

Tectonics

Tectonics: noun.

1. geological structural features as a whole
2. branch of geology concerned with the structure of the crust of a planet (as Earth) or moon and especially with the formation of folds and faults in it

What is tectonics?

Mother Earth is alive. She flows and swells and changes her skin over time. Mountains rise from the ocean, lakes get left behind by retreating glaciers, sandy beaches build up against shorelines, oil bubbles from deep underground. Sometimes these changes happen very slowly, sometimes they happen in an instant.

What evidence have you seen of Mother Earth changing?

Tectonics is the study of Mother Earth's skin and the large-scale changes it experiences.



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Looking inside

What do you think the inside of a planet looks like?

No one has ever been able to take a look at the Earth all the way to the core. We know lots about what happens on the surface, because we live there. Our ancestors lived with the Earth and she gave them knowledge of herself - which stones to use for tools, what minerals could be ground into paints, where food would grow best, how rivers could flood in the spring. Today, we still know the surface the best, but new tools allow us to listen and hear other stories the Earth mother has to tell.

About 300 years ago, Isaac Newton theorized that whatever was inside the Earth had to be about twice as dense as what was on the surface.

Do you know what density measures?

Newton formed these ideas by combining what he knew about gravity and planets with math. Today, instruments that measure gravity, magnetic fields, the flow of heat from inside the planet and the way waves made by earthquakes move, tell us that his theory was a good one.



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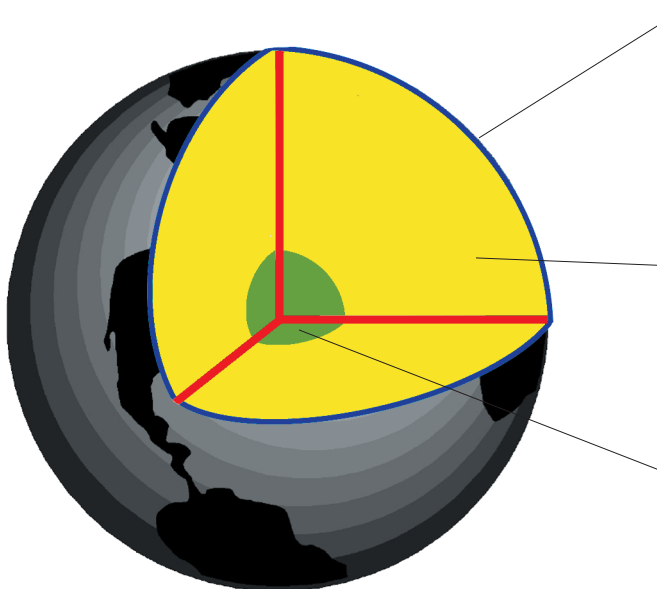
Sir Isaac Newton

Even though we can't see inside the Earth, we now believe it is made up of three different layers, each one consisting of a different kind of material, and each one denser than the one above it. If we could cut the Earth in half, we'd be able to see the layers.

Thickness and density of Earth's layers

Layer	Average thickness (km)	Density (g/cm ³)	
		Top of layer	Bottom of layer
Crust	30	2.2	2.9
Upper mantle	720	3.4	4.4
Lower mantle	2 171	4.4	5.6
Outer core	2,259	9.9	12.2
Inner core	1,221	12.8	13.1

Table based on information from the United States Geological Survey publication "The interior of the Earth", <http://pubs.usgs.gov/gip/interior>



Crust: The crust is the surface we live on. There are actually two kinds of crust - the continental crust (land) and the oceanic crust (under the ocean). Continental crust varies in thickness from 20km (under low elevations) to 80km (under huge mountains). Oceanic crust is about 7km thick. The crust is made from relatively low density rock.

Mantle: The mantle is a hot, semi-solid layer of denser rock. By studying the way earthquake waves travel through the planet, scientists have come to believe that the upper mantle and lower mantle are made from different kinds of rock and have different mechanical properties.

Core: The core is the centre of the planet. By listening to the stories the Earth tells during earthquakes, scientists are pretty sure the core has two layers: Both layers appear to be a metal alloy of nickel and iron. The outer core is liquid metal, while the inner core is solid.

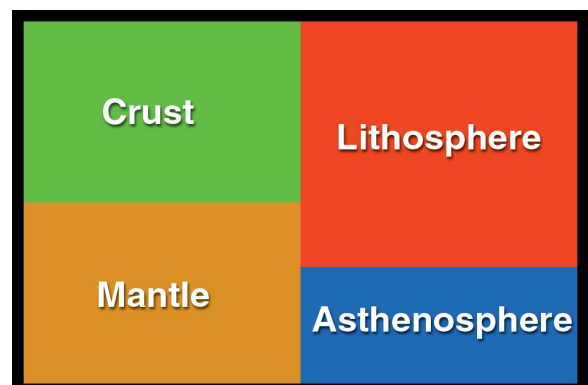
If you could travel to the centre of the Earth, what kind of conditions do you think you would find?

The lithosphere

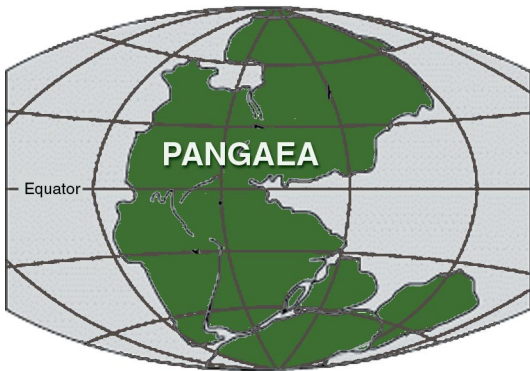
In order to understand Mother Earth's changes and cycles, geologists and geological engineers have come up with more than one way of thinking about the Earth's surface and interior. The divisions of crust, mantle and core are based mainly on the layers' physical properties. The layers of Mother Earth can also be described by their long-term mechanical properties.

What is the difference between physical and mechanical properties?

Taken together, the crust and the uppermost part of the mantle form a rigid layer called the lithosphere. They are grouped this way because they actually move together over a more fluid layer of the mantle called the asthenosphere.



The lithosphere isn't one solid piece. It is made up of about 12 pieces, some incredibly large and others much smaller. Each of these pieces is a tectonic plate. The plates move towards and away from each other; they move over and under each other; and sometimes they bump and grind together with earth shattering results.



Pangaea

The whole idea of moving continents has been around for at least 400 years. In 1912, a man named Alfred Wegener suggested that all the continents had once been locked together in one huge land mass which he called Pangaea. According to him, the supercontinent broke apart and the pieces drifted off in different directions. Wegener said that it took millions and millions of years for the continents to get to their current positions.

What do you think of Wegener's theory of continental drift?

At the time, people didn't think much about Wegener's idea. They believed the continents and oceans were fixed, permanent features on the Earth's surface. It took another 60 or so years to prove that Wegener was probably right - or at least on the right track.

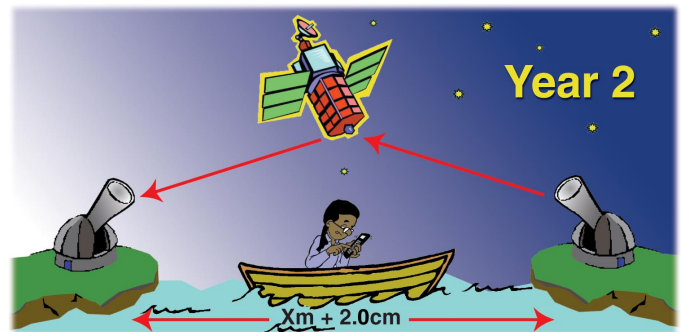
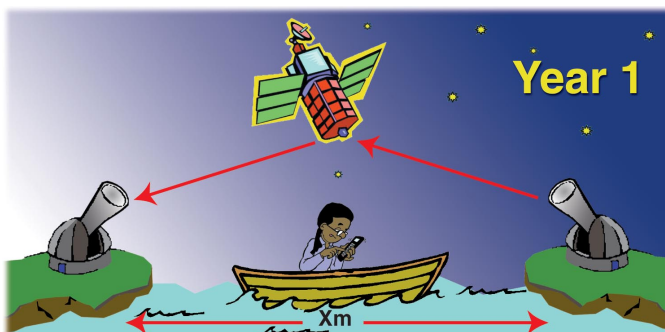
Evidence and mystery

If you had a theory that the continents were moving, how would you try to prove it?

It may be hard to believe that Mother Earth's skin moves, but by making some really precise measurements, scientists think they've come up with some pretty solid evidence supporting the idea.

They pick two spots, each on a different continent (say Europe and Turtle Island). To make it easy, they choose astronomical observatories which already have all the equipment they need. They then bounce a laser beam off a satellite-based mirror, sending it from one observatory to the other. By timing how long it takes for the beam to travel between the two observatories, and knowing the location of the satellite, scientists can then calculate the exact distance between the two observatories.

Do you think this measurement alone gives them enough information to figure out if the continents are moving towards or away from each other?



In order to show that the continents are moving towards or away from each other, scientists have to take measurements several times over the course of a year. They then compare the calculated distance between observatories for each measurement, to see if they are closer together, farther apart or at exactly the same distance as the time before. The measurements they have taken tell us that Europe and North America are moving away from each other at a rate of 20mm per year.

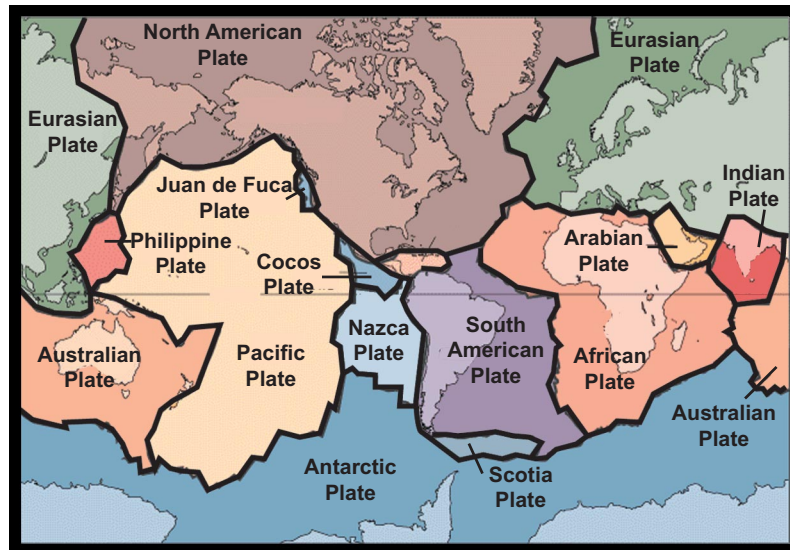
If you live to be 100, how far apart will Europe and Turtle Island move in your life time?

Even though scientists are now pretty sure tectonic plates do move relative to each other, they still can't answer the same question Wegener was left with: What forces are strong enough to move such massive pieces of rock over such huge distances? The answer to that question may only belong to Mother Earth

The biggest recycling project on Earth

*Imagine two huge moving plates.
How many ways do you think they can interact?*

We also see evidence of tectonics in the boundary zones where the massive plates meet. These areas often experience earthquakes and volcanic activity. To understand why, we have to understand what happens when two plates interact.



This map of the world shows the boundaries of the major tectonic plates.

Divergent boundaries. At divergent boundaries, plates are moving away from each other as Mother Earth creates new skin. As the plates pull apart faults form and allow magma to rise from deep within the Earth. New lithosphere, topped by mountains and volcanoes, is created as the molten rock solidifies.

In between the North American and Eurasian plates is one of the world's great mountain ranges, the mid-Atlantic Ridge (MAR). The MAR is a divergent boundary. It runs from a point south of the tip of Africa, all the way north and up through Iceland. Most of the MAR is deep beneath the Atlantic Ocean, but it is visible on the surface in Iceland, which is being torn in two by the spreading plates.

Surface features of divergent boundaries are often called rift valleys, because the rifting or cracking of Mother's Earth's skin is clearly visible.

Photo reproduced with permission, Nordvulk, Icelandic Volcanology Institute. Sigurjon Sindrason, photographer.



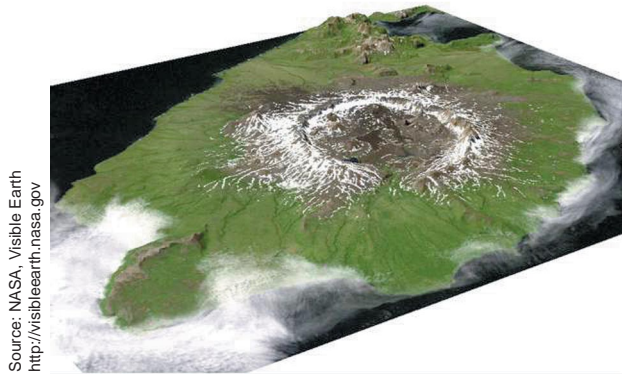
The Hekla Volcano in Iceland is one of few places where the activity of Mid-Atlantic Ridge can be seen on the surface.

Where on Earth can you find rift valleys?

Convergent boundaries: Mother Earth requires balance. When new lithosphere is created, old lithosphere must be destroyed in nearly equal amounts. The destruction or recycling of lithosphere is what happens (most of the time) at convergent boundaries where plates move together.

What would happen if the lithosphere wasn't created and destroyed in equal amounts?

There are three types of convergent boundaries.



Source: NASA, Visible Earth
http://visibleearth.nasa.gov

This image shows Umnak Island, one of the Aleutian Islands. The mound in the middle is the active Okmok volcano.

When oceanic crust meets continental crust, the oceanic crust (which is denser) gets subducted under the continental crust. While the denser crust is sinking, it may push up on the continental crust above it, creating mountain ranges and volcanoes. The Andes Mountains in South America are being built up by the subduction of the Nazca plate under the South American plate.

When two plates of oceanic crust meet, one sinks under, or is subducted beneath, the other. The subducted rock goes deep into the Earth. At the point where the two plates meet ocean trenches that are 8-10km deep form. Volcanoes are very common near these subduction zones. The Aleutian Islands, a chain running between Alaska and northern Russia in the north Pacific, were produced by the meeting of two oceanic plates. The Aleutians are home to the Unangan peoples.



Source: http://www.clipart.com

Machu Picchu is an ancient Incan city in the Andes Mountains of Peru. Machu Picchu means "Old Peak" in the Quechua language.



Source: http://www.clipart.com

Mount Everest, the highest mountain in the world, lies in the Himalaya Mountains of Nepal.

When two continental plates meet, the results can be spectacular. The rock of continental plates is relatively lightweight and resistant to sinking. When two plates meet head on they buckle and break pushing each other up or to the side. The biggest mountains on Earth, the Himalayas, were formed by the meeting of the Eurasian and Indian plates.

Have you seen other materials in nature that push up against each other when they meet?

Transform boundaries. When tectonic plates slide horizontally past each other the contact between the plates is called a transform boundary. The famous San Andreas fault in California is a transform boundary, so is the Queen Charlotte fault which runs along the islands of Haida Gwaii.

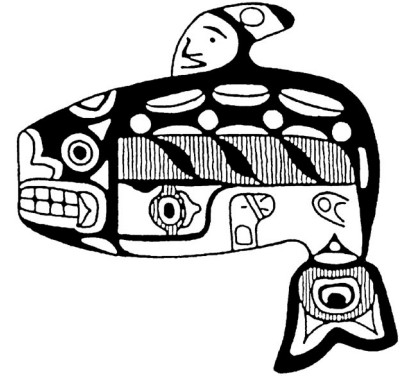
Earthquakes



Up and down the west coast of Turtle Island, from Vancouver Island, BC to the southern part of the state Oregon, people tell stories of great battles between Thunderbird and the Whale. The Quileute say that during struggles there is a “shaking, jumping up and trembling of the earth beneath, and a rolling up of the great waters.”

Most of the world’s earthquakes and volcanic activity occur in the boundary zones between tectonic plates. Plates moving into or sliding past each other sometimes become locked together and build up huge amounts of stress deep within the Earth. Earthquakes occur when the plates shift, suddenly unlocking all the stored up energy.

Northern Washington, the region where the Quileute live, is on the western edge of the North American plate. The area is sometimes called the Cascadia Subduction Zone, because the Cascade mountains are being built up by the subduction of the oceanic Juan de Fuca plate by the North American plate. Historically, the Cascades have suffered some massive earthquakes. The stories of the Aboriginal people in the region are one of the best records we have of these events.



Do your Elders tell any stories about earthquakes?

Volcanoes

On the Great Plains, Lakota Elders have long known of Tunka-shila, Grandfather Rock. They tell that before the beginning, everything existed as spirits in the mind of the Creator. Looking for a place to begin life, the spirits travelled through space, first to the sun, which was too hot, then to the Earth, which was covered in water. A huge burning rock rose out of the waters. Its heat created steam which became the clouds. As it grew and cooled, the rock became dry land, a home from which life could begin. The Lakota call that oldest, very first rock, Tunka-shila, which means Grandfather Rock, because it came before everything else.

Source: United States Geological Survey
http://vulcan.wr.usgs.gov/Volcanoes/MSH/SlideSet/lf_slideet.html. D.A. Swanson, photographer.



Volcanoes are vents to the interior of Mother Earth. They tend to occur in two places: convergent plate boundaries where one plate is being subducted by the other, like Mount St. Helen’s, and the rift zones of divergent plate boundaries, like the MAR. About three-quarters of all volcanoes are in under water in these rift zones.

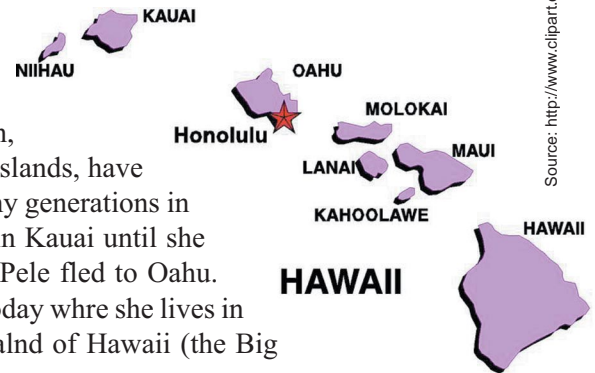
Can you find examples of volcanoes in each of these zones?

Mount St. Helen’s in the Cascades was silent for 123 years. In March 1980, earthquake activity in the region signaled the mountain was waking up. This picture was taken more than a month before the mountain erupted, just after visible evidence of volcanic activity started.

Volcanoes also occur in the middle of tectonic plates far away from either convergent or divergent boundaries. These volcanoes are built through a different process. In places called hotspots, the mantle is extremely hot with very low density. This hot material flows upward and can melt through the overlying plate, to produce molten rock or magma. Magma spills onto the sea floor, where it cools and solidifies. Over long periods of time, these under water volcanoes grow large enough to break the surface of the ocean and form new land. Eventually the tectonic plate moves enough to cut the volcano off from its source of magma, and the process starts again as another island begins forming under the ocean.

*There is a word to describe volcanoes that no longer have a supply of magma.
Do you know what it is?*

The Hawaiian islands were formed by the volcanic activity of a hotspot. The Pacific plate is slowly moving in a northwesterly direction over the hotspot. The islands in the northwest of the chain, Kauai and Niihau, are much older than the newest island in the chain, Hawaii which still has an active volcano. The native peoples of the islands, have passed down geological knowledge of the ages of the islands for many generations in songs and stories about Pele, the goddess of Volcanoes. Pele lived in Kauai until she was attacked by her sister, Namakaokahai, the goddess of the sea. Pele fled to Oahu. Each time Namakaokahai attacked, Pele fled to another island until today where she lives in the Halemaumau crater at the top of the Kilauea volcano on the island of Hawaii (the Big Island).



Geological engineers

Geological engineers (as well as geologists and geophysicists) have a very special relationship with Mother Earth. They watch her movements, listen to her sounds and explore her parts to understand the knowledge she has to share with us regarding her natural cycles. They study rocks, minerals, fluids, fossils, mountains, sediments, glaciers, volcanoes and earthquakes. They look at how natural materials act and interact with the weather, animals, plants, people, and chemicals. To do so they use their eyes and ears, as well as special instruments designed to let them see what is happening deep below the surface. Geological scientists use these observations to understand more about Mother Earth and our relationship with her.

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Connecting to Math

The Klickitat people call Mount St. Helens *Louwalla-Clough* which means smoking mountain. In one of the stories they tell, the mountain was once a beautiful woman named Loowit. When two sons of the Great Spirit, Wyeast and Klickitat, fell in love with her, Loowit could not choose between them. So, the two men fought over her, each trying to win her heart, and in the process burying villages and destroying forests. Their father, angry with the devastation they had caused, killed the young lovers and erected mountains where they died. Every now and again, these mountains (Mount St. Helens, Mount Hood and Mount Adams) still burst forth causing destruction.

On May 18, 1980, after more than 100 years of being quiet, Mount St. Helens experienced a spectacular eruption. In an explosion which lasted several days, the mountain lost a good deal of height shrinking from 2950m to 2549m. Ash from the explosion was scattered over 56,980 square kilometres, and circled the Earth in 15 days.



1. People used to say that Mount St. Helen's looked a lot like Mount Fuji in Japan. Both volcanoes looked like circular cones with long sloping sides and nearly perfectly round bases. If the base of Mount St. Helen's is 9.66 kilometres in diameter, what volume of material was blown off the top during the 1980 eruption?
2. If ash from the explosion was scattered over 56,980 square kilometres, how far away from the mountain did ash land on the ground?
3. Some of the ash was too light to fall to the ground and circled the Earth on the prevailing winds. If it circled the Earth in 15 days, how fast was it travelling? The radius of the Earth is 6378km. Bonus: Will this radius give you an accurate answer?

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