with your observations of the igneous rock model. Then answer questions 4 and 5 in the What It Means section.

Which rocks contain fossils?

What It Means

1. How did the process you used to create the model imitate how rock really forms on Earth?
2. Without opening the bag, examine the rock model. Describe the texture and color of the wax.
3. Look for the crayon "fossil" in the bag (keep the bag closed). Record whether you can find the fossil, and if so, how it has changed since you placed it in the bag.
4. Examine a specimen of a fossil embedded in the rock. Which of the three rock models does the specimen most closely resemble? Why?
5. Examine samples of the three types of rock. Can you tell which is sedimentary? How?

Advising the Team

Based on your observations, in which rock type(s) should the team look for fossils, and which rock type(s) should they avoid? Can you locate areas of sedimentary, igneous, or metamorphic rock in the satellite images?

Rock Model Observations

	Sedimentary Rock	Metamorphic Rock	Igneous Rock
How did you make the model?			
Description of rock model			
Observations of crayon "fossil"			

How does erosion change the landscape?

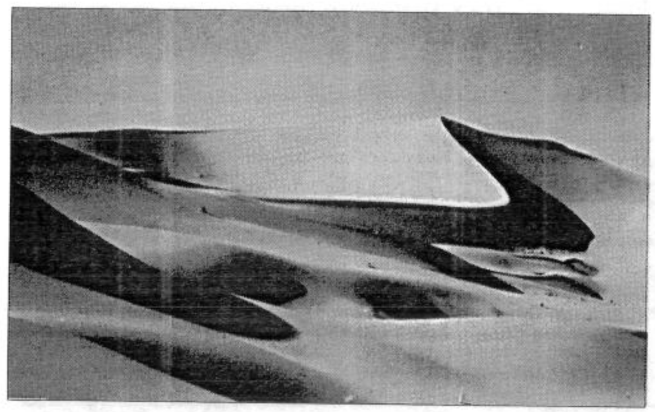
Wind Erosion

The wind is a powerful force that can move sailboats across the surface of the ocean and make tall buildings sway. In a sandstorm, wind picks up sediments — sand, dirt, and even tiny rocks, and carries them along. The stronger the wind, the heavier the objects it can pick up, and the farther it can carry them. The wind throws these sediments against rocks and other things that are sticking up from the surface.

Imagine what would happen to your face if you stood out in a sandstorm for 1,000 years. Being hit by flying sediments over and over wears down even strong surfaces like rock by breaking small bits of rock off the surface. This process of wearing down solid rock is called **weathering**. Some of these broken bits of rock are then carried away by the wind. This is called **erosion**. Together, weathering and erosion help shape the surface of the Earth.

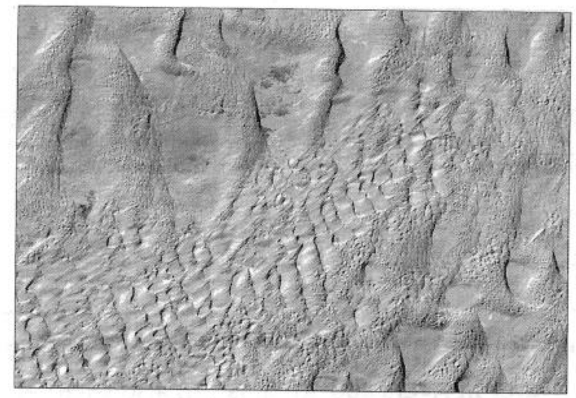
Since wind happens pretty much everywhere on Earth, all landforms can be changed by wind. In deserts, strong winds can sometimes sweep away all the loose sand and soil from the surface of the ground. This leaves a flat layer of small rocks and pebbles called **desert pavement**. These rocks, which are too heavy to be picked up by the wind, protect the ground underneath from further wind erosion.

As the wind carries sediments along, it eventually drops them elsewhere. This is called **deposition** because the wind deposits sand and other sediments on the ground. In some places, the deposited sand piles up into **dunes**. Sand dunes aren't made of solid rock, but are huge hills of loose sand that look like giant waves or ripples.



Sand dunes are one landform created by wind. These are giant hills of sand that can form along ocean coasts and in some deserts.

Satellite Tip



Using satellites, we can see things from the air that we can't see on land. This satellite image shows sand dunes in a desert in China. From above, the sand dunes look similar to ripples of water. But on the ground they look like giant hills.

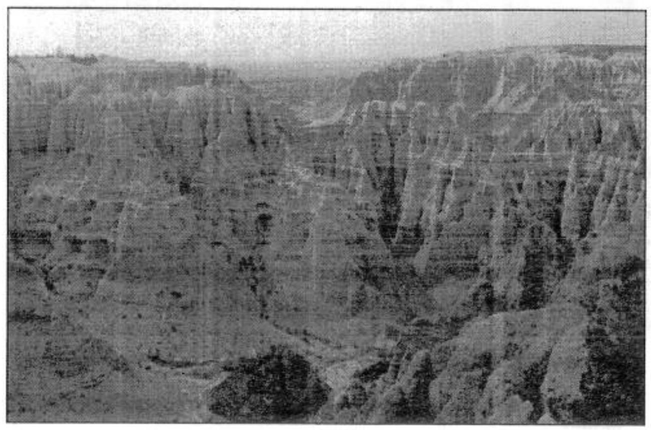
How does erosion change the landscape?

Water Erosion

At the same time that mountains and hills are being created on Earth's surface by plate tectonics, the forces of weathering and erosion are working to flatten everything out again. Over time, water can help wear a steep mountain range down into gently rolling hills.

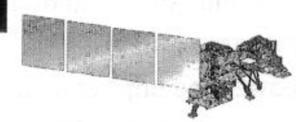
A raindrop falling to the ground is like a tiny hammer that beats against solid rock. It happens slowly, but over time thousands of drops of rain can chip away small bits of rock. This is called **weathering**. Water in rivers and streams can also weather solid rock. Have you ever noticed that rocks on a beach or at the bottom of a river are often very smooth and rounded? As rivers and streams flow down hillsides and across the land toward the ocean, sand and small rocks being carried by the water rub against rocks in the stream bed, and against each other. They act kind of like sandpaper, breaking little bits off each others' surfaces. The bits that break off the solid rock are carried away by the moving water. This is called **erosion**. Some of these loose sediments build up on river banks, creating twists and turns in the path of the river. When the river floods, some of the sediments carried in the water get deposited in a layer on the ground surrounding the river. (This area is called a flood plain.) Eventually, much of the sediment carried by rivers ends up on the ocean floor.

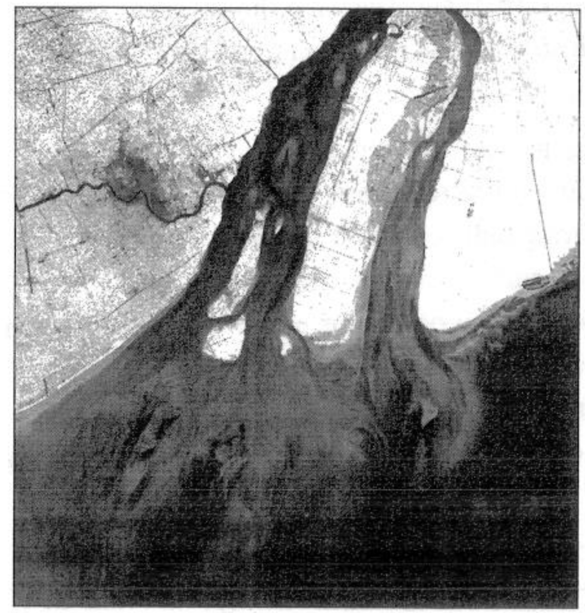
Rainwater and rivers do a great job of helping us find fossils that were formed deep underground inside rock. A river winding its way over the land may carve a deep trench through the rock below. Over thousands of years, it cuts down through the solid rock, exposing a cross section of the rock that's underground. The Grand Canyon in Arizona is a place where a river has worn away layers of sedimentary rock that were formed long ago at the bottom of a shallow ocean. People who hike down into the Grand Canyon can see fossils of marine life embedded in the rock of the canyon walls.



A cross section of sedimentary rock looks something like a layer cake. The layers of rock (called *strata*) can be different colors and textures because of the kind of sediments they're made of. A layer of rock made from sand looks different from one made of mud.

Satellite Tip





In this satellite image of a river delta (the place where river water spills out into the ocean) you can see the lighter-colored sediments that are flowing out with the river water and getting deposited on the ocean floor.

How does erosion change the landscape?

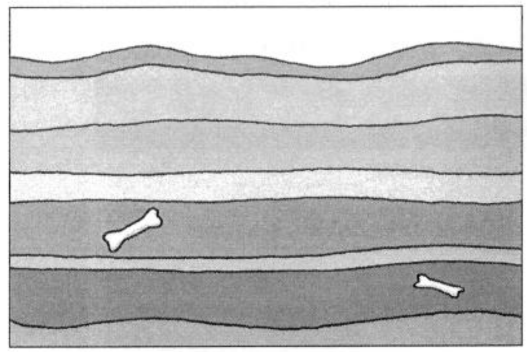
Finding Fossils

One day in 1988, Thad Williams, an eight-year-old from Mill Sap, Texas, was walking along when he noticed a strange-looking rock in a dry creek bed. It turned out to be part of the skull of a large dinosaur. Soon, paleontologists had unearthed three 15-foot dinosaurs from the rock wall of the creek bed. Thad was lucky. When you send the Science Seekers paleontology team out into Vastland it can't just pick up any rock and expect to find a fossil. Fossils are actually very rare.

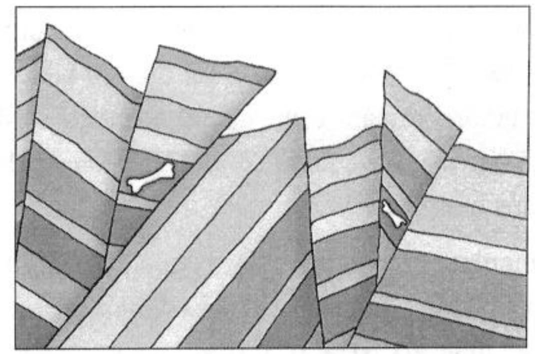
If fossils are formed deep underground in sedimentary rock, how do they get up to the surface where paleontologists can find them? First, uplift caused by plate tectonics brings the rocks that contain fossils from deep underground up closer to the surface. Then a second process, called **erosion**, takes over. Over thousands of years wind, water, and other elements wear away the solid rock surrounding the fossils. The best fossil sites are ones where small parts of fossils are actually sticking out of rock on the ground or in a hillside.

How Fossils Reach the Surface

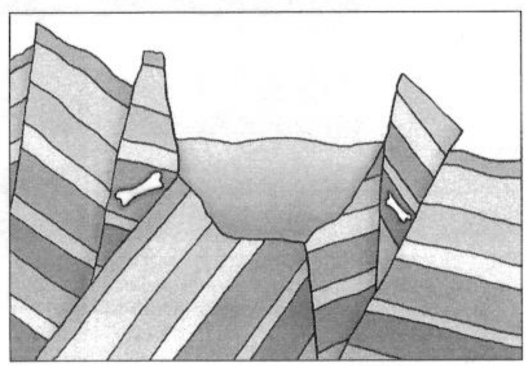
It takes thousands of years for a fossil that was formed in sedimentary rock deep underground to make its way to the surface.



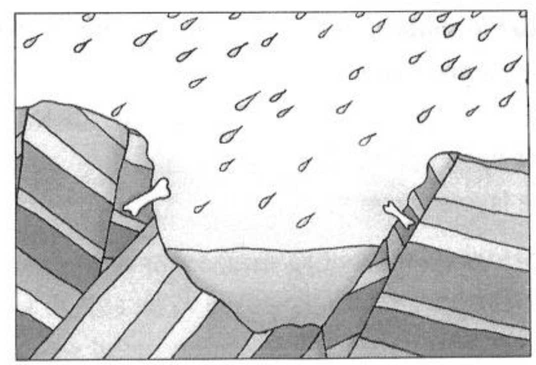
1. Bones buried in dirt or sand get buried under more layers of sediment. Over time, the bottom layers harden into sedimentary rock. At the same time, the bones become fossils.



2. Plate tectonics causes the layers of rock to be uplifted. Some fossils that were deep underground are now much closer to the surface. At the same time, wind and water begin wearing down the rock on the surface.



3. As a river carves its way through the rocks, it creates a river canyon. The sides of the canyon look a little like a layer cake.



4. With a little help from wind and rain, the river wears away the rock in the walls of the canyon. Over many years, fossils buried in the rock are exposed.

How does erosion change the landscape?

Earth's History

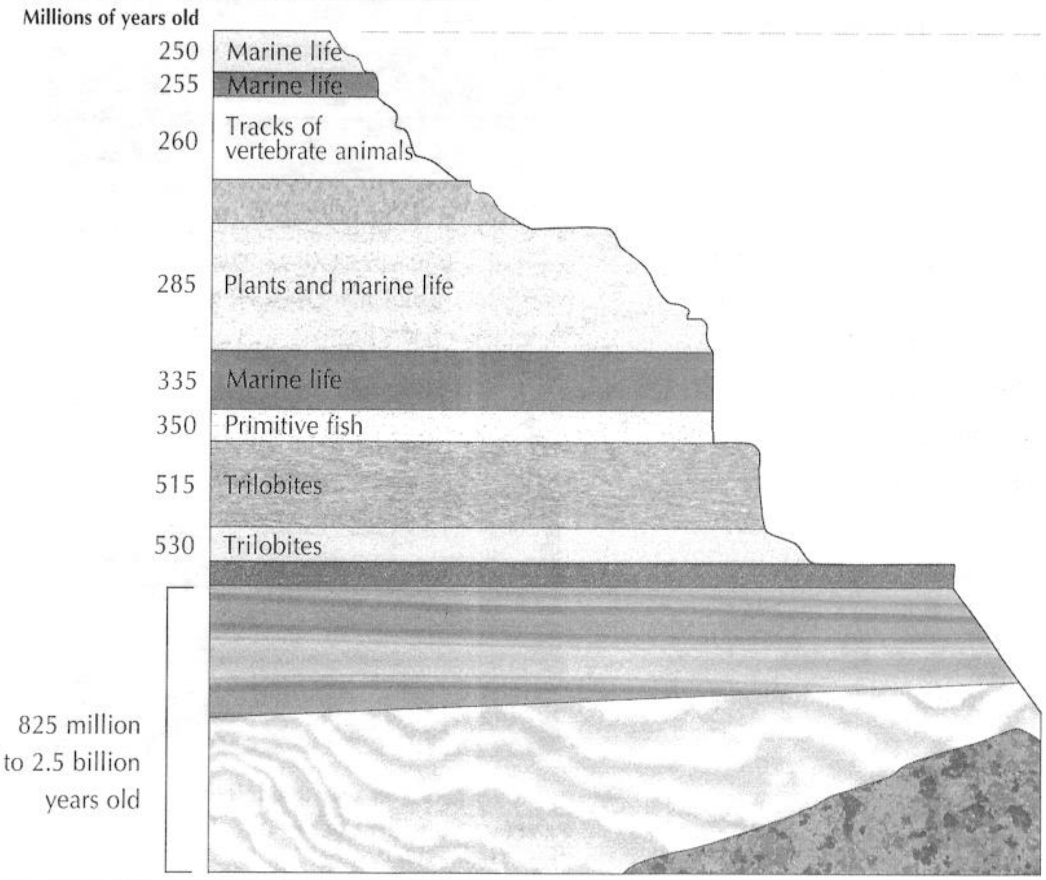
Human civilization has been around for about 10,000 years. Written historical records have been around for even less time than that. To find out what was happening on Earth for the 4.6 billion years before humans came along, scientists study the things that have been around a lot longer than humans have: rocks.

Sedimentary rock keeps a pretty good record of Earth's history. This is because sedimentary rock is formed in layers (**strata**). If these layers remain flat, it's pretty easy to tell which layer was created first, and which is most recent. It's like the dirty clothes on the floor of your bedroom — the ones on the bottom have been there the longest. This is called the Law of Superposition. Scientists can use this law to figure out when dinosaur species existed. A fossil in the lower layers of sedimentary rock that hasn't been uplifted is probably older than a fossil in the layers above it.

But before scientists can study rocks to find out about Earth's history, they have to be able to *see* the rocks. If all the rock stayed underground where it was formed, you'd have to dig down a few miles to find any fossils. Rock containing *Tyrannosaurus rex* fossils was created about 65 million years ago — it would be underneath all the rock layers that formed after it.

In places like the Grand Canyon in Arizona, nature has helped uncover fossils deep underground. River water has slowly cut down through the layers of rock beneath it. (The process of wearing away solid rock is called **weathering** and **erosion**.) The canyon walls are like a slice of time where we can see layers of rock formed millions of years ago, and the fossils in those layers.

Grand Canyon Rocks & Fossils



How does erosion change the landscape?

Water Erosion Observations

Number of Pours	Observations
2	
4	
6	
8	
10	
12	
14	

What It Means

1. What happened to the sand as the water flowed through it?

____

2. Look at the shape of your model canyon. Compare it to the shape of the river canyon shown on Investigation Sheet 3B. How is the shape of your canyon model like a real canyon? How is it different?

____

____

3. If each pour stands for 1,000,000 years, how many years did it take for your model canyon to start forming? How many years did it take for the fossil to be uncovered?

   Years for canyon to start ________________

   Years for fossil to show ________________

4. Estimate what fraction of the sand in the tray was eroded before the fossil first appeared. (circle one)

   1/4 1/3 1/2 2/3 3/4 all

Advising the Team

Look at your group's Satellite Imagery poster to see if you can observe areas that have been shaped by water erosion.

How does erosion change the landscape?

What You Need

newspapers

erosion tray

shell

damp sand

blocks or a binder notebook

2 (or more) rubber bands

bucket or tub

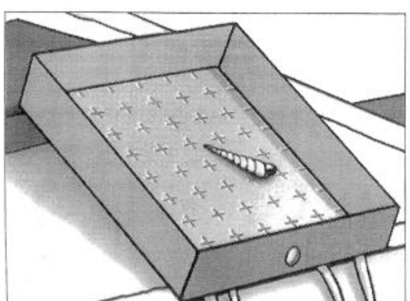
scissors

paper cone

plastic 1-oz cup

water

centimeter ruler

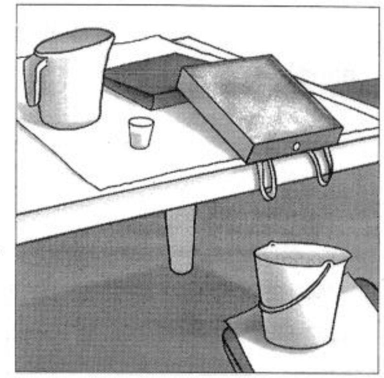


Washing Away

Imagine a dinosaur fossil embedded deep inside a rock, so perfectly preserved that every tooth is still in the jaw. Now imagine that the rock lies under 30 feet of other rocks. No one would have much chance of finding it, would one? When you are fossil-hunting, it's best to look in a place where weathering and erosion have already done some of the work for you. How does erosion help uncover fossils? How can you recognize landforms that were shaped by erosion? In this Science Lab, you will create a model showing how weathering and erosion by water can form a canyon and reveal objects that may be hidden in sedimentary rock.

What To Do

1. Cover your work surface with newspapers. This will make cleanup faster and easier.
2. Place the shell in the erosion tray, as shown. The shell will represent a fossil in this erosion model.
3. Now take the erosion tray, with the shell, and fill it to the top with damp sand, burying the shell "fossil." *Gently* pack the sand to make sure the tray is completely full. (If you pack too hard, you may crack the tray.) The sand represents solid rock on Earth's surface.
4. Prop one end of the erosion tray on one or two blocks at the edge of the table, as shown. A narrow binder notebook also works well. The high end of the tray should be raised about 4 cm. The low end, with the hole in it, should be right at the edge of the table. You may need to place a rubber band or two under the low end of the tray to keep it from sliding off.



5. Put newspaper on the seat of a chair. Set the bucket or tub on the chair and place it under the hole in the erosion tray, as shown. Put newspapers on the floor around the chair to catch spills.
6. Use scissors to cut the tip off the paper cone to make a funnel.
7. Fill a 1-oz cup with water. Hold the funnel over the sand at the middle of the top edge of the tray. **Important: Do not poke the funnel into the sand.**
8. Slowly pour the water through the funnel onto the sand. Watch until the water disappears completely into the sand. Each cup of water poured on the sand represents river water flowing over the land for 1,000,000 years.
9. Fill the small cup with water again. Pour it through the funnel onto the sand at exactly the same place as before. Watch until the water disappears completely into the sand. Record your observations in the first space in the "Water Erosion Observations" chart.
10. Keep pouring small cups of water through the funnel onto exactly the same place at the top edge of the sand. Pour slowly and let the water completely disappear or completely run out of the hole between each pour. Every two pours, stop to record your observations in the chart. Be sure to record when a canyon begins to form and when you can first see the fossil. Stop pouring when you can first see the bottom of the erosion tray. (If you need more than 14 pours to do this, then continue your chart on another sheet of paper.)

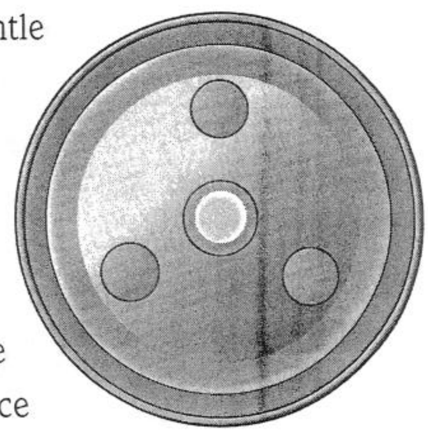
Extension Activities

The concepts and content introduced in *Science Seekers: Hidden in Rocks* provide a foundation for further research. Here are some suggestions for extending what students have learned.

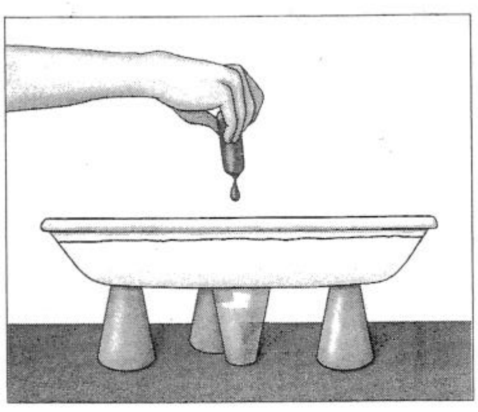
Mantle Material Modeling

Earth's plates move around on a layer of hot, dense rock material that makes up the upper mantle. Scientific evidence suggests although this material is solid, it can behave fluidly, like a liquid over long periods of time. Solids have a definite shape, do not flow, and can break into pieces. Liquids have no definite shape, flow easily, and cannot break into pieces. Make a solid material that can move fluidly like a liquid. Put three or four spoonfuls of cornstarch in a dish. Add a few spoonfuls of water. Use your hands to mix the cornstarch and water until the mixture holds together when you squeeze it, falls apart when you let go, and does not splatter when you pat it. Form this mixture into a ball. Break the ball in two. Set half of the ball on a plate. Watch the piece flow into a pancake after you put it down. Use a plastic knife to cut the pancake. Like Earth's mantle, this solid material is rigid over short periods of time. But over longer periods of time, it behaves fluidly.

Convection Currents



Evidence suggests that *convection currents* within the mantle are what drives the movements of Earth's plates. To model a convection current, rest a glass or clear plastic dish on four cups that are the same size, as shown. Make sure the cups are fully supporting the plate, then lift up the plate again. Without moving the cups, fill the middle cup with very hot water. Then, put the dish back on top of the cups, and fill the dish with ice-cold water, (leave out the ice cubes). Wait for the water in the dish to settle, then put a drop of food coloring in the middle of the dish. Watch the food coloring from above and from the side of the dish for five minutes. Where is the food coloring rising? Where is it sinking? At what kind of plate boundary would the mantle be rising? At what kind of boundary would it be sinking?



Toothpaste Volcano

Volcanoes often form at places where Earth's crust has cracks, faults, or other weak spots. To model how a weak spot can lead to a volcanic eruption, get a toothpaste tube, a clean pin, and permission to poke a hole in the toothpaste tube. Make sure the cap is on the tube. Use the pin to poke a small hole through one wall of the toothpaste tube. Squeeze the tube gently. What happens? In a similar way, magma from inside earth can ooze out through a weak spot in Earth's crust.

Layer Cake Core Sample

How do geologists know what kinds of rocks lie beneath the surface? One way is by taking a *core sample*, a sample of rocks drilled out of the Earth by a special machine. You can model a core sample using a clear drinking straw and a piece of layer cake (or a filled cupcake) on a plate. Hold the straw with one open end above the cake. Gently push and twist the straw down into the cake. Stop when the straw hits the plate. Slowly pull and twist the straw out of the cake. If necessary, wipe off the outside of the straw, so you can observe the layers within the clear straw. What does this core sample tell you about what is under the surface of the cake? What would a core sample of Earth's crust tell geologists about what is under Earth's surface? Why might it be difficult to take a core sample of loose dirt?

Local Rocks

What kinds of rocks are common in your area? Put on a pair of sturdy, comfortable shoes and go on a rock-observing trip. Bring a magnifying glass and a field guide to rocks, if you have them. Look for places where rocks are visible at the surface, such as hillsides, along streams and rivers, and in road-cuts on quiet streets. If you live in a city, observe the rocks that are used on the outsides of many buildings at street level (these rocks may not be local, but they are interesting). What kinds of rocks do you see? Are any grains or crystals visible in the rocks? Are any layers noticeable? What color(s) are the rocks? Can you find any clues that tell you whether the rocks are igneous, sedimentary, or metamorphic? **Note:** Always take someone else with you on trips outdoors, only visit places that are safe, and always tell an adult where you are going and when you expect to be back.

Crystal Formation

Some igneous rocks form at Earth's surface from lava that cools quickly. Other igneous rocks form below Earth's surface from magma that cools slowly. Crystal size is a clue to how an igneous rock formed. Make some crystals form quickly and other crystals form slowly in the following way. Heat some water on the stove until it is almost boiling. Dissolve 1/4 cup Epsom salts (hydrated magnesium sulfate) in 1/4 cup of the hot water. Put 2 tablespoons of this solution onto each of two matching plates. Place one plate in a refrigerator (at the back, where it is less likely to be spilled). Place the other dish in a place where it will be at room temperature and out of the way. Look at both dishes after 1–2 days. Which dish cooled faster? Which cooled slower? Which one has thinner crystals? Which has thicker crystals? If an igneous rock has large crystals, what does that tell you about where it formed?

Wind Erosion

Cut off the top and one end of a box that is about 12 x 12 x 18 inches (or longer). Place a shell or other object on the floor of the box, to represent a fossil, and cover it with a small pile of dry sand. Blow a steady stream of air through a straw at the pile of sand. Observe what happens to the sand dune as the wind blows over it. How does this wind erosion help reveal the fossil?

Ice Weathering

Weathering is the process that breaks rocks into smaller pieces that are then *eroded*, or carried away by water or wind. Water is the single most important agent of weathering. Freezing water is an even more powerful agent of weathering than liquid water. Demonstrate the power of freezing water this way: Find a large plastic jar and a small glass jar that fits inside it, both with screw-on lids. Completely fill the small glass jar with water and put on its lid. Place the filled glass jar into the empty plastic jar and put on the plastic jar's lid. Place the jars in the freezer overnight. The next day, look through the plastic jar to observe what has happened to the glass jar. **Caution:** Avoid sharp edges! Discard these materials without opening the plastic jar.

Erosion Protection

Plants not only cover up fossils, they also protect fossil-bearing rock from weathering and erosion. Try this demonstration for yourself. Go outdoors with a partner and a sprinkling can of water. Find a slope with few plants growing on it. Find another slope that is covered with plants such as grass, trees, or vines. Use the sprinkling can to water both slopes. Which slope is eroded more? Which slope is better protected from erosion?

Making Tracks

Much of what is known about dinosaurs comes from fossils of their footprints, also called *tracks*. Just from its tracks, paleontologists can figure out whether a dinosaur walked on two feet or four, its walking or running speed, approximate size, and other information. Discover how much you can learn from tracks. Go to a place with fresh snow, or with loose or soft soil (such as a beach or dirt road). Walk slowly for 10 steps, run for 10 steps, and hop forward on one foot 5 times. Go back and look at your tracks. What clues do your tracks hold about how you moved and about your overall size? If you have a dog, walk and run alongside it. How do the tracks show which creature walked on four feet and which walked on two? If you don't have access to snow or sand, take a bucket of water-soluble paint such as poster paint and a long roll of butcher paper to a paved area outside. Wear one or two pairs of old socks you can throw away later, and be sure to roll up your pants! Use rocks to hold down several long pieces of butcher paper. Then dip your feet in the paint and make tracks on the paper. Be careful not to slip on the wet paint.

Piecing It Together

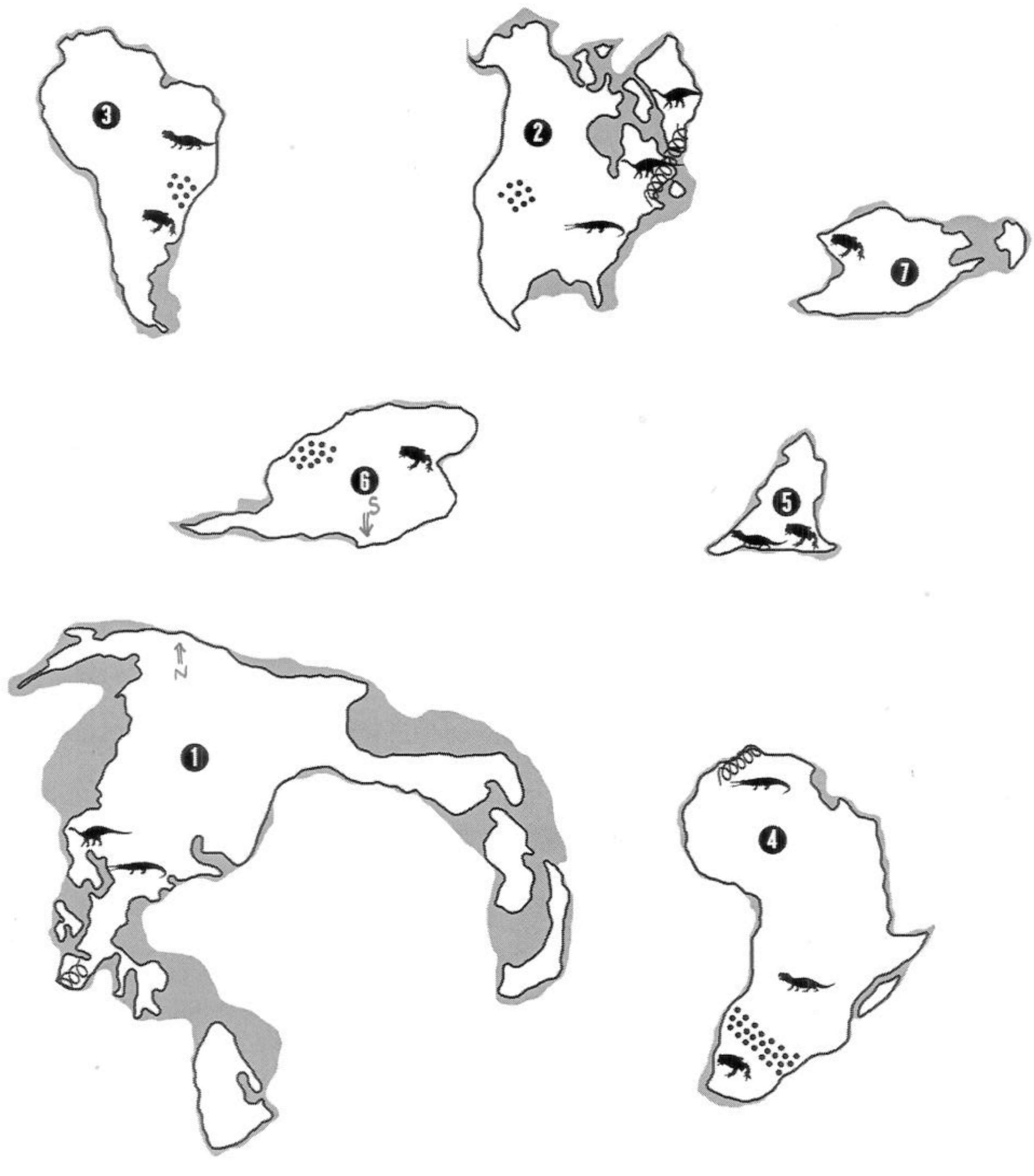
Once paleontologists have collected and prepared fossil dinosaur bones, they face the challenge of putting the bones back together. Often, they do this with pieces missing and without knowing for sure how the bones went together in the first place. You can find out for yourself how challenging this task is. Clean, separate, and save the bones from a roasted chicken or turkey, or get an owl pellet and separate the bones from the fur (owl pellets are available from companies that supply science equipment to schools). Try to put the skeleton together again. How long does it take? How do you know you are doing it correctly? When you are finished, try to draw a picture of the animal, based on its skeleton. Can you figure out what color the animal was, or what it was covered with? Would you be able to tell this from the bones alone?

Make Your Own Fossil

Many fossils, including tracks, form as *casts* of the original object or footprint. Make a model cast. Coat the bottom and sides of a flexible, disposable plastic dish with petroleum jelly. Fill the bottom of the dish with modeling clay to about a half-inch deep. Push a shell or other object into the clay with the interesting side up. Coat the clay and the object with another thin layer of petroleum jelly. Mix plaster of Paris according to the directions on the package. Add enough plaster to the dish to cover all the parts of the mold to a half-inch deep. Leave the plaster to harden for one hour, then gently pop the plaster cast of the fossil out of the container. Set the fossil aside to harden for 24 hours.

A Plate Tectonics Puzzle

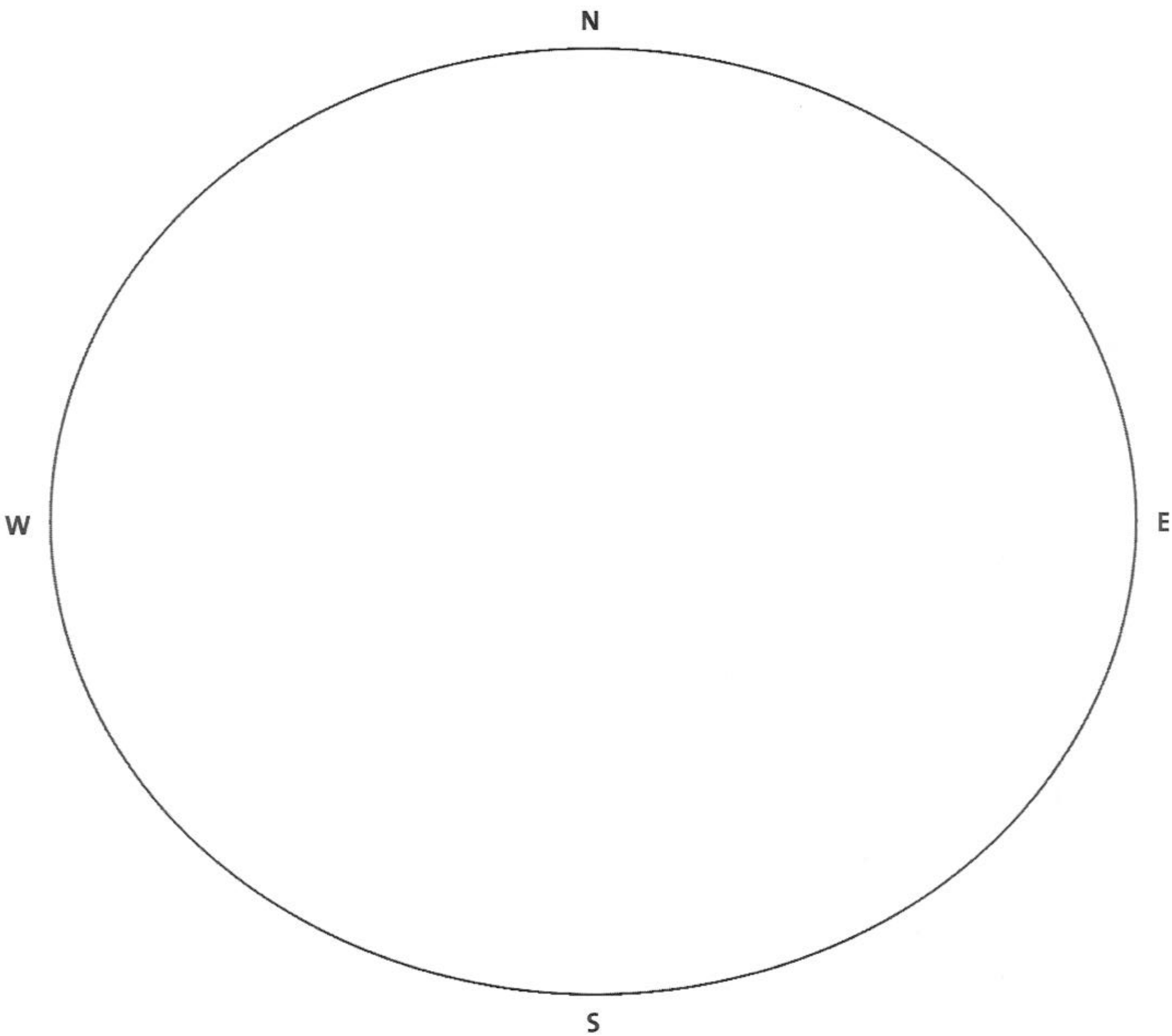
LANDMASSES TO CUT OUT



A Plate Tectonics Puzzle

LEGEND

❶ Europe & Asia	❹ Africa	❼ Australia	basalt	*Plateosaurus*
❷ North America	❺ India	landmasses BELOW sea level	desert	*Phytosaur*
❸ South America	❻ Antarctica	landmasses ABOVE sea level	amphibian	*Rhynchosaur*



Name: ____________________

What Gondwanaland May Have Looked Like

1. Cut out the shapes of the following continents and countries from the Classroom Activity Sheet: South America, Antarctica, Australia, Africa, Madagascar, and India.

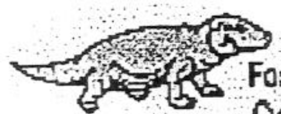
2. In the space below, arrange the continents into what you think Gondwanaland looked like. Look at the shapes of the continents. Then take a closer look at the fossil locations marked on your map.

FOSSIL COLOR KEY

G

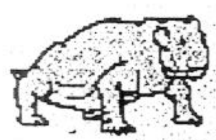
Fossils of the fern *Glossopteris*, found in all of the southern continents, show that they were once joined.

C



Fossil remains of *Cynognathus*, a Triassic land reptile approximately 3 m long.

L



Fossil evidence of the Triassic land reptile *Lystrosaurus*.

M

Fossil remains of the freshwater reptile *Mesosaurus*.

DiscoverySchool.com

Prehistoric Landmasses

DiscoverySchool.com