

Plate tectonics: Mysteries solved!

Why do South America and Africa look like they fit together?

Why is there evidence of glaciers in the tropics?

Why is there tropical limestone in Illinois?

Why are fossils of the same tree found in Antarctica, Africa, and South America?

Why do the Hawaiian Islands form a long chain in the Pacific?

Why is the West Coast of North America lined with volcanoes?

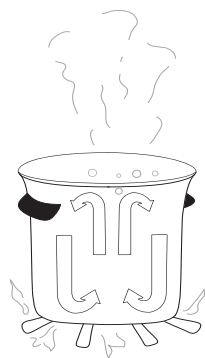
Why are there fossil seashells at the top of the Himalayas?

Explaining the unusual

These unusual observations have puzzled scientists and non-scientists for years. As long ago as the 1600s, cartographers (map makers) wondered about the similar outlines of South America and Africa. Only in the last few decades have answers to these mysteries been assembled. Together, they give an account of an astounding natural process: the movement of the Earth's continents.

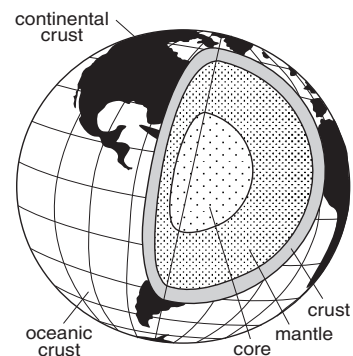
Continental drift was first proposed by Alfred Wegener in 1912. A German meteorologist (weather scientist), he wanted to find an explanation for ancient climates: there was evidence of glaciers in Africa while there were tropical climates in North America. These unusual observations could all be explained by the astonishing idea of moving the continents around. But Wegener could offer no reason for how the continents drifted. He froze to death in Greenland gathering more evidence for his theories. Until the mid-1960s, most geologists rejected Wegener's idea because no one could suggest a mechanism that could move the continents.

In the last few decades, information collected about fossils, magnetism in rocks, earthquakes, and other phenomena has provided the evidence that shows us the "how" of continental drift. The explanation of this process is called the theory of plate tectonics, and it answers all of these questions.



Hot rock, like water rising in a boiling pot, moves up, rising to the surface in some areas. Once cooled, pieces of crust sink down in other areas. This process apparently drives plate tectonics, where whole pieces (plates) of the Earth's brittle surface move slowly about on the upper mantle, carrying the low-density continents with them.

The Earth is built up of several layers. At the center is an iron/nickel core; this core is surrounded by a thick, dense mantle. The outer surface is a relatively thin, brittle crust.



The outer part of the Earth is broken into tectonic plates. These plates are formed continually from dense basaltic magma (molten rock) that rises from the Earth's mantle. This dense material forms oceanic crust, which is generally covered by ocean waters. Embedded in these oceanic plates are masses of low-density material that rose to the surface billions of years ago when the Earth began to cool. This low-density material formed the continents (continental crust). The tectonic plates, comprising both oceanic and continental crusts, move slowly (centimeters per year) across the Earth's surface. The denser oceanic crust is constantly being formed or destroyed at boundaries with other plates, but the less dense continental crust survives, although greatly modified by the forces of plate tectonics.

Much of the planet's geologic activity—rising mountain ranges, earthquakes, and volcanoes—takes place near or at the plate boundaries. There are several types of plate boundaries at which different processes occur and different features form.

Convergent plate boundaries: Collision zone, part 1

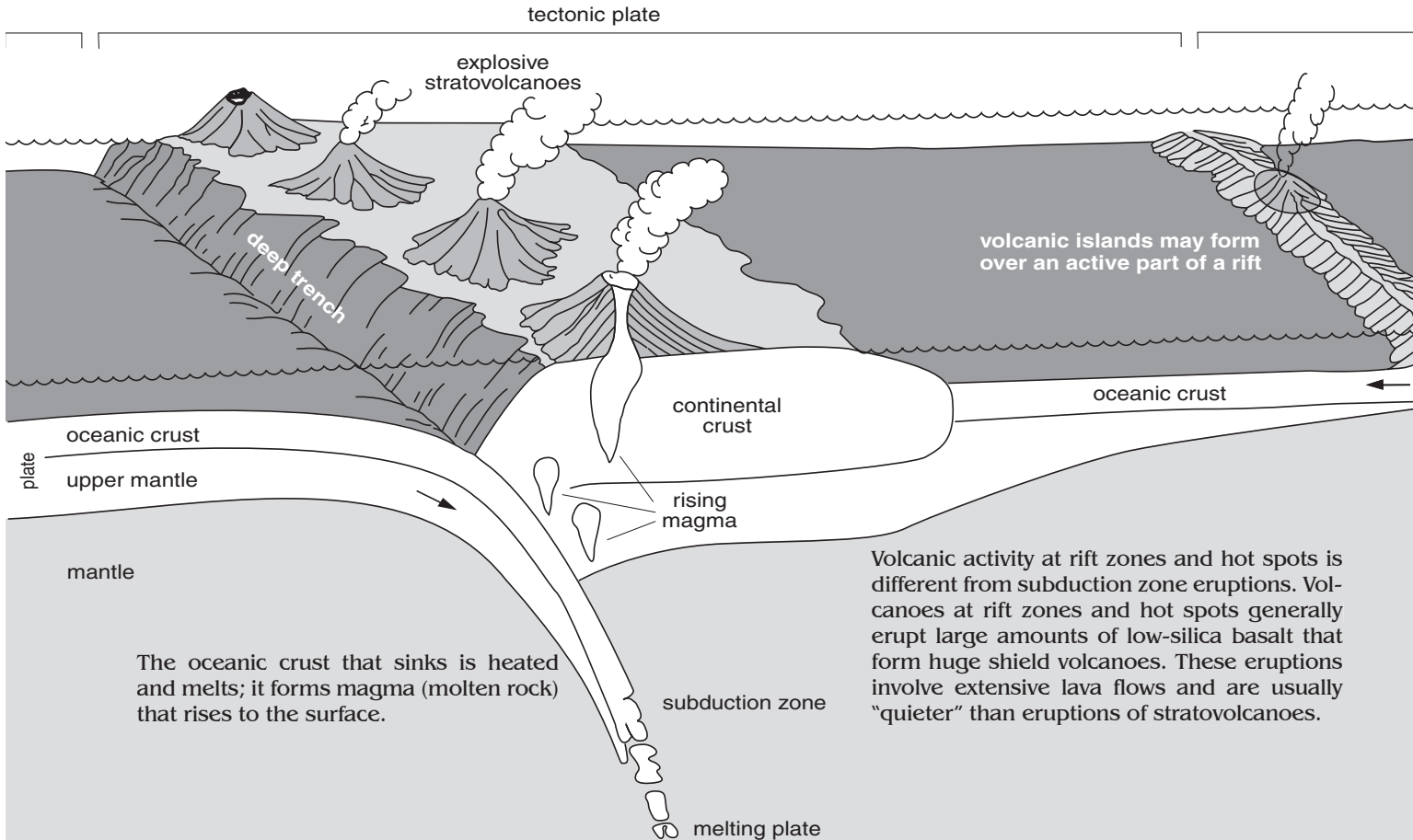
At convergent boundaries, there is a collision between two plates. Where the plates meet, the cold, denser plate sinks under the warmer, less dense plate in a process called **subduction**. This process forms deep trenches in the ocean floor and creates chains of explosive **stratovolcanoes** that form islands rising from the ocean bottom.

Continents, made of less dense material, generally do not subduct under oceanic crust, but ride over them; the oceanic crust sinks and is destroyed. Where a continent overrides oceanic crust, a chain of towering stratovolcanoes may form on the continent, as shown in the figure below. The Cascade Mountain Range, including Mt. St. Helens, formed this way.

Divergent plate boundaries: The world comes apart!

Hot material slowly rises like molten plastic from the mantle. Where this hot material (magma) reaches the planet's surface, it cools and forms new oceanic crust, which spreads apart at a **rift zone** or **spreading center**. This process forms great ridges on the ocean bottoms and is called sea floor spreading.

Continents may be torn apart if the rift occurs beneath them. As the land separates, water floods in, leaving a sea or ocean where dry land once stood. The Atlantic Ocean formed when the Americas were separated from Africa and Europe by a rift.



The oceanic crust that sinks is heated and melts; it forms magma (molten rock) that rises to the surface.

Volcanic activity at rift zones and hot spots is different from subduction zone eruptions. Volcanoes at rift zones and hot spots generally erupt large amounts of low-silica basalt that form huge shield volcanoes. These eruptions involve extensive lava flows and are usually "quieter" than eruptions of stratovolcanoes.

The life cycle of a plate is similar to the movement of a huge conveyor belt. At the rift zone where the plate is created out of rising magma, the plate cools and moves outward. Where it collides with another plate, one sinks and descends into the mantle, where it is melted and the material is "recycled". The less dense plate remains on the surface.

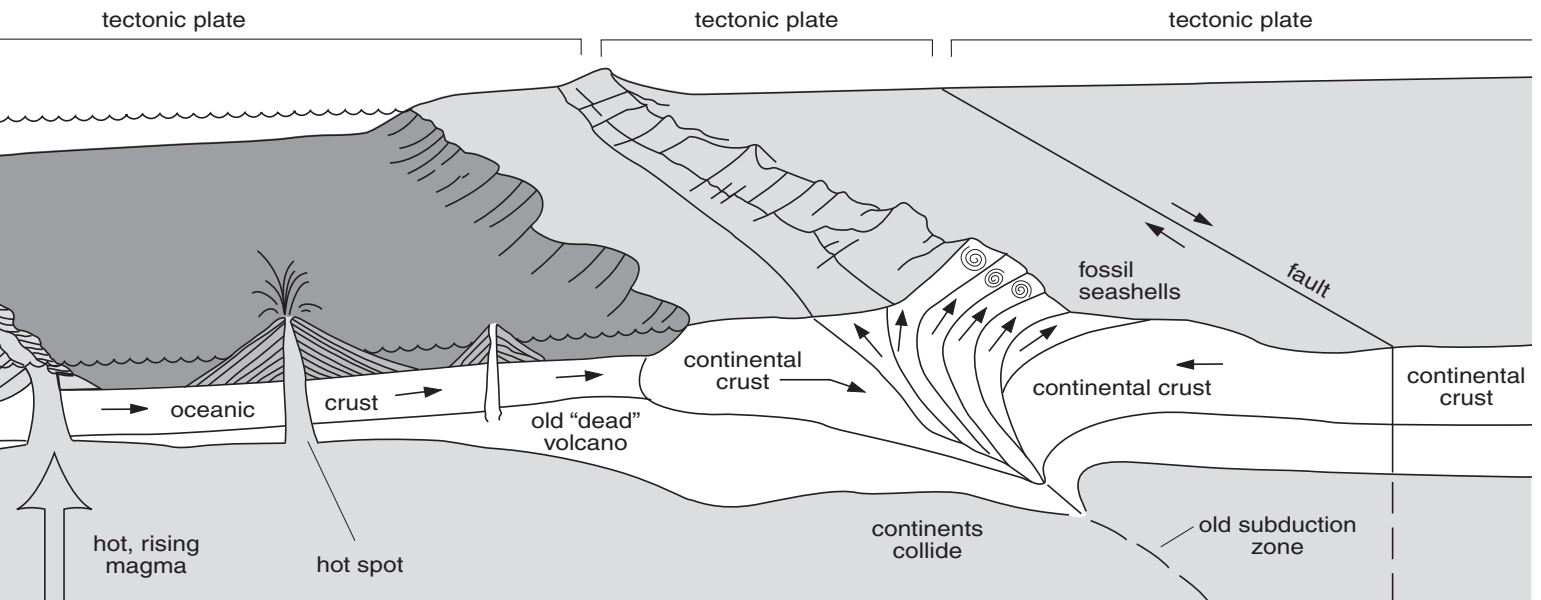
Convergent plate boundaries: Collision zone, part 2

When two continents collide, neither sinks because each is too buoyant. Instead, the colliding continents crumple and pile up, forming rugged mountain ranges. Some of the old ocean bottom that once lay between the continents may be shoved up as part of the mountains, leaving fossil seashells high in the mountains.

The Himalayas and Alps are well-known examples of collisions between continents.

Transform plate boundaries: Whose fault is it?

At transform boundaries, two plates slowly grind past each other; a fault separates them. As the plates move, tremendous strain can build up. The pent-up energy may then be released gradually as small earthquakes or suddenly in a single catastrophic earthquake. The plates each continue on their separate ways. The San Andreas Fault is a famous example of a transform fault along the eastern edge of the Pacific plate. This plate, which includes the western edge of California, is moving northwestward relative to the North American plate.



In some places, hot local plumes of rising magma don't rise between the plates, but instead "punch through" them to form a hot spot. As the plate inches along over the hot spot, the rising magma creates a line of volcanoes in the middle of the plate. Hawaii is the best-known example of such a hot spot.



Plate tectonics in Illinois?

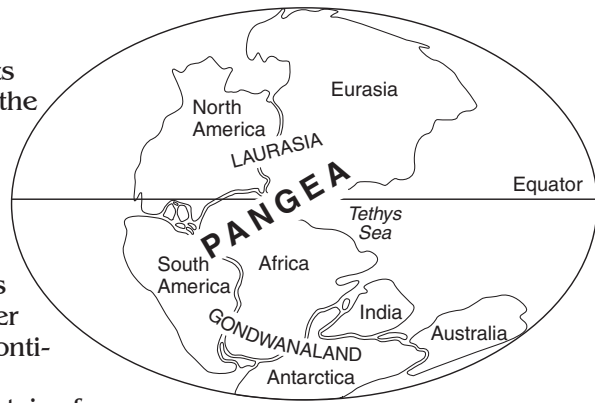
Although the interiors of continents are usually stable, plate tectonics is also at work in Illinois. The 1811–1812 earthquakes near New Madrid, Missouri, resulted from plate tectonics. These earthquakes locally changed the course of the Mississippi River, formed a 10-square-mile lake in northwestern Tennessee, and were felt 1,000 miles away in Boston. These quakes, the largest recent quakes on the continent, were probably related to the stresses caused by plate movement on an ancient rift zone beneath the mid-continent. This rift zone never fully developed, but left a weak place in the plate. Earthquakes continue to occur along this zone.

Plate tectonics "tells" the story:

Remember the unsolved mysteries on the first page? Those mysteries are explained by the theory of plate tectonics. Let's go back 500 million years. . .

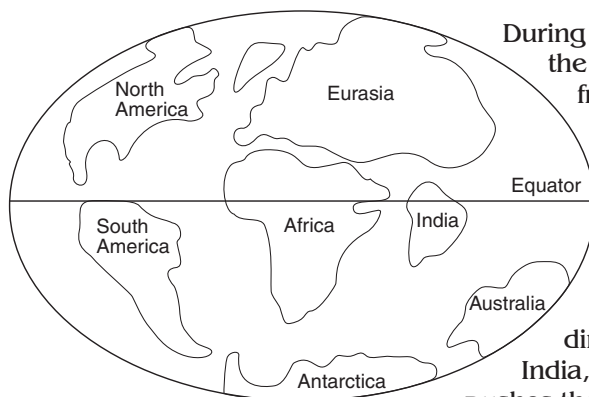
Plate tectonics: The mysteries solved!

It's 500 million years ago, ancient North America drifts near the equator, and the warm sun shines down on the tropical oceans that cover what is now Illinois. Long before dinosaurs roam the Earth, fish and corals live in an Illinois landscape much like the waters off the Bahamas. Far to the south, parts of Africa and South America freeze under a blanket of ice. Over the next 250 million years, as the North American plate moves north and eastward, it sweeps up small pieces of other land and collides with Europe and Africa. The supercontinent of Pangea has formed.



Pangea—250 million years ago

During this time, sediments washing off the mountains form a vast river delta that fills in the tropical ocean of Illinois. Billions of trees live, die, and are buried on the deltas where, over millions of years, they turn into coal.



After the breakup—65 million years ago

During the next 185 million years, dinosaurs wander across the Americas, Africa, and Antarctica, and plants spread freely between the continents. Then Africa, Eurasia, and North America split and slowly move apart as the Atlantic Ocean widens between them. Descendants of plants and animals that lived together are now thousands of miles apart on separate continents. South America splits from Africa and moves west. Slowly, India and Africa move north.

Sixty-five million years before the present, the dinosaurs become extinct, and mammals rule the Earth. India, moving northward, collides with Asia. The collision pushes the shallow ocean sediments between the plates into the towering mountains we call the Himalayas, carrying fossil seashells up as part of the mountains. In Europe, the collision of Italy into Europe produces the Alps.

As North America moves west, towering stratovolcanoes create the Aleutian Islands and the Cascade Mountains. The American West becomes parallel chains of faulted and folded mountains. The continental plate "picks up" small pieces of crust and piles them into a mismatched collection on the west edge. As the Rockies rise, they cut off moisture to the plains to the east.

As the global climate temporarily cools, glaciers cover the Midwest many times and completely reshape Illinois into a landscape of plains and rolling hills. Today the North American and Pacific plates slide past each other, creating earthquakes along the San Andreas Fault. The Pacific plate glides over a hot spot, which "punches through" the plate to build the island chain we call Hawaii. As the continents move, changes in the wind and ocean patterns may spawn a new Ice Age.

This, then, is the story of plate tectonics. The continents have rifted, drifted, and collided numerous times during the past four billion years. This process has had a profound effect on geology, climate, and evolution. The striking features of our planet—mountain ranges, valleys, towering volcanoes, and deep ocean trenches—are a direct result of plate tectonics!

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