

# PLATE TECTONICS

## Teacher Guide

including

Lesson Plans, Student Readers, and More Information

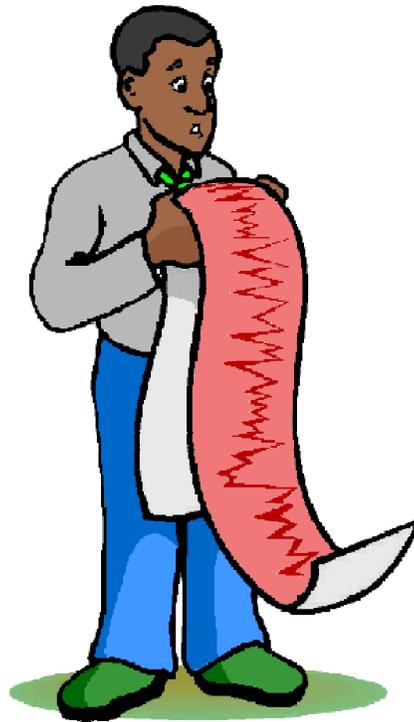
**Lesson 1** - Evidence of Plate Tectonics

**Lesson 2** - Plotting Earthquakes and Volcanoes

**Lesson 3** - Case History - Geology of California

**Lesson 4** - Continents through the Ages

**Lesson 5** - Virtual Plate Tectonics



*designed to be used as an Electronic Textbook  
in class or at home*

**materials can be obtained from the Math/Science Nucleus**

# EARTH SCIENCES - PLATE TECTONICS

## Lesson 1 - EVIDENCE OF PLATE TECTONICS

### MATERIALS:

hydrographic globe  
physiographic globe  
reader  
maps

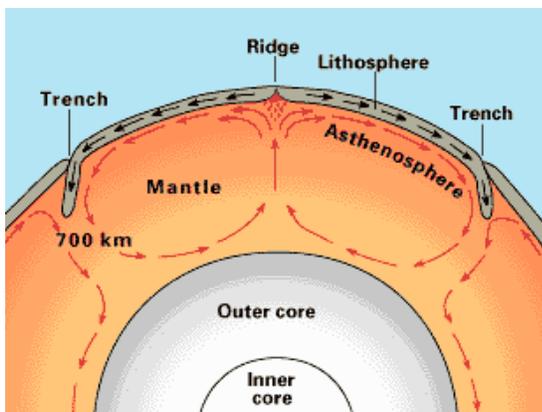
**Objective:** Students learn about the theory of plate tectonics evolved.

### Teacher note

Show students a map of the world and illustrate how the Atlantic coastlines of Africa/Europe line up with the Atlantic coastlines of North and South America. If you use a hydrographic globe you can show students trenches and underwater mountain ranges that have helped us understand the mechanism of plate tectonics.

Students should have learned about earthquakes and volcanoes in previous units, now we put the information together so they understand how the pieces evolved in a working model of Plate Tectonics.

If you have ever looked at a map of the world, you may have noticed the shapes of the continents seem to fit. For example, the east coast of South America and the west coast of Africa, if you moved them together, fit like puzzle pieces. Geologists have long noticed these patterns but until the 1960's did not fully understand their significance. Other patterns such as the locations of earthquakes, mountain belts, and volcanoes, the shape of the sea floor,



and the distribution of rocks and fossils can

be seen. Geologists have developed the theory of **plate tectonics** to explain these features.

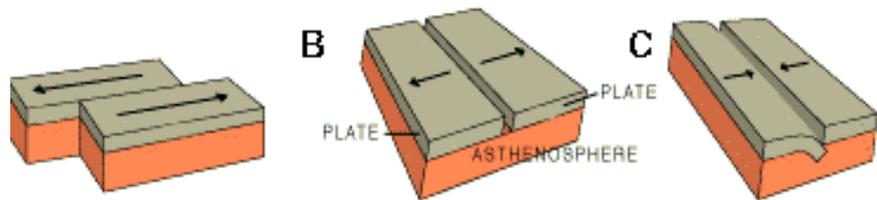
According to plate tectonics, the outer part of the Earth is a layer of rock about 100 kilometers thick. This shell is very thin compared to the size of the Earth. This shell is divided into at least 25 pieces, which are called plates. These plates move very slowly on the partially **molten** Earth layer (**asthenosphere**) below them.



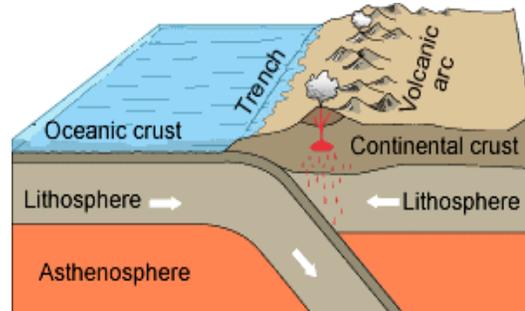
This is amazing when you think about it. We all think of the Earth as being solid and unmoving beneath our feet, but it is actually in motion. Plate movement is slow. Plate speeds range from 5 to 17 centimeters per year. This is about as fast as your fingernails grow in a year. This may seem slow, but over the millions of years of Earth history, it means that plates can move long distances.

Plates interact in three basic ways they past by each other (A), they diverge from each other (B), or they converge or collide into each other (C). To

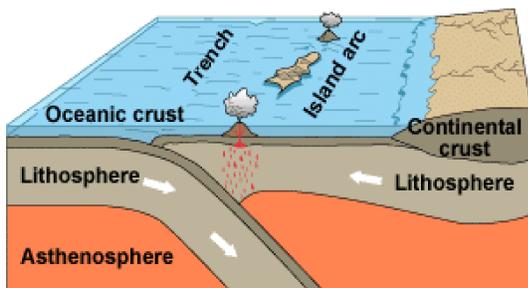
develop this amazing story it took many lines of evidence to convince the scientific community that the Earth can actually move.



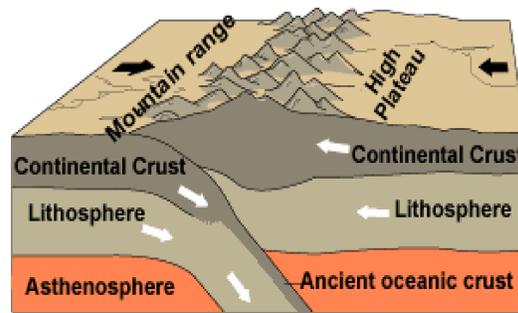
Plates can collide to build mountains in different ways. They can create trenches and island arcs when oceanic crust and oceanic crust “bump” into each other. This creates volcanoes and earthquakes. An example of this type of collision is the Japanese Islands in the western Pacific Ocean. You can also have oceanic crust collide with continental crust, like you have along northern California to Washington coastline. This creates trenches and volcanic mountains. Earthquakes are common in this type of collision. Continental crust that bumps into another continental crust produces very large mountain ranges, like in the Himalaya Mountains on the southern Asian continent. This produces earthquakes but no volcanoes.



Oceanic-continental convergence



Oceanic-oceanic convergence



Continental-continental convergence



So what were the clues that made people start to think? Paleontologists had long recognized that fossils from the east coast of South America and the west coast of Africa had many fossils in common. Biologists had also noted that living animals like garden snails, earthworms, mussels, and mud minnows also “linked” across the ocean. By the late 1800's, naturalists who explored new territories accumulated more evidence of these biological and paleontological similarities.

Some scientists developed these elaborate “land bridge” theories. Organisms would be able to walk freely along these connections. However, many scientists realized this land bridge theory had some serious problems. Geologists started to visualize a moving continent or what they called “continental drift” to account for similarities.

A German scientist by the name of **Alfred Wegener**, developed the theory of continental drift in the early 1900's. Wegener proposed that the continents were once together and had drifted apart. Most scientist of the time did not accept Wegener's theory.



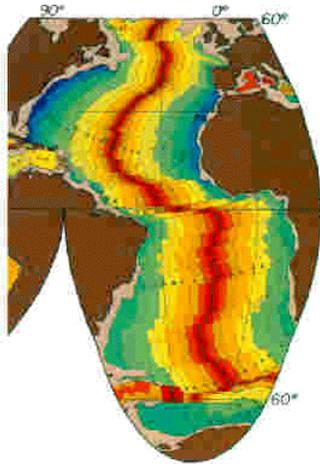
Alfred Wegener

But how could this happen? Continents did not float and easily moved. So more data has to be assembled to explain a moving crust.

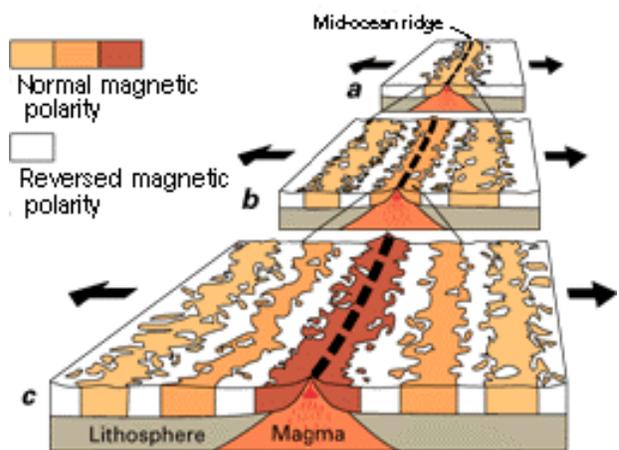
In the 1950's and 1960's instruments were developed which allowed scientists to study the ocean floor. Their findings provided Wegener's theory with explanations that evolved his theory into Plate Tectonics. Continents did not drift, entire plates moved! Instruments used to study the ocean floor found large underwater mountain ranges. Running through the center of these ridges are deep cracks called **rift valleys**. These underwater mountain ranges are called **midocean ridges**.

Volcanic activity occurs at the midocean ridges. Lava erupts out of these ridges and spreads to the sides of the rift valley. The lava hardens, forming new ocean floor. This process is called ocean-floor spreading. As the new ocean floor moves away from the rift valley, the continents on top of the ocean floor move also.

Scientists know that some minerals have magnetic properties. In molten rock the magnetic properties line up in relation to **Earth's magnetic poles**. When the rocks harden, a permanent record of the Earth's magnetic poles are revealed. Scientists discovered that on each side of the midocean ridges there were magnetic stripes.

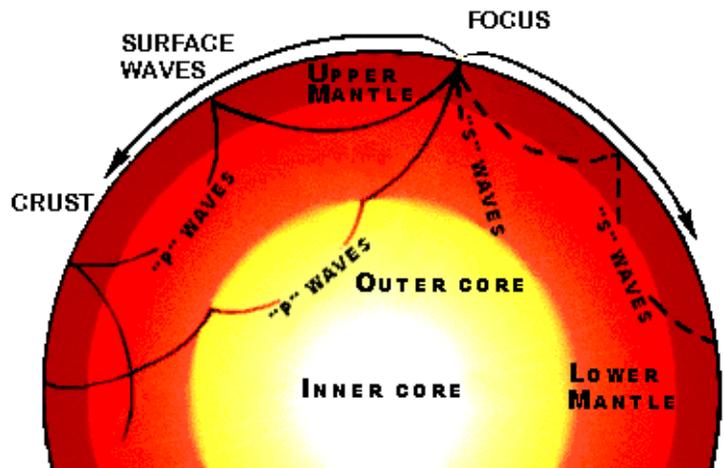


The stripes showed that at several times in Earth's history, the magnetic poles have reversed. The stripes matched up on each side of the midocean ridge. This discovery added more evidence to support ocean-floor spreading.



The stripes matched up on each side of the midocean ridge. This discovery added more evidence to support ocean-floor spreading.

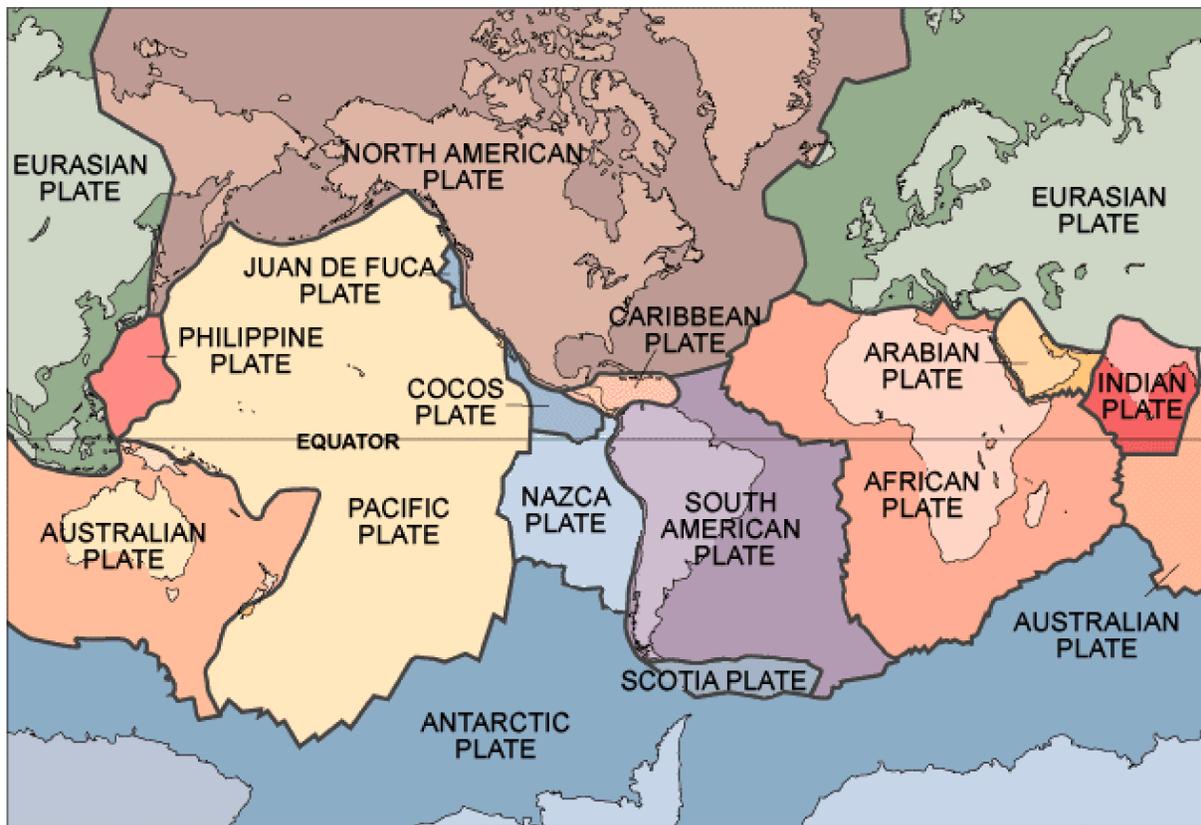
Earthquakes cause the fracturing of rock masses along faults. This causes sudden movement along faults. The point at which the Earth breaks at which the movement occurs is called the **focus of the earthquake**. The point on the surface of the Earth above the focus is the **epicenter**. An earthquake occurs when rocks have been stressed. This stress is stored until the actual break (the earthquake) releases the energy. This energy travels in the form of waves. Geologists record and study these waves.



There are many different types of waves generated from earthquakes. The major types are P (push/pull, compression, primary) and S (shear, secondary). P waves are faster than S waves. S waves cannot travel through liquid. P waves can travel through liquids and solids. These basic facts (plus many more) help geologists to interpret the inner structure of the Earth, and create a picture of the inside of the Earth. Without data from waves, we could not determine the boundaries. We cannot even drill through the upper part of the crust.

Plate Tectonics is a good example of how the science community collects evidence and then continuously tests the theory. We cannot make a mathematical nor real model of plate tectonics. We have a hypothesis of the general mechanics, but there might be pieces of data that do not fit the overall principle. Earthquakes that are in the middle of the country, like New Madrid can sometimes “negate” some of the principles. Hawaiian volcanoes, explained as “hot spots” may be an oversimplification of the real process at work. The understanding of Plate Tectonics will continue to be tested as we try to interpret earthquakes and volcanoes. Most fit the theory, but others do not.

As plate tectonics matures from a theory to a principle, changes may occur. New evidence can change the understanding, but then that is what science is all about, the search for the truth.



# EARTH SCIENCES - PLATE TECTONICS

## Lesson 2 - PLOTTING EARTHQUAKES AND VOLCANOES

### MATERIALS:

reader

**Objective:** To research and plot earthquakes and volcanoes using

### Teacher note

In this lab, students will put their research skills to work. They are to use reference materials in order to find the locations of selected earthquakes and volcanoes. They should find 5 volcanoes and 5 earthquakes that occurred outside of the U.S. Ask the students to not use the same earthquakes and volcanoes as their partners. Students should record the number of people killed and the magnitude of the disasters, if this information is available, in the comments box.

Students can use encyclopedias, the *Guinness Book of World Records*, and any other books that contain all the necessary information. Websites will contain the most up to date information available. Use a search engine to find earthquakes and volcanoes. If you want the students to use one site to help direct their research go to the U.S. Geological Survey site ([www.usgs.gov](http://www.usgs.gov)).

After each student has found 10 data points on their own, have them share the information with the rest of the lab group. Each group should collect about 40 data points so that each student ends up with at least 35 data points. Each student records their information on the "Earthquakes and Volcanoes" lab sheet.

After they record the data, plot the volcanoes and earthquakes on an inflatable globe and wall map. You may want them use stick-on dots, map pins, or post-its to locate data points on the globe. Students can use 2 different colored pencils to record the volcanoes and earthquakes on the map provided.

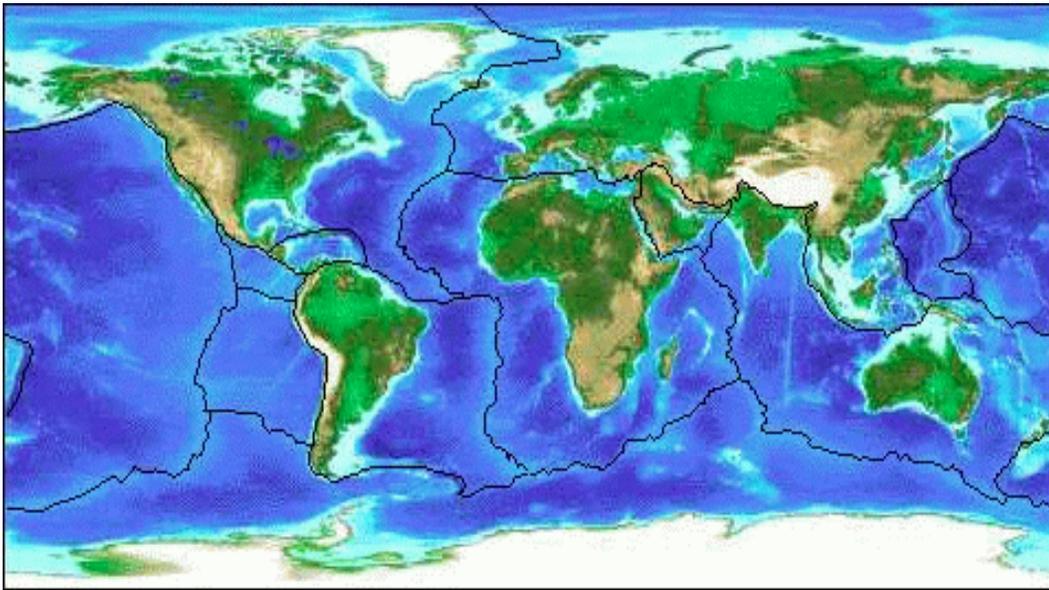
Using the wall map for full class viewing, discuss the findings. Point out patterns where there are large concentrations of earthquakes and volcanoes. Point out on the map where the Earth's plates are located. Help the students make the connection that many earthquakes and volcanoes occur along the plate boundaries.

As an extension, ask each student to pick one earthquake or one volcano to further research. The students should find out as much as they can about their disaster and prepare a one to two page report.

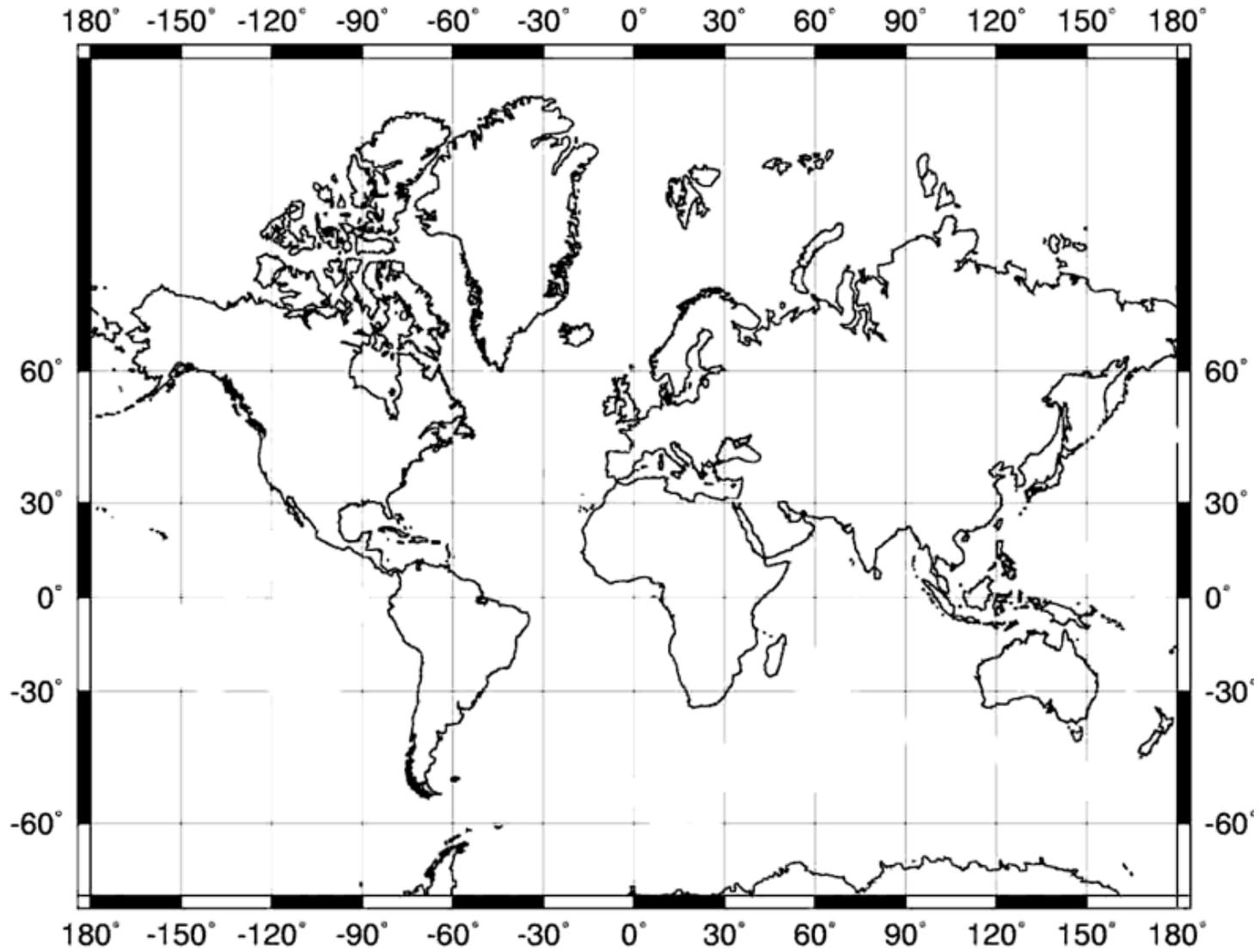
Volcanoes and earthquakes provide the evidence for plate tectonics. Volcanoes provide a location, type of eruption, and type of rocks produced. Earthquakes emit waves that give clues to the inside of the Earth. The evidence is very different, but yet when you plot the data a picture emerges. The zones in which earthquakes and volcanoes occur provide us with the notion that the Earth is broken like cracked eggs in defined “plates.”

In this lab you will put your research skills to work. You are to use reference materials to find the locations of recent earthquakes and volcanoes. Find 5 volcanoes and 5 earthquakes that occurred within the last 10 years using the web sites that your teachers provides or others that you might find.

After you have found 10 data points, share the information with the rest of your lab group. Each group should collect between 35-40 data points. Each student records the data on the lab sheet. After you record all the data, plot the volcanoes and earthquakes on a map of the world that is provided. You may want to use a globe to make sure of the longitude and latitude before you plot it on the map. Answer the questions at the end of the lab sheet. Under “comments” write any interesting facts you may have found about the earthquakes and volcanoes.







# EARTH SCIENCES- PLATE TECTONICS

## Lesson 3 - CASE HISTORY - GEOLOGY OF CALIFORNIA

### MATERIALS:

map of California (geographic)  
map "Rocks of California"

**Objective:** To investigate the rocks common to California.

### Teacher note

Information about the Earth's history is locked securely in the rocks of an area. By looking at the types of rocks in an area, geologists can often determine what the environment and landscape of an area was thousands of years ago. We are only a moment in geological time. Someday our environment and landscape will be locked in stone.

Each student team should be provided with a copy of the geomorphic provinces of California. In addition a map showing California landmarks (i.e. road map) will also be helpful. If you are in another state contact your state geologic agency. They can provide you with a geologic map of your state. Since they are state agencies, they may have similar exercises. If not, ask if they can help.

Answers:

1. Modoc Plateau, Tertiary, volcanic; 2. Cascade, Tertiary, volcanic; 3. Klamath, Mesozoic, metamorphic and granitic; 4. Coast Range, Cenozoic to Cretaceous, mixed rocks; 5. Great Valley, Quaternary, sedimentary; 6. Sierra Nevada, Paleozoic to Mesozoic; metamorphic and granitic; 7. Basin and Range, Precambrian to Recent, mixed rocks; 8. Mojave Desert, Precambrian to Recent; mixed rocks; 9. Transverse Range, Tertiary, sedimentary; 10. Peninsular Range, Mesozoic to Paleozoic, metamorphic and granitic; 11. Salton Trough, Quaternary, sedimentary.
2. Mt. Lassen (Cascade Range), Mono Lake (Basin and Range), Mt. Whitney (Basin and Range), Yosemite National Park (Sierra Nevada), Death Valley (Basin and Range), Point Reyes (Coast Range), Lake Tahoe (Sierra Nevada)
3. San Andreas, Garlock, San Gabriel, San Jacinto, Calaveras, Hayward, Elsinore, South Fork Mt, Nacimiento, Death Valley, White Wolf, Kern Canyon, Pleito, Sierra Nevada, Santa Ynez
4. east, west, southern
5. erosion
6. along the coast, and probably offshore

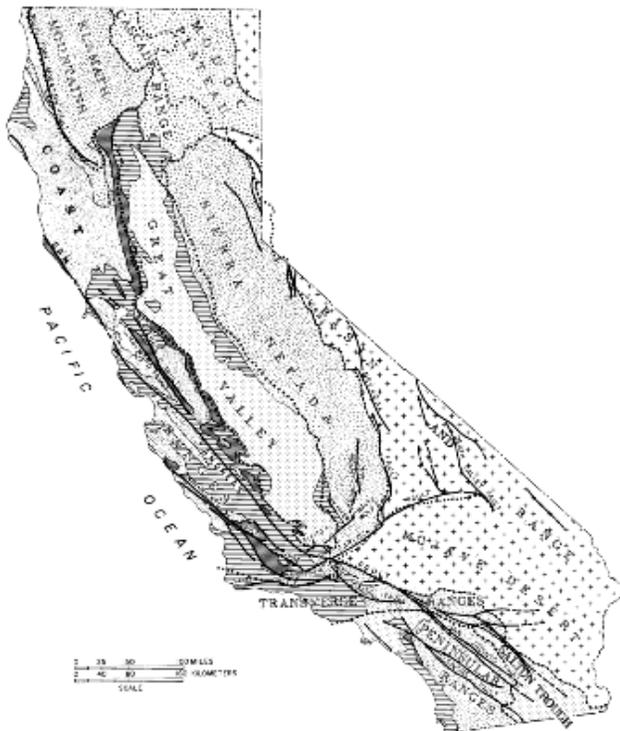
The Earth is basically one large "rock." The surface rocks give us clues as to how the surface moved through time. The clues in the rocks include the type of rock and fossils found. For instance, if you find deposits of basalt, that means an ancient volcano produced it. If you found trilobites, that means the area was in shallow marine water at one time.

The land we live on now records billions of years of rock "action." It is the geologist's job to use rocks and fossils to interpret the area we live near.

California is a very beautiful state, mainly because of its geologic history. Yosemite Valley was carved by glaciers; the Sierra Nevada was once a pluton deep inside the crust; and the high sea cliffs of the Pacific Coast have been pushed up by active faults.



Yosemite, Sierra Nevada, California



California was created by a very complex geological evolution. It has all three types of rocks, igneous, sedimentary, and metamorphic, in different combinations all around the state. Many of these rocks are mined, either to extract their mineral wealth, or as ingredients of building materials. On the map of California you can see the areas and the overall rocks of these areas.

On the map provide in your worksheet, California is divided into time areas. Quaternary is up to 10 thousand years ago; Tertiary is up to 65 million years ago; Mesozoic is up to 225 million years ago; Paleozoic is up to 600 million years ago; and Pre-Cambrian is anything older than Paleozoic. The state can also be divided into geomorphic provinces, which refer to areas that have a similar landscape, representing different types of rocks.

**EARTH SCIENCES - PLATE TECTONICS  
CASE HISTORY - GEOLOGY OF CALIFORNIA**

**PROBLEM:** How can rocks tell a story of Earth's history?

**HYPOTHESIS:** \_\_\_\_\_

**PROCEDURE:**

Look at the Generalized Geologic Map of California. Answer the questions below. You will need to refer to a geographic map and/or topographic map to find landmarks in California.

1. This is a generalized geologic map of California. List the 11 geomorphic provinces that are found on the map. They are written in capital letters. Then determine the overall age of the rocks and the overall rock type.

<b>GEOMORPHIC PROVINCE</b>	<b>AGE OF AREA</b>	<b>TYPE OF ROCK</b>

2. Look at a geographic and/or topographic map of California and find the following areas. Describe the areas and from the Generalized Geologic Map determine the age, type of rocks and geomorphic province.

LOCATION	GEOMORPHIC PROVINCE
Mt. Lassen	
Mono Lake	
Mt. Whitney	
Yosemite National Park	
Death Valley	
Point Reyes	
Lake Tahoe	

3. List the major faults.

4. San Francisco is found on what side (east or west)of the San Andreas fault.

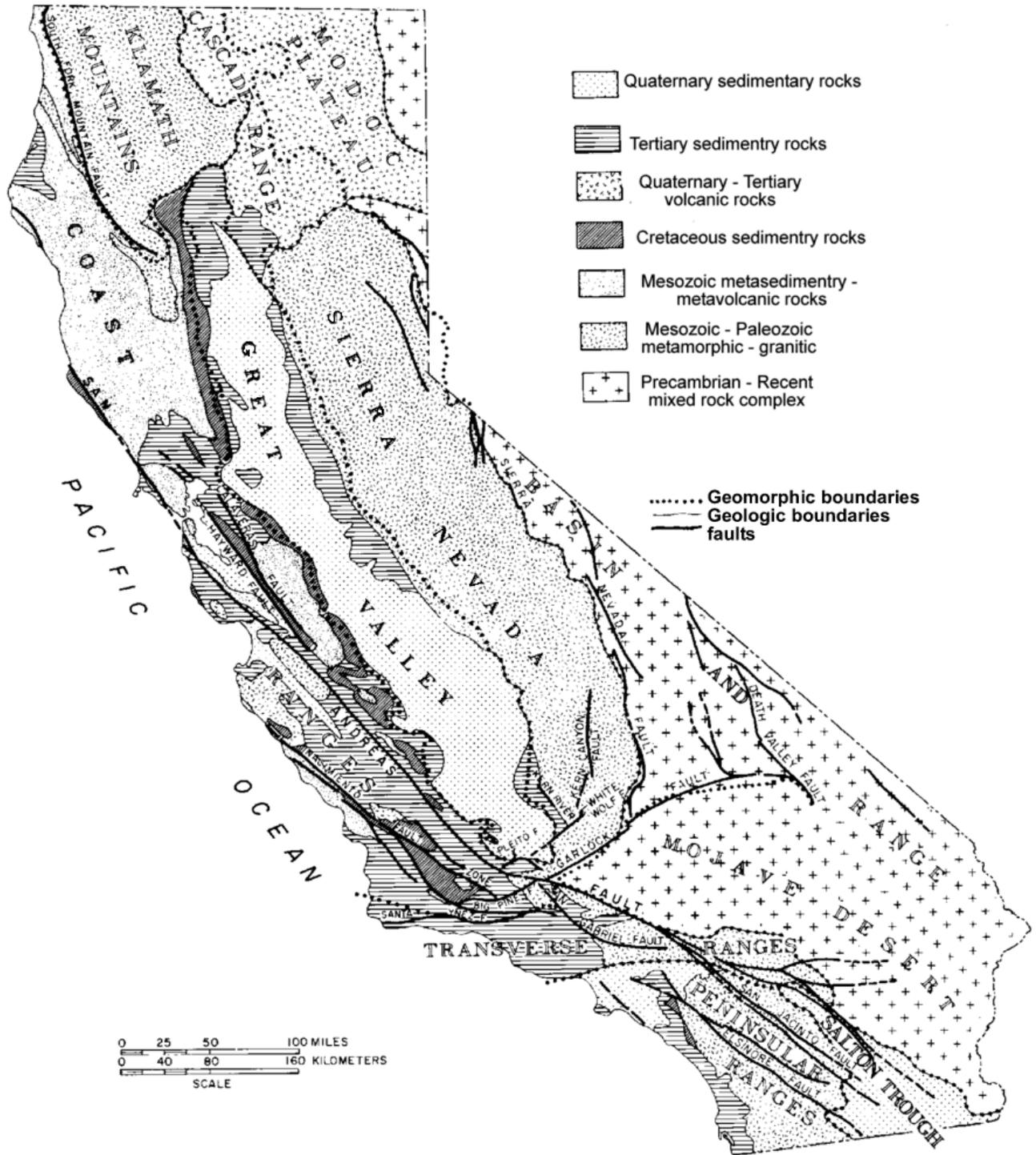
Los Angeles is east or west of the San Andreas fault?

Are most of the major faults located in the northern part or southern part of the state of California?

5. The Sierra Nevada is mainly a granitic type of rock that was originally cooled deep inside the crust of the earth. How do you think the Sierra Nevada mountains got to the surface?

6. Do you think these geologic units continue into the Pacific Ocean? Explain.

# Geomorphic Map of California



# EARTH SCIENCES - PLATE TECTONICS

## Lesson 4 - CONTINENTS THROUGH THE AGES

### MATERIALS:

reader

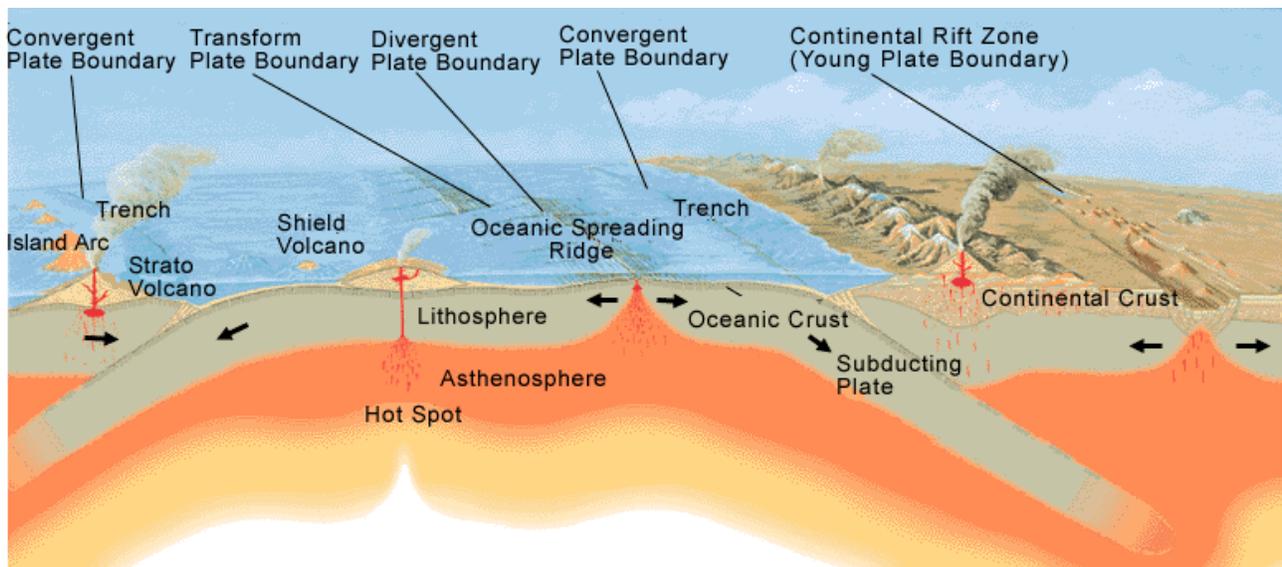
**Objective:** Students observe the movement of the Earth's crust.

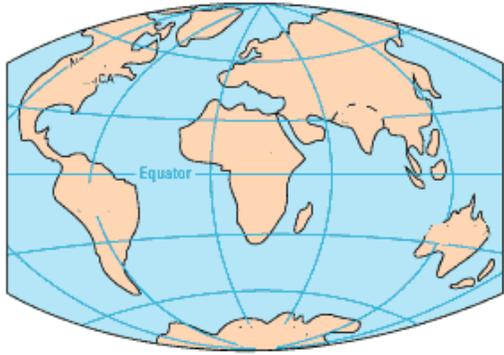
### Teacher note

The crust of the Earth has been moving for at least 1 billion years, if not longer. The further we go back in time, the more difficult it is to determine the exact movement.

This section helps students to visualize the motion and to illustrate what the Earth may have looked like through time.

Geologists have learned that the inside of the Earth has many layers. The outermost Earth layer is composed of rocks. It is called the **lithosphere**. The lithosphere is about 100 kilometers (a bit more than 60 miles) thick. The lithosphere is not a solid shell of rock, but broken into large plates. Imagine a hard boiled eggshell that has been cracked on a table top, but the size of the Earth. Unlike an eggshell, the plates of the lithosphere are not stationary. They are all in constant motion. Plate movement is slow.



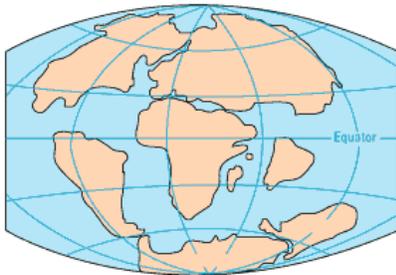


Today

Geologists use clues from earthquakes and volcanoes to explore how the Earth's lithosphere is moving today. However, clues from fossils, paleomagnetism, and rocks can help reconstruct how the Earth's surface looked in the past.

When the Earth first formed 4.5 billion years ago, there was probably no water. So the land masses included the entire crust of the Earth. Evidence of an atmosphere and basins of water did not reveal itself until 3.5 billion years ago. Determining what the surface of the land looked like back then is almost impossible.

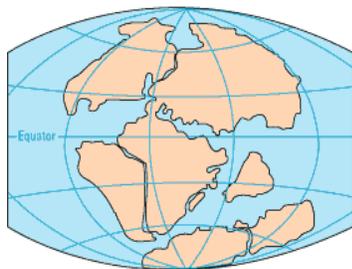
The continents are embedded into the plates. The rocks that compose the continents are less dense than the rocks that make up the ocean basin. The majority of continental crust seems to remain on the top of the lithosphere. The continental rocks provide clues of how the Earth formed over the last 3.5 billion years (the oldest rocks found on continents). The older the rock the unclearer the clues are. It is like an ancient murder mystery, the clues are long gone to the investigator.



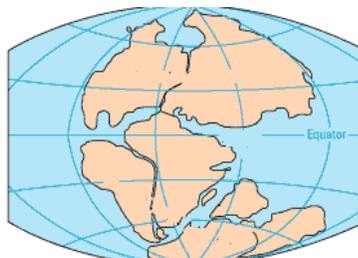
Cretaceous 65 million years

Therefore, as the plates move, the continents move. For example, North America and Europe are getting further away from each other because the plates they are embedded in are moving apart. Plates can also come together. This may cause continents to collide. The Himalaya Mountains are forming from the collision between the continents of Asia and India. This movement of India into Asia started in the Jurassic, with the impact into the Cenozoic.

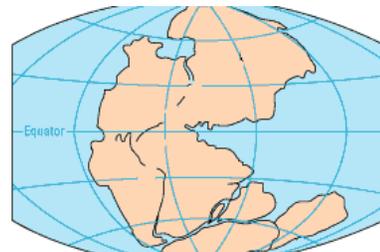
There have been times in the Earth's past when many plates carrying continents came together at the same time. This formed one huge plate that contained a single supercontinent.



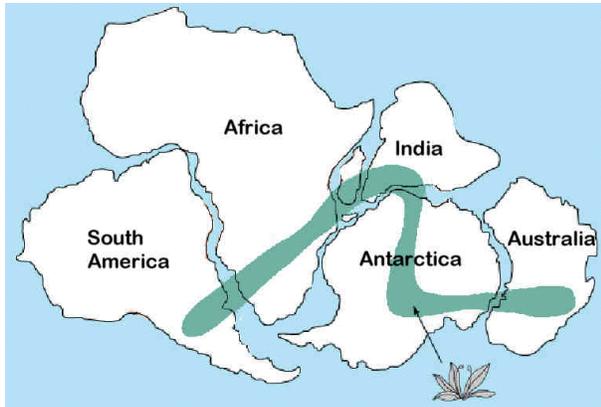
Jurassic 180 million years



Triassic 225 million years



Permian 280 million years

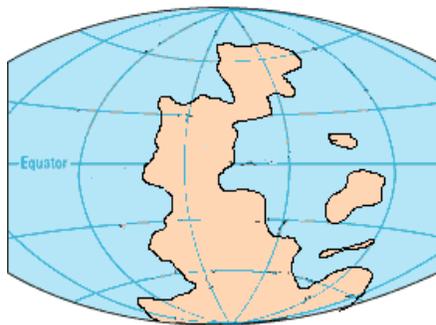


One of the most recent supercontinents was called **Gondwana**. Gondwana consisted of the modern continents of South America, Africa, India, Australia, and Antarctica. Gondwana existed for most of the Paleozoic Era, from about 500 to 220 million years ago. The supercontinent was named after the Gondwana region of central India, where many of the rocks from this time are well exposed.

One of the Gondwana fossils that can be found in 5 regions.

Gondwana is gone. It has split apart, giving rise to the modern continents. How do geologists know that Gondwana once existed?

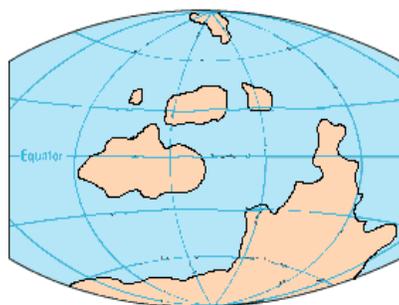
Some of the best clues to Gondwana's ancient presence are found by matching the rocks and fossils from one area with the rocks and fossils from another area. This shows that at one time the two areas were connected and then split apart.



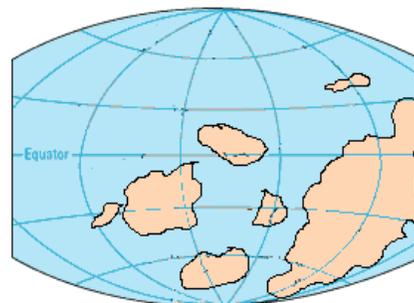
Pennsylvanian 380 million years

The farther you go back into time, the more difficult it is to find reliable clues. Fossils are important in the reconstruction, but there are few fossils with hard parts in rocks older than 630 million years (Precambrian).

Paleomagnetism, which helped confirm plate tectonics in Cenozoic rocks (65 million years and younger) is not very reliable in the older the rock becomes. As new techniques become available the configuration of the Earth's crust will surely change.



Silurian 430 million years



Cambrian 570 million years

# EARTH SCIENCES - PLATE TECTONICS

## Lesson 5 - Virtual Plate Tectonics

### MATERIALS:

reader  
Internet

**Objective:** Students explore the internet to reconstruct plate positions through time.

### Teacher note

Plate Tectonics is sometimes difficult for students to understand because of geologic time. Over millions of years, even the smallest movement every year can accumulate into thousands of kilometers in offset.

Search engines are important to use, in order to learn new information that is posted on the web. Remember the Internet was developed for scientists to share data. Most students do not realize that the Internet is now a commercial reality of scientists' urge to conduct group collaboration.

The internet can show some of this movement in a small time using different graphical representations. Students in this exercise use the internet to compare the motion mainly using constructions as far back as 1100 million years. We suggest the following sites to help students compare and contrast movement.

<http://www.odsn.de/odsn/services/paleomap/paleomap.html>

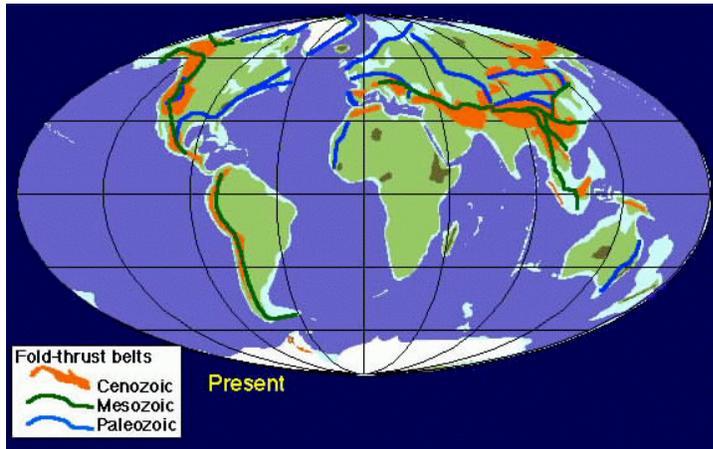
reconstruction back to 150 my

<http://www.ucmp.berkeley.edu/geology/tectonics.html>

Animations of plate reconstructions from 510 million years.

<http://www.scotese.com/>

Reconstruction of the plates in the last 1100 million years.



from [www.scotese.com](http://www.scotese.com)

The internet is an encyclopedic account of many topics. You can learn or you can get frustrated. Learning how to search the internet can help you find information quick and easy. This exercise will help you to choose the correct word, to see if the different search engines can help you.

Some search engines are better than others. This exercise will compare 3 search engines that your teacher assigns you. You are looking for animated cartoons of the

plates moving. The words that you may want to use are “plate reconstruction,” “plate tectonics,” or “geology.”

See what URL's you can locate that might help to illustrate the principles of plate tectonics better. Use the worksheet to help guide your survey of the internet. First look at the assigned sites. Remember some sites change, and the search engines may not record this change.

## VIRTUAL PLATE TECTONICS WORKSHEET

1. Look at the websites given to you by your teacher. Compare the sites. Which one gives you the best picture of how the plates may have moved through time.


2. Use 3 search engines using the same word (i.e. plate tectonics). Determine which one gives you the best sites. List the word, sites used, and describe the matches with other URL's.

Word used \_\_\_\_\_

site used	description of URL's linked

## Earth Science - PLATE TECTONICS - Unit Test

**Part 1. Definitions** Match the number of the term or concept in Column 1 with the letter of the correct definition in Column 2.

Column 1	Column 2
1. Alfred Wegener	a. plates coming together, with one going under the other
2. earthquakes and volcanoes	b. evidence of continent location through time
3. Lithosphere	c. oceanic-oceanic convergence
4. Paleomagnetism	d. proposed the theory of continental drift
5. Hawaiian volcanoes	e. helped to find connections between continents
6. California	f. Supercontinent during Paleozoic
7. subduction	g. example of transform motion
8. Island arcs	h. hot spots
9. Fossils	i. Thickness of plates
10. Gondwana	j. data points for plate tectonics

**Part 2. Multiple Choice** Choose the best answer to complete each statement.

- Plates that are moving together are referred to as
  - converging
  - diverging
  - transform
  - faults
- Plates that are moving away from each other are \_\_\_\_\_ :
  - converging
  - diverging
  - transform
  - faults
- Plates that slip slide past each other are referred to as
  - converging
  - diverging
  - transform
  - faults

4. The asthenosphere is
  - a. a molten part of the inner core
  - b. is a partially molten part of the upper mantle
  - c. is a molten part of the upper mantle
  - d. is a partially molten part of the lower mantle
  
5. Earthquakes are found when plates
  - a. diverge
  - b. converge
  - c. slip slide past each other
  - d. all of these
  
6. Himalayan Mountains are being formed by
  - a. continental-oceanic collision
  - b. oceanic collision
  - c. continental- continental collision
  - d. none of these
  
7. Diverging plates produce
  - a. ridge valleys
  - b. plate valley
  - c. diverging valley
  - d. rift valley
  
8. The point on the surface of the Earth above the focus is called
  - a. epicenter
  - b. epicycles
  - c. fault
  - d. earthquake
  
9. "S" waves
  - a. can go through liquid rock
  - b. can go through solid and molten rock
  - c. can only go through solid rock
  - d. none of the above
  
10. "P" waves
  - a. can go through liquid rock
  - b. can go through solid and molten rock
  - c. can only go through solid rock
  - d. none of the above

**ANSWERS:**

**PART I.**

1. D
2. J
3. I
4. B
5. H
6. G
7. A
8. C
9. E
10. F

**PART II.**

1. A
2. B
3. C
4. B
5. D
6. C
7. D
8. A
9. C
10. B