Reflect

The kinds of plants and animals that have lived on Earth have changed over time. Prehistoric humans hunted woolly mammoths. Long before humans, dinosaurs roamed our planet. Before that, all life was in the ocean.

How is it we know about the things that lived long ago? How do we know which things lived when?

The last dinosaurs died long before the first humans ever appeared on Earth.

Evidence of Past Life

You have probably heard of **fossils**. You may think of fossils as old bones that have turned to rock. This is not completely wrong, but it's not the whole story. Plants don't have bones, but plants can leave fossils. Sometimes even footprints or burrows left behind by animals can become fossils. Really, a fossil is just any physical evidence of a plant or animal that lived long ago.

Even before those who discovered fossils understood them completely, people noticed something interesting. Specifically, they noticed that the same kinds of fossils were always found together in the same layer of rock. In fact, rock layers were identified by their unique fossils. This fossil fern is evidence of a plant that lived millions of years ago. Some unique fossils were discovered in rocks in Russia.

The rocks were named **Permian**, after Permia, an old Russian kingdom, by the geologist who discovered them, Sir Roderick Murchison. The kinds of fossils found above and below Permian rock are different.

Which came first?

Eventually, people figured out that fossils formed when rock formed. The fossils in the rock represent the plants and animals that lived during that time. If different layers of rock have different fossils, this means they formed at different times when different plants and animals were alive. Fossils form in sedimentary rock. Sedimentary rock is formed when sediments, tiny bits of broken rock, are laid down by moving air, water, or ice. Over time, sediment accumulates.

The older sedimentary rock layers lie on the bottom; the youngest layers are on top.

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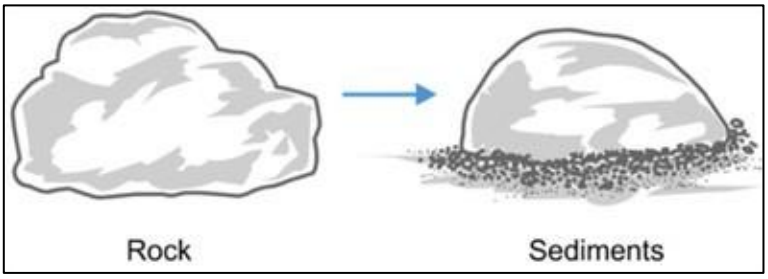
Processes That Shape the Land
The geologic features that help define the distinct landscape of Massachusetts have been—and are still being—shaped by the natural processes of weathering, erosion, and deposition. These processes affect land differently depending on the types of soil, rocks, and vegetation found in an ecoregion. These processes can also be affected by other natural features such as **climate** and **topography**.

Weathering
Weathering is the process by which rocks are broken down into sediments slowly over time. There are two major types of weathering: mechanical (or physical) and chemical.



Mechanical weathering breaks down rocks into smaller pieces—called *sediments*—through physical processes. Mechanical weathering changes the shape and size of a rock, but it doesn't change the rock's chemical composition. Wind and water are two of the main agents that cause mechanical weathering. Other agents include living things and changing temperatures. (An *agent* is something that causes something else.)

For example, winds can pick up small particles and blast them against rock, slowly scraping away at the rock over time. Moving water can weather rocks in a similar way; it often carries larger particles that scrape away at the rock more quickly. For example, millions of years ago, the Colorado River flowed over relatively flat land in what would become the southwestern United States. Slowly over time, the river carved away the rocks and carried the sediments downstream. This process created a depression in the flat land that gradually became a deep, wide canyon.

Water can also weather rocks by getting into cracks and freezing. When water freezes, it expands. When the water freezes in the cracks, it pushes the rocks apart. Plants growing in the cracks of a rock can push apart the rock in a similar manner. Drastic changes in temperature can also cause rocks to crack and break down as they expand and contract.

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Chemical weathering breaks down rocks through chemical processes that change the rocks' chemical composition. For example, some rocks such as limestone can be dissolved by water. Other compounds dissolved in the water can cause additional chemical reactions with the elements in the rock. Chemical compounds in air can also cause chemical reactions that weather rocks. For example, many rocks contain minerals that are composed of the element iron. Chemicals in water and air can cause the iron in these minerals to rust or *oxidize*. Rusting changes the iron (Fe) into iron oxide (Fe_2O_3), a different kind of chemical.

Some rocks are better able to withstand weathering agents than others. Rocks that are made of quartz, a very hard mineral, are highly resistant to mechanical weathering. Limestone, made of the mineral calcite, is the opposite of quartz. It is very easy to dissolve through chemical weathering. When a region contains many rock types, those that are more resistant to weathering will take longer to break down. This is called *differential weathering*. Differential weathering can shape the landscape by leaving peaks of highly resistant rocks and holes or depressions where less resistant rocks have been broken down.

Erosion

Weathering breaks rocks down into sediments, and the process of *erosion* moves sediments to other locations. Water—liquid and frozen—is an important agent of erosion. Flowing water can carry rocks, sediments, and soil downstream. The faster the water flows, the larger the particles it can carry. These particles may scrape against each other or nearby rocks, causing mechanical weathering at the same time as erosion. Glaciers—large sheets of moving ice—can also cause mechanical weathering, ripping chunks of rock out of the ground as they move across the land. The rocks and sediments caught up in a glacier are carried along the glacier's path, causing erosion.

Wind is another agent of erosion. Compared to water, winds usually carry smaller sediments. As these sediments scrape against rock in the wind's path, they can cause mechanical weathering at the same time as erosion. Animals are agents of erosion as they burrow into the ground, moving sediments out of their way. Another erosional agent is gravity, which constantly pulls rocks downhill as they weather. Many rocks are broken as they erode downhill, causing additional mechanical weathering.

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Because weathering and erosion tend to occur at the same time, rocks that are carried long distances by erosion tend to be more weathered. These rocks tend to be broken into smaller pieces and become more rounded. Rocks that are carried shorter distances, particularly through gravity, tend to be in larger pieces with more angular edges. Differential weathering also plays a role. For example, if many different types of rocks are carried downstream for the same amount of time, those that are more resistant to weathering tend to be larger and less rounded than those that are less resistant.

Deposition

Sediments, rocks, and soil cannot keep moving forever. Eventually, the particles stop moving and settle where the erosional agents have carried them. This process is called *deposition*. When sediments are eroded by wind, flowing water, ice, or gravity, they are generally deposited in horizontal layers. The oldest layer of sediments is positioned at the bottom, and the more recently deposited layers are at the top. Depending on which agents caused the erosion, the sediments may be deposited in different ways.

There are three main types of rocks.

Geologists classify rocks into three main categories: sedimentary, igneous, and metamorphic. Rocks are separated into these three types based on how they were made. A rock's physical characteristics reflect the processes under which it formed. So does a rock's **mineral** composition.

When rocks undergo additional processes, they can change from one type of rock to another. Depending on the processes the rock goes through, any type of rock can become any of the other types. It could even become a new rock of the same type. For example, a sedimentary rock could become a metamorphic rock, an igneous rock, or a new type of sedimentary rock, depending on what happens to it. The processes by which rocks change into new rocks make up the *rock cycle*.

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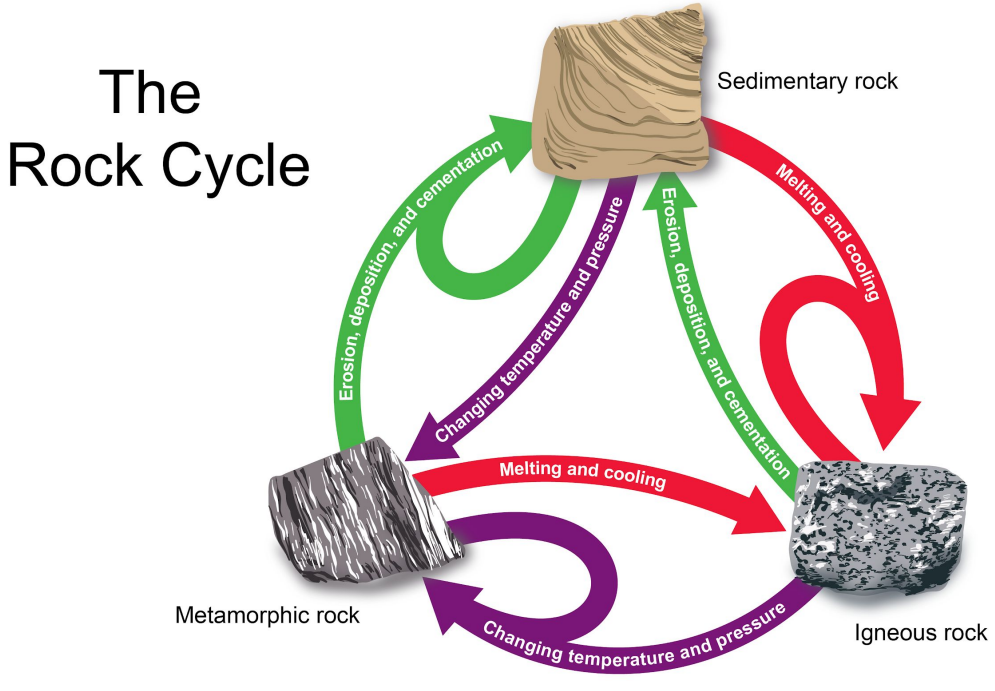
Igneous rocks have characteristics unique to how they form.
Igneous rocks are formed when lava or magma cools and solidifies. This solidification is known as *crystallization*. When magma erupts out of a volcano or seeps through cracks in Earth's crust, it becomes known as *lava*.

Sedimentary rocks have characteristics unique to how they form.
Once rocks are broken down by the process of weather and erosion, the smaller pieces are called *sediments*. Layers of sediment can be crushed together as more sediment is deposited on top. This crushing is called *compaction*. Sometimes water will fill in the tight spaces between the grains of sediment. Eventually, the water evaporates. When this happens, any minerals that were dissolved in the water are left behind. Small mineral crystals grow while the water evaporates. These crystals "glue" the sediment grains together in a process called *cementation*. Once the sediment grains are bound together, they become a *sedimentary* rock.

Metamorphic rocks have characteristics unique to how they form.
Rocks are often buried in Earth's crust. Sometimes sediment is deposited on top of them over time. Sometimes they are buried through the movement of **tectonic plates**. As they become buried deeper and deeper, the weight of the crust above puts pressure on the rocks. In addition, as the rocks get closer to the **mantle**, their temperatures increase. Pressure can change an existing rock into a new metamorphic rock by changing the rock's texture. Sometimes the sediment grains of a sedimentary rock or the crystals of an igneous or other metamorphic rock will be squeezed tightly together. This can change the rocks into new, denser metamorphic rocks. Many sedimentary rocks already contain parallel layers. These parallel layers can be squeezed by pressure and become the wavy layers of a metamorphic rock.



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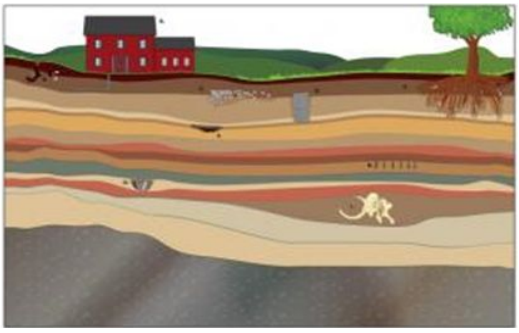
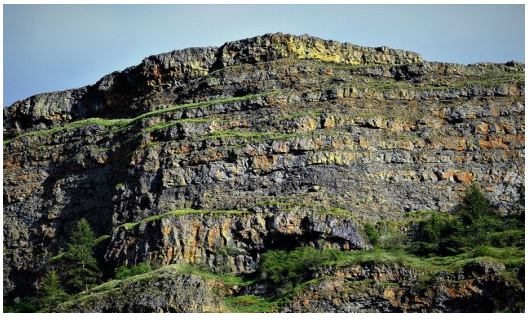
Stratigraphy

Erosion and uplift of Earth's surface reveal ancient rock layers (strata) and fossils that are clues to Earth's major geologic events. The study of rock layers (strata) is called *stratigraphy*. Over the long history of Earth, layers of sediment and rock have been deposited, one on top of the other, preserving the clues to the past. Sometimes the remains for plants and animals get buried in these layers and become fossilized. Geologists studied portions of these rock layers and discovered several patterns that are useful in interpreting geologic cross-sections:

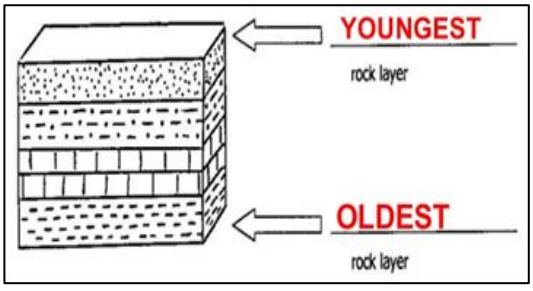


Geologic processes that occur today are the same as those that operated in the past.

Geologists compared marks in old rock layers and noticed that the same structures are seen in present rock layers. Geologists concluded that the processes that are now operating on Earth must be the same processes that operated in the past. So when a section of ancient exposed rock layer shows repeated layers of basalt, geologists might conclude that volcanic activity occurred many times during its geologic history.



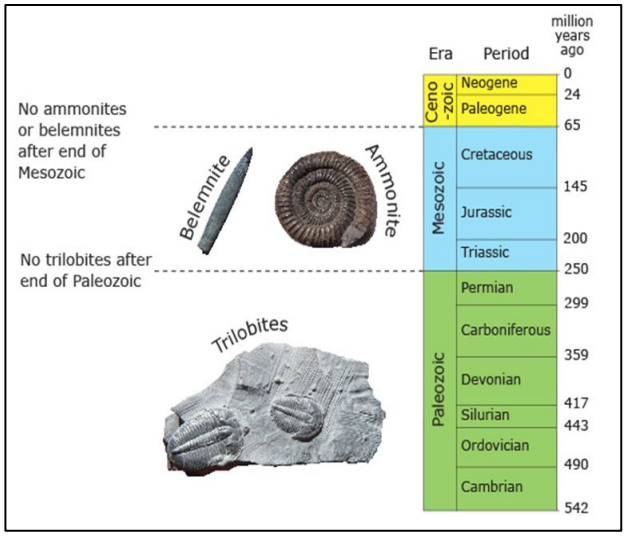
The oldest rock layers are at the bottom; the youngest layers are on top.



Because of Earth's gravity, younger sediments are deposited over older sediments. Therefore, in a sequence of layers that have not deformed, the oldest layer is on the bottom, and the youngest layer is on top.

Index fossils can identify the age of rock layers.

Certain fossils are organisms that lived only a short time. These **index fossils** become markers for that specific time period. Trilobites lived at a different time than ammonites and belemnites. Finding a trilobite fossil in a rock tells you that the rock was formed in the Paleozoic era.



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What Do You Think?

Geologists identify four major eras in the history of Earth: Precambrian, Paleozoic, Mesozoic, and Cenozoic. Read through the geologic time scale listed below. Do you see a pattern between the geologic events that changed the surface of Earth and the appearance or extinction of life on Earth?

A Brief Look at Earth's History

The biological, geological, and climatic events listed appear in reverse chronological order, with the oldest event at the bottom and most recent event at the top

Era	Period	Epoch	Beginning of Interval	Major Biological Events of the Era	Major Geologic and Climatic Events of the Era
Cenozoic	Quaternary	Holocene or Recent	(10,000 years ago)	Human Civilization	Earth's climate stable for the past 8,000 years. Great Lakes formed as glacial ice melted.
		Pleistocene	1.7 million years ago (MYA)	Saber-toothed Cats, First Humans, Bears, Mammoths, Sloths	Peak of the last ice age was 21, 000 years ago. Earth had several periods of ice ages and no ice-age conditions.
	Tertiary	Pliocene Miocene Oligocene Eocene Paleocene	66 MYA	Flowering Plants Horses, Cats, Dogs, Primates, Camels Rhinoceroses, Deer, Pigs, Small Mammals	Earth became colder and drier. Volvanic activity in western North America. Andes, Alps, and Himalaya Mountains formed. Colorado River carved out Grand Canyon. Inland seas in North America drained away.
Mesozoic	Cretaceous			Extinction of Dinosaurs First Flowerig Plants Most Dinosaurs	Asteroid impact kills off dinosaurs Rocky and Sierra Nevada Mountains formed. Climate much warmer than today. Shallow seas covered North America. Atlantic Ocean formed. North America and Africa moved apart. Pangaea began to break up.
	Jurassic			Larger, Fiercer Dinosaurs First Birds First Small Mammals	
	Triassic		245 MYA	Many Cycads and Conifer Trees Reptiles First Dinosaurs	
Paleozoic	Permian			Many Amphibians and Reptiles First Conifer Plants	Land became drier. Water drained into large basins. Ural and Appalachian Mountains formed. Continents moved together, forming Pangaea. Coal formed in swampy regions. Shallow seas covered most of land.
	Carboniferous Pennsylvanian Mississippian			First Reptiles Coal=Forming Swamps	
	Devonian			First Amphibians, Sharks, and Insects	
	Silurian			Coral Reefs Form First Land Plants	
	Ordovician			First Fish (Vertebrates)	
	Cambrian		570 MYA	First Invertebrates, Trilobites,Brachiopods	
Precambrian			4.6 billion years ago	Simple Marine Life, Bacteria, Algae, Jellyfish	Ozone layer formed. Outgassing formed atmosphere and the oceans. Meteorites bombarded Earth. Solid Earth divided into core, mantle, crust. Earth formed approximately 4.6 billion years ago.

M.Y.A = million years ago

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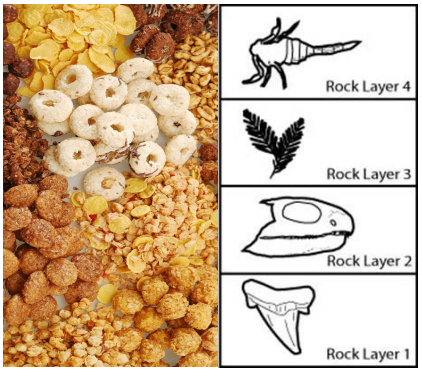
Reflect

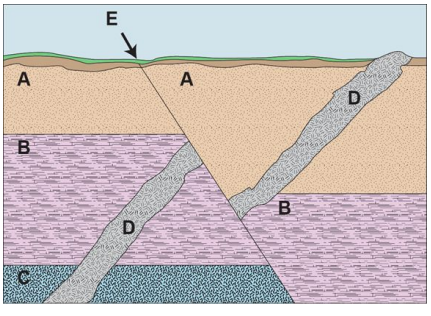
Law of Superposition

Imagine that you poured several layers of different cereals in a bowl. Where would you find the first cereal you poured in a bowl? Where would you find the cereal you poured in last? You could probably see that the first layer you poured would be on the bottom of the bowl. The last layer would be on top. By looking at any two layers, you would know which came before the other one, based on their relative positions.



The layers of cereal would pile up on top of each other like sediments that form sedimentary rock. When analyzing rock layers, geologists follow the law of superposition. This simply means that the oldest layer is generally found at the bottom, with younger layers on top! Sometimes each layer represents thousands of years of deposition of sediments.

On the right is an example of how the sequence of rock layers A, B, and C is disturbed by a fault (a crack in the crust along which sections move up or down), as shown in E. Layers can also be affected by intrusions (the insertion of other molten rock that cools), as shown in D.



Putting It All Together

Over many years, geologists in different countries discovered different rock layers from a specific time period. The rock layers, with their unique fossils found at a certain age, often took on the names of the regions where they were first discovered. Not every location had every rock layer, but by looking in different regions with the same rock layers and noticing which layers were above and below, geologists were able to build up a kind of map of geologic time by putting all the different layers in order, from oldest to youngest. It took many years to develop the technology that allowed scientists to declare that Cambrian rock formed between 540 million years ago and 485 million years ago, and to assign actual numbers to these time periods. The relative positions only let us say that Cambrian rock is older than Ordovician rock.

Rock Layer Name	Location Named For
Jurassic	*Jura* mountains in Switzerland
Devonian	*Devon*, a county in England
Ordovician	*Ordovices*, the ancient people of Wales
Cambrian	*Cambria*, ancient name for Wales

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