Unit 4:

The Forces within Earth

Earth Systems 3209 Unit 4 – Lesson 1: Intro to Continental Drift

What is Continental Drift?

Alfred Wegener's Theory of Continental Drift States that roughly 200 million years ago a super continent called Pangaea started to break apart. Laurasia was formed in the north and Gondwanaland was formed in the south. Over the past 150 million years, these landmasses split apart to form the continents we see today.

Since the mid 1900's, much evidence have been collected to support the theory of continental drift and plate tectonics.

Textbook Reference: page 540-545, 520-524

Evidence to Support Continental Drift

1. Fit of the Continents

Continental coastlines appear to fit closely together, for example, South America and Africa. But with further investigation Alexander DuToit suggested that the continental shelves would fit better because of the absence of erosion beneath the oceans.

*Draw fig 19.3 from text p.516

2. Fossil Correlation

Wegener and other scientist had proof of similar organisms that existed in both South America and Africa.

Fossil evidence of a fern plant (Glossopteris) and an aquatic reptile (Mesosaurus) provided the best evidence that the continents were once together.

*Draw fig 19.4 from text p.516/7

3. Rock Types and Structures

Scientists also noted that even though the continents appear to fit together, the overall picture has to be continuous from one continent to another.

This picture included the type of rock on neighboring continents and structural similarities such as mountains. For example, the Appalachian Mountains go from the Continental United States, through the Eastern Part of Canada and then again in Europe.

*Draw fig 19.6 from text p.518

4. Ancient Climates

Glacial deposits were found in South America, Africa, India, and Australia. These continents are presently not in cold climates, therefore must have been in a colder climate in the past and the continents later moved to the positions they are presently in today.

*Draw fig 19.7 from text p.519

Questions:

1. Describe the four pieces of evidence that Wegener used to support the theory of Continental Drift. Make sure you give examples for each.

<u>Earth Systems 3209 Unit 4 – Lesson 2: Plate Tectonic Theory</u>

What is Plate Tectonics? It is one of the great advances in the twentieth century.

In the 1960's, **scientists such as Alfred Wegener** proposed the **"continental drift theory",** and **Tuzo Wilson** put forth the idea that, "**Earth consisted of several different fragments called plates, instead of being made up of one static, rigid, solid layer**."

This revolutionized the way scientists think of Earth today, because before there was no mechanism, or reason, for the plates to shift. Now there is a driving force behind it.

Textbook Reference: Pages 525-526, 23 CD 805-809, 818-820

<u>A little more in depth</u>

In the late 1960's scientific studies of the ocean floor led to the development of a theory that better explained the idea of a mobile Earth, This theory was called the Plate Tectonic Theory. A Canadian geologist named Tuzo Wilson was the person to propose the Plate Tectonic Theory.

<u>The Theory of Plate Tectonics States:</u>

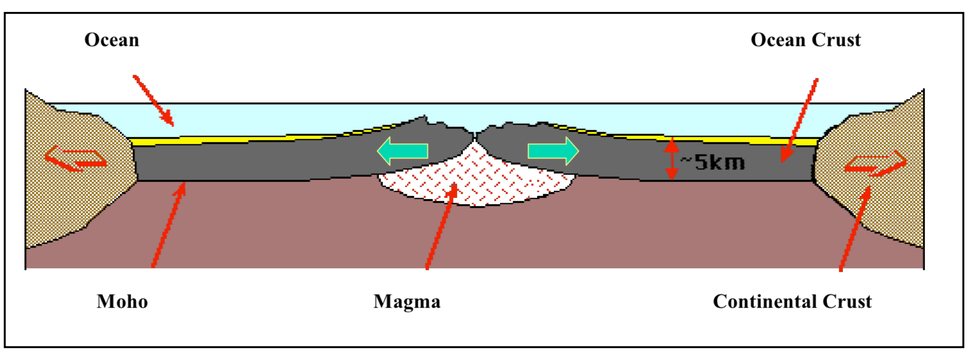
"Earth's crust is divided into approximately 20 rigid slabs called tectonic plates."

These tectonic plates are in continuous slow motion relative to each other, which occurs along one of three types of boundaries bordering each plate.

<u>An introduction to the Three Types of Plate Boundaries:</u>

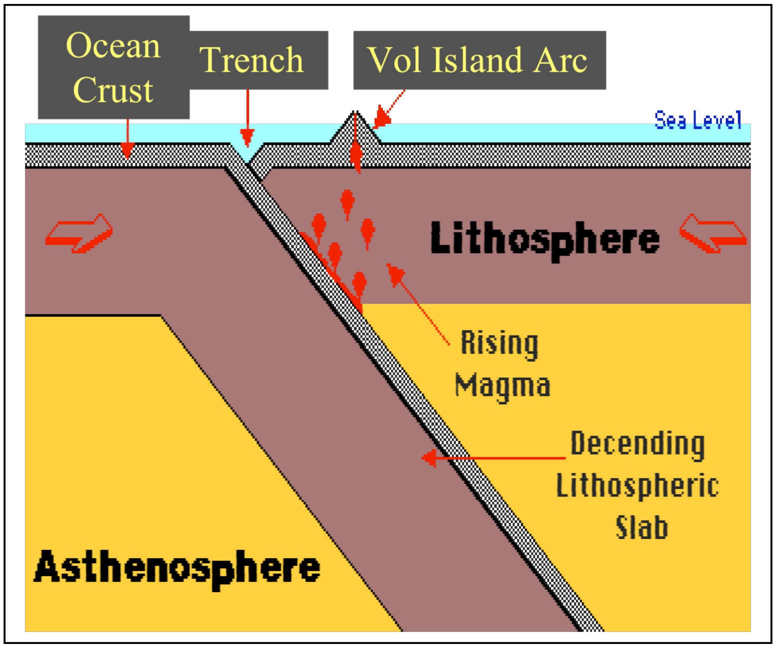
<u>1. Divergent Boundary</u>

Here, plates move apart, resulting in upwelling of molten material from the mantle to create new ocean floor. Features on the ocean floor called Ridges, show this form of plate movement. Tensional forces cause the plates to move apart.



2. Convergent Boundary

Here, plates move together, causing one slab of lithosphere to be consumed into the mantle as it descends beneath the overriding plate. Features called ocean trenches (or *subduction zones*) are formed at these boundaries. Lithosphere is destroyed at these boundaries. Compressional forces cause the plates to move together.



3. Transform Boundary

Plates move past each other in opposite directions. Lithosphere is not created or destroyed at these boundaries. No vertical movement. For example, the San Andreas Fault. Shearing forces cause the plates to move past one another.

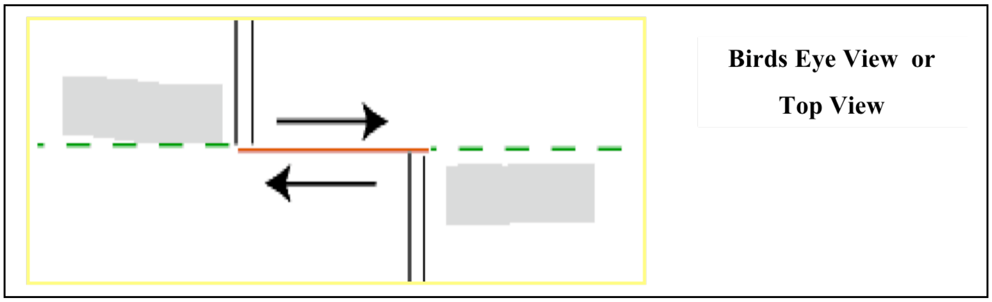


Plate Tectonic Theory – Evidence

(Use your textbook to fill in a point or two about each piece of evidence. This will be done in greater detail later.)

Evidence	Notes
1) Earthquakes and Volcanoes	
2) Polar wandering	
3) Magnetic Reversals and Seafloor Spreading	
4) Ocean Drilling and Heat Flow	
5) Hot Spots	

Special Scientists

For each of these people, you need to know their name and what they accomplished. It is outlined in the Table to the right, *and is definitely testable material*!

Frank Taylor	1910 – Explained the formation of the Himalayan Mountains by moving continents (no evidence given).
Alfred Wegener	1915 – Proposed the theory of continental drift (evidence given, but no mechanism provided).
Alexander DuToit	1937 – Proposed that Earth's continents would fit more closely together at the continental margins.
Arthur Holmes	1950s – Proposed the existence of a mechanism for movement; mantle convection.
Harry Hess and Robert Deitz	1960s – Proposed the theory of seafloor spreading.
Fredrick Vine and Drummond Matthews	1963 – Proposed the idea of magnetic reversals as evidence to support the theory of seafloor spreading.
J. Tuzo Wilson	1965 - Proposed the existence of "plates" on Earth's surface as a result of mapping the world's volcanoes and earthquakes. He also proposed the existence of transform faults along plate boundaries; and that stationary hotspots in Earth's mantle caused volcanism within plates.
Xavier Le Pichon and Dan McKenzie	1970s – Proposed the theory of plate tectonics

Questions

1. Using Plate Tectonics, explain why the Hawaiian Islands vary in age and amount of volcanic activity.

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2. How does Plate Tectonics Theory differ from Continental Drift? Explain.

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3. Choose any three special scientists and write a “blurb” on each of their accomplishments.

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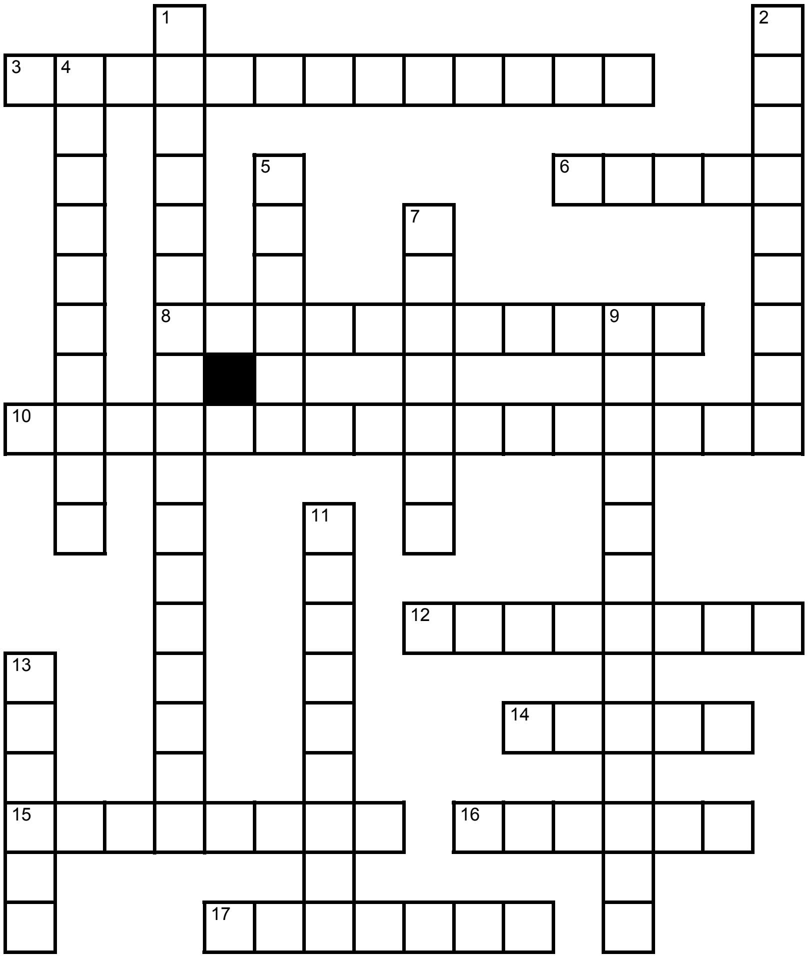
PLATE TECTONICS

Name: ______________________



Across

3. The zone below the lithosphere. It is more 'plastic' than the lithosphere so it is easier to bend and move.

6. The most outer solid portion of the planet Earth.

8. The outer part of the Earth's crust. it is composed of solid rock.

10. Places where new seafloor is being created.

12. The deepest parts of the oceans.

14. The Theory of Continental ____________.

15. The Earth's ____________ field reverses from time to time.

16. Alfred Wegener noticed that the coast of South America seemed to fit into the coast of this continent, just like a jigsaw puzzle.

17. Scientist who first proposed the theory that the continents drifted.

Down

1. The primary force that causes the seafloor to spread and continents to drift.

2. Plate ____________.

4. ____________ zones. Places where the seafloor is forced under continental plates.

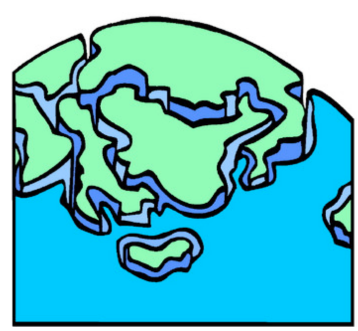
5. Section of the Earth below the crust.

7. Paleontologists noticed that these were the same on different continents even though the continents were separated by oceans.

9. Source of heat in the mantle.

11. Seafloor ____________.

13. Scientist who first proposed that thermal convection in the mantle causes continental drift.



Earth Systems 3209 Unit 4 – Lesson 3: Convection and Seafloor Spreading

In order to understand Continental Drift and Plate Tectonics, there is a requirement for you to understand the internal processes of Earth.

Convection currents happen in the asthenosphere, proposed by Arthur Holmes. Seafloor spreading idea, proposed by Harry Hess, provides evidence for a mobile Earth. Plate Tectonics became THE theory to explain crustal movements because it combines the seafloor-spreading model with continental drift and is proved by earthquake information.

Textbook Reference: Pages 523-524, 547-548, 840-864, CD 72, 74-75

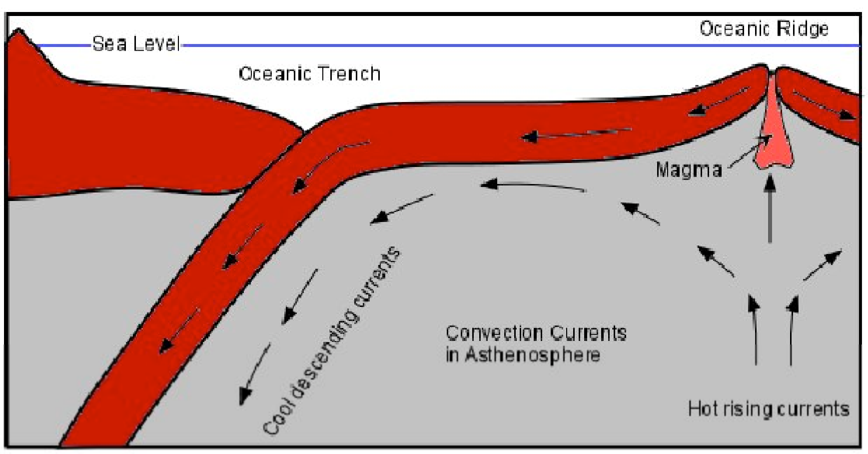
Convection Currents

The plates that make up the earth's crust sit directly on a "plastic" layer of the mantle called the *Asthenosphere*. Holmes found evidence to prove that tectonic plates moved on what he referred to as *convection currents*.

REMEMBER: Convection happens because of heat in liquids. Heat in Earth comes from two main sources: 1) radioactive decay and 2) residual heat.

If the asthenosphere is moving because of convection, then this could be the mechanism responsible for plate tectonics. Hess using Holmes' ideas, said that deep within the asthenosphere, heated material expands, becomes less dense, rises, and pushes it way up through ridges. It then moves along the base of oceanic plates, pulling the plates in opposite directions. We call this *Seafloor Spreading*.

When this slowly moving material reaches cooler areas it contracts and sinks causing one plate to move downward (subducting plate) beneath another (over-riding plate). This material is then recycled back into the mantle. This is illustrated in the diagram below.



NOTE: If you can remember how to draw this diagram, you're pretty well set to answer any question on this unit. Can you figure out why?

Ocean Depths

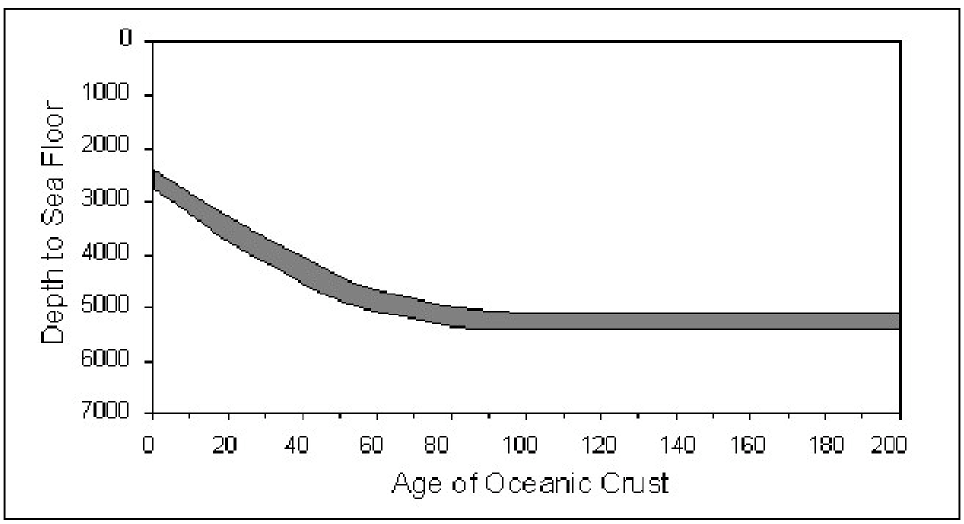
This is another important aspect of the Plate Tectonic Theory. In WW2, geologists employed by the military carried out studies of the sea floor, a part of the Earth that had received little scientific study.

The topographic studies involved measuring the depth to the sea floor. The studies revealed the presence of two important features:

1. *Oceanic Ridges* - long sinuous ridges that occupy the middle of the Atlantic Ocean and the eastern part of the Pacific Ocean.

2. *Oceanic Trenches* - deep trenches along the margins of continents, particularly surrounding the Pacific Ocean.

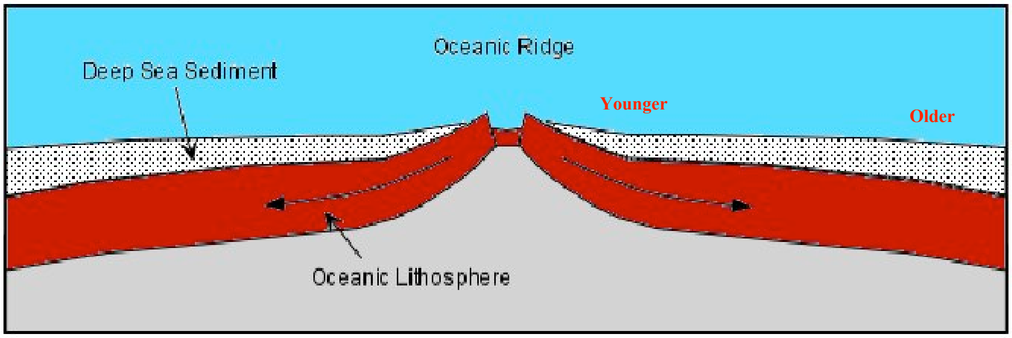
Studies also noted that as oceanic lithosphere moves away from the ridge, it cools and sinks deeper into the asthenosphere. Thus, the depth to the sea floor increases with increasing age away from the ridge. This is illustrated in the Diagram below:



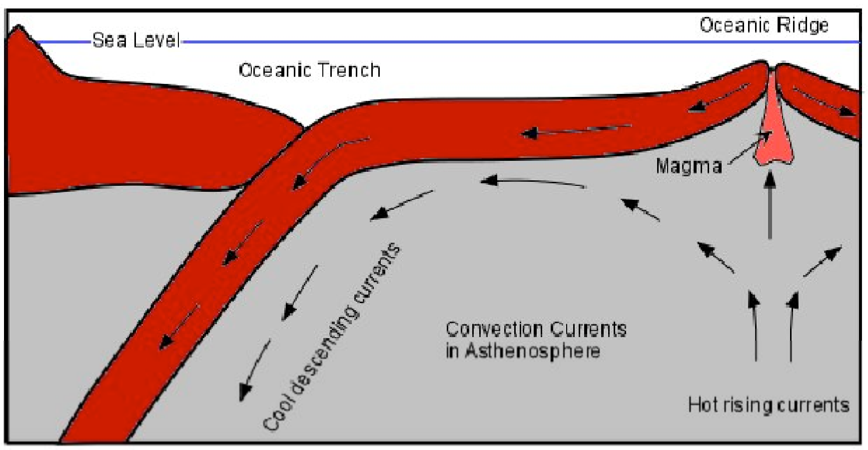
Seafloor Sediment and Age

This is more proof that Plate Tectonics exist. As we have previously discussed, oceanic ridges are areas of young crust. There is very little sediment accumulation on them. Sediment thickness increases in both directions away from the ridge. Therefore the older the crust the thicker the sediment.

When oceanic crust is created it is pushed aside in two directions. So, the farther the crust is from the ridge, the older it gets. This is seen in the diagram on the next page.



Oceanic lithosphere is created at ridges and destroyed at subduction zones (trenches). Oceanic basins are continuously being recycled and are relatively young. The oldest oceanic crust occurs farthest away from a ridge so in the Atlantic Ocean, the oldest oceanic crust is about 180 million years old (Jurassic). This is illustrated in the Diagram below.



Questions

1. Explain why it is impossible for oceanic crust to be older than 200 million years.

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2. Describe the difference between an ocean trench and an ocean ridge. Where would you find them?

3. Where does convection occur inside the earth? What are two reasons for it?

4. Draw a diagram (or two) illustrating how sediment thickness increases the farther away you get from an Ocean Ridge AND why the oldest ocean crust is Jurassic period rock (roughly 180 million years old).

Earth Systems 3209 Unit 4 – Lesson 4: Plate Boundaries

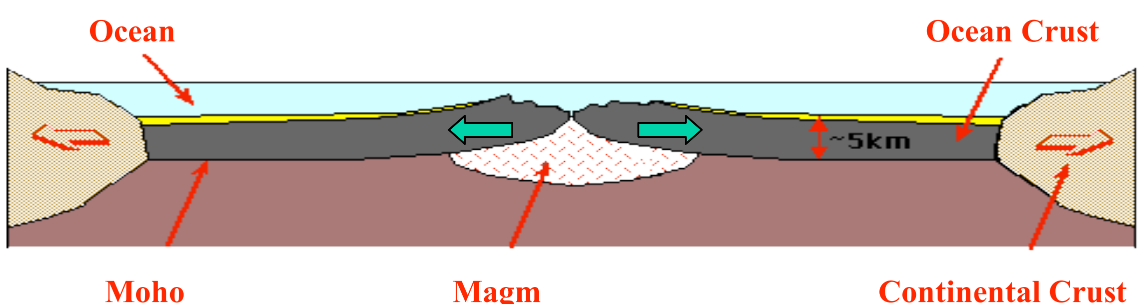
According to the Plate tectonic theory, one or more catagories of boundaries may exist at the edges of each tectonic plate.
1) Divergent Boundary (Ridge)
2) Convergent Boundary (Trench)
3) Transform Boundary

Divergent Boundary

Plates move apart, resulting in upwelling of molten material from the mantle to create new ocean floor.

Features on the ocean floor called Ridges, show this form of plate movement.

Tensional forces cause the plates to move apart.



Three Types of Convergent Plate Boundaries:

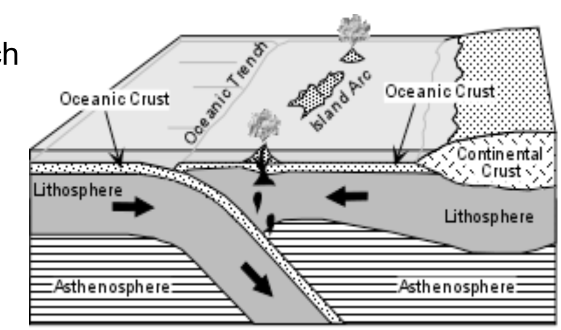
Ocean – Ocean Convergent Boundary

Compressional forces cause plates to move together, causing one slab of lithosphere to be consumed into the mantle initiating volcanic activity which creates volcanoes to form on the ocean floor.

Features called ocean trenches are formed at these boundaries. Lithosphere is destroyed as one oceanic slab descends beneath another.

Fluid, basaltic magmas feed the volcanic islands and form shield volcanoes.

Example include the Japan island arc and the Japan trench



Ocean - Ocean Convergence

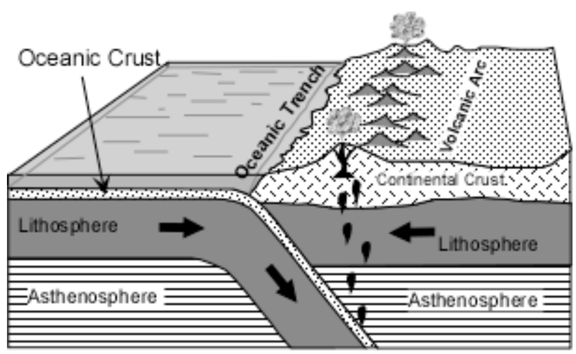
Ocean – Continent Convergent Boundary

Compressional forces cause an ocean plate and a continent plate to move together, causing the more dense ocean plate to sink into the asthenosphere. This region where the ocean plate sinks is called a subduction zone.

Deep ocean trenches form adjacent to the zone of subduction. These trenches can range up to thousands of kilometers long and 8 – 10 km deep. Lithosphere is destroyed as one oceanic slab descends beneath another.

At depths of about 100 km the oceanic plate and parts of the mantle partially melt producing viscous magmas. This molten rock rises slowly where it cools and solidifies at depths producing plutons. However, some magma may reach the surface and erupt through composite volcanoes as violent volcanic eruptions.

If the subduction occurs beneath continental crust, a continental volcanic arc is produced (such as the Cascades of the western U.S.,or the Andes mountains of the South America).

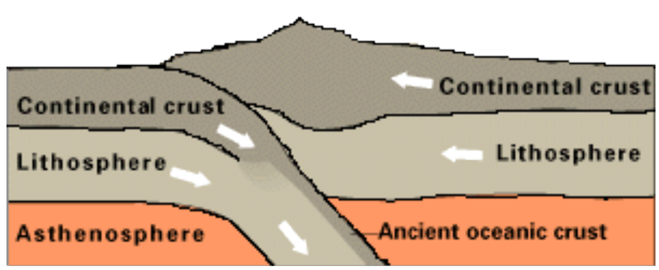


Ocean - Continent Convergence

Continent – Continent Convergent Boundary

Compressional forces cause two continental plates to move together. Because of the low density of continental crust neither plate will subduct and the two plates ram into one another forming mountains.

Such a collision occurred when India collided with Asia forming the Himalayas. During these collisions the continental crust is buckled and fractured pushing rock up to very high elevations.

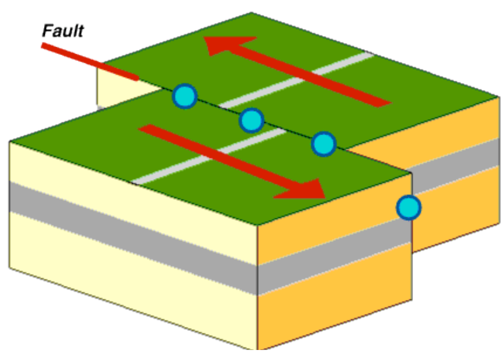


Transform Boundary

Where lithospheric plates slide past one another in a horizontal manner, a transform fault is created. Earthquakes along such transform faults are shallow focus earthquakes. Lithosphere is not created or destroyed at these boundaries.

One of the largest such transform boundaries occurs along the boundary of the North American and Pacific plates and is known as the San Andreas Fault. Here the transform fault cuts through continental lithosphere.

Most transform faults occur where oceanic ridges are offset on the sea floor.



Practice Questions

1. Using a labelled diagram, briefly describe what happens at a mid-ocean ridge.

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2. Using labelled diagrams, briefly describe the differences between the three convergent boundaries

i.______________________________________

ii.______________________________________

iii.______________________________________

3. Using a labelled Diagram, describe a transform boundary.

Earth Systems 3209 Unit 4 – Lesson 5: Faults and Folds

Folding and Faulting are two features seen in collision mountains. These occur when stress is greater than the strength of the rock, and the rock deforms.

When stress is applied to rocks they first deform elastically (bend).

Once the elastic limit is reached then one of two things happen (depends on if the rock is in a deep Earth or a surface environment):

Deep Earth – plastic deformation resulting in folding or flow.

Surface – plastic deformation to elastic limit and then fracture.

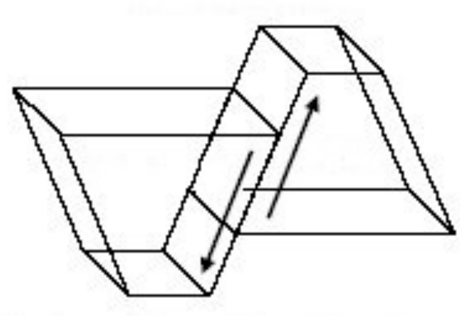
Faults

Fault - a break or crack in Earth's crust along which movement has occurred.

Hanging Wall - the top part of the rock above the fault plane.

Foot Wall - the bottom part of the rock below the fault plane.

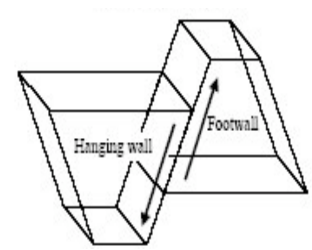
Fault Plane - the surface that separates the two moving pieces



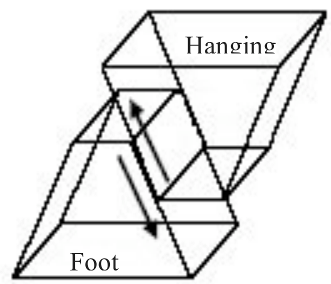
Fault Types

Normal Fault (dip-slip)

Caused by tensional forces.
Hanging wall drops in relation to the foot wall.

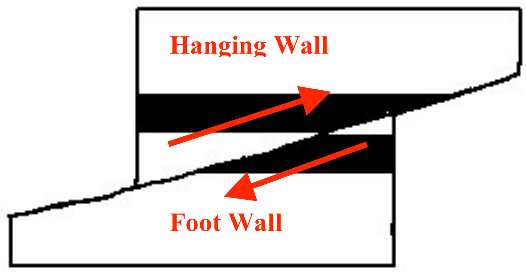


Reverse Fault (dip-slip)



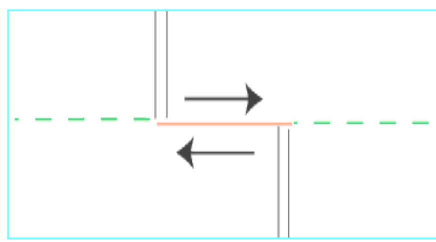
Caused by compressional forces.
Hanging wall moves upward in relation to the foot wall.

Thrust Fault (dip-slip)



Caused by Compressional forces.
Hanging wall moves up over foot wall.
Low angle reverse fault.
Sometimes called "Overthrust"

Transform Fault (strike-slip)



Caused by shearing forces.
Two plates slide side by side.
No vertical movement.

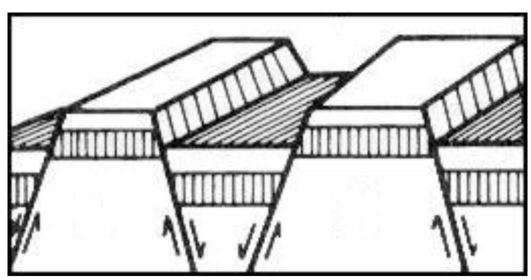
<u>The Horst and Graben</u>

Horst

An uplifted block of crust bounded by two normal faults.
Caused by tensional forces

Graben

A valley formed by the downward displacement of a block of crust bounded by two faults.
Caused by tensional forces.

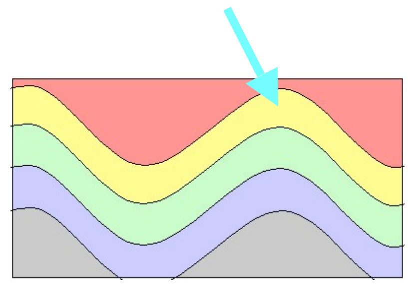


Folds

Parts of a Fold include;

Anticline –

Caused by compressional forces.
Crust moves upward forming a hill
Referred to as an up-fold.

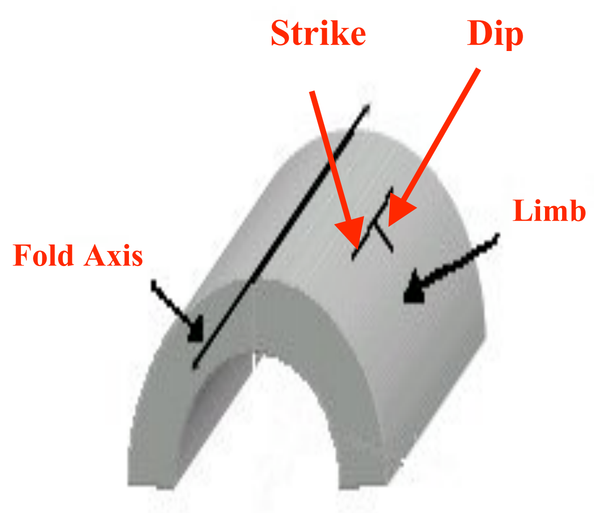


Syncline -

Caused by Compressional forces.
Crust moves down forming a valley
Referred to as a down-fold.

Limbs

Side part of a syncline or anticline



Fold Axis

Point where limbs change angle

Strike

Direction of fold axis

Dip

Angle of limb with the horizontal.

NOTE: After the Earthquakes Booklet, you will be doing Core Lab 5

Questions

1. With the aid of a clearly labelled diagram, describe the difference between a normal fault and a reverse fault

2. With the aid of a clearly labelled diagram, explain how the Horst and Graben is formed.

3. With the aid of a clearly labelled diagram, describe how folding occurs.

Earthquakes Workbook

Name: ______________________

Today's Date: ________________

Due date: _________________

Things to know:

1. This is a workbook. It is a collection of notes, diagrams and questions that will help you with this part of the course.

2. You may use ***Chapter 16 in your textbook*** to complete the following assignment, or other research tools of your choosing.

3. This is an ***in-class*** and ***take-home assignment*** to be ***completed on time***. Only when you pass it in will you receive marks.

4. Garland rules apply: There is a penalty for late work. ***5% for each day late.*** There is a bonus for early work. ***5% for each school day before the due date.***

5. If you need ***extra space***, you can ***attach loose-leaf***. You are allowed.

6. You only get ***ONE COPY*** of this assignment. If you lose it, you are responsible to find your own.

7. Make sure you read every question fully before answering the questions. ***SOME QUESTIONS HAVE MORE THAN ONE PART.***

/60 = __________%

Key Terms – p 469 of textbook *(27 marks)*

Aftershock - ____

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Body Wave - ____

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Earthquake - ____

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Elastic Rebound - ____

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Epicentre - ____

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Fault - ____

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Fault Creep - ____

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Focus - ____

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Foreshock - ____

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Inertia - ____

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Intensity - ____

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Liquefaction - ____

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Long (L) waves - ____

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Magnitude - ____

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Mercalli Scale - ____

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Moment Magnitude - ____

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Primary (P) Waves - ____

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Richter Scale - ____

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Secondary (S) Waves - ____

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Seismic gaps - ____

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Seismic sea wave - ____

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Seismogram - ____

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Seismograph - ____

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Seismology - ____

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Surface Wave - ____

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Tsunami - ____

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Benioff Zones - ____

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Part 1 - Causes of Earthquakes

What is an Earthquake?

An earthquake is the vibration of Earth produced by the sudden, rapid release of energy.

Seismology

When an earthquake occurs, the elastic energy is released and sends out vibrations that travel throughout the Earth. These vibrations are called seismic waves. The study of how seismic waves behave within Earth is called ***seismolog***y.

Reference - *Textbook: Pages 441-443, CD 865-869, 971-976, 986-990*

Focus and Epicenter

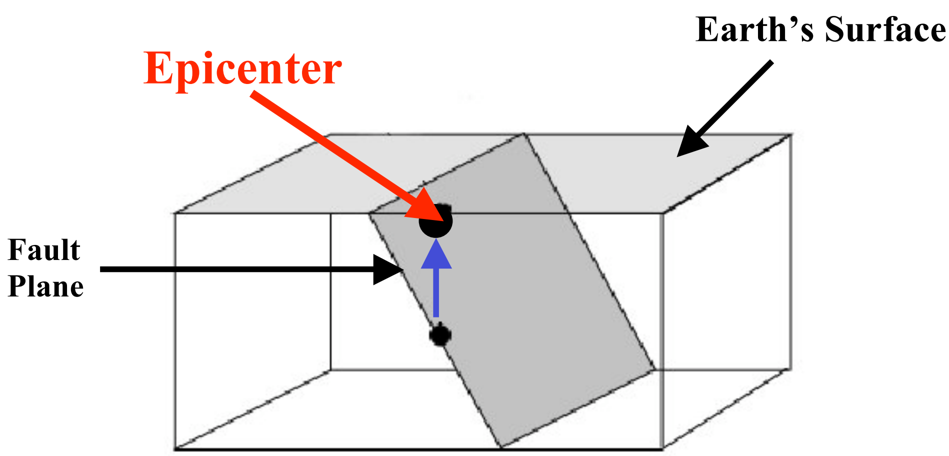
What are the Earthquake Focus and Epicenter?

Focus:

The exact location within Earth were seismic waves are generated by sudden release of stored elastic energy. Most often located on a pre-existing fault.

Epicenter:

The point on the surface of Earth directly above the focus.



Earthquakes occur when energy stored in elastically strained rocks is suddenly released.

This release of energy causes intense ground shaking in the area near the source of the earthquake **(Focus)** and sends waves of elastic energy, called seismic waves, in all directions throughout Earth.

Earthquakes can be generated by bomb blasts, volcanic eruptions, and sudden slippage along faults.

Earthquakes are definitely a geologic hazard for people living in earthquake regions, but the seismic waves generated by earthquakes are invaluable for studying the interior of the Earth.

How Do Earthquakes Originate?

Movement in areas along the fault plane stops (fault sticks).

Elastic energy is stored in the rock as the rock becomes deformed and bends, much like a bent stick.

When the elastic strain built up along the fault exceeds the elastic limit, the rock will break or slip at its weakest point which we call the the focus.

This slippage along the fault allows the rock to “snap back” and the vibrations sends out waves of energy in all directions called seismic waves, or earthquake waves.

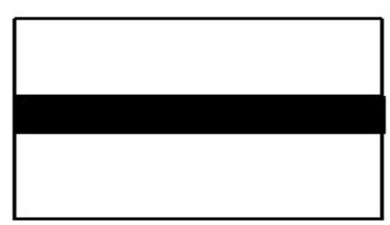
*The springing back of the rock is called “elastic rebound***”.**

What is the Elastic Rebound Theory?

The mechanism that cause earthquakes was not understood until H. F. Reid proposed his idea of “Elastic rebound.”

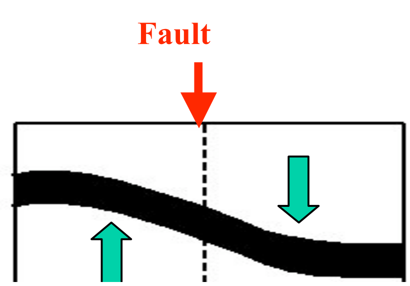
Reid suggested that most natural earthquakes are caused by sudden slippage along a fault zone.

Original position of rocks before any strain.



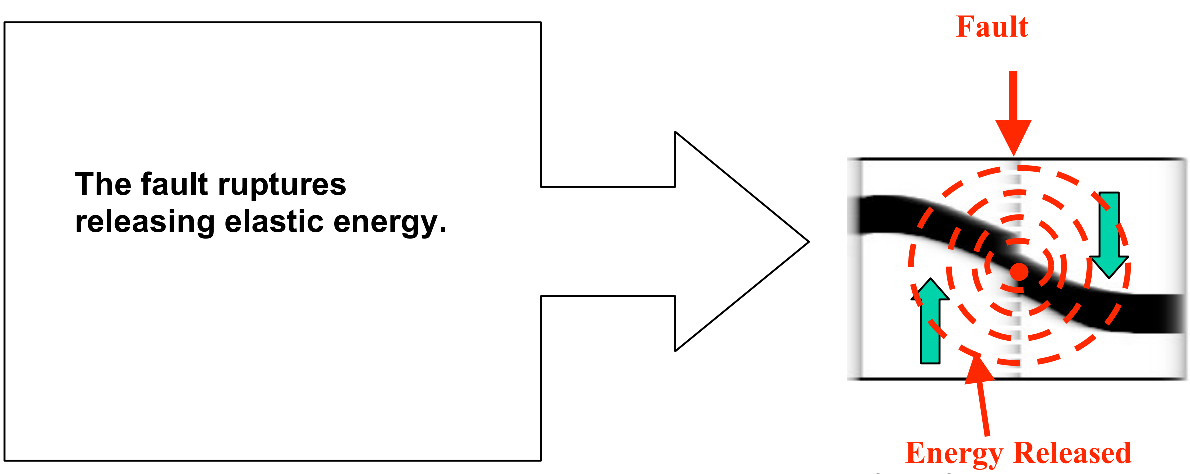
The ***elastic rebound theory*** suggests that if movement along a fault gets stuck, elastic strain energy builds up deforming rocks on either side of the fault.

A feature across the fault bends as the rocks on both sides of the fault pushes in opposite directions and elastic strain builds up.

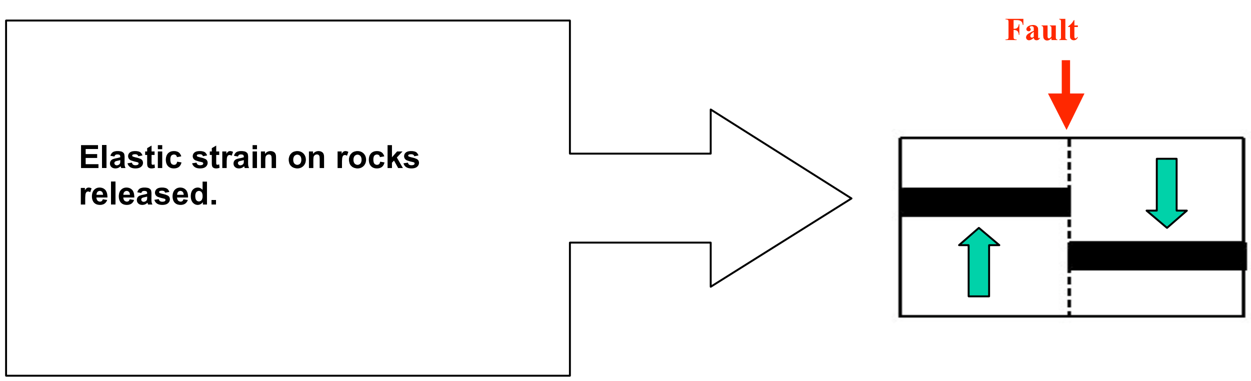


When the rocks along the fault can no longer hold the strain slippage occurs at the weakest point along a fault (focus) which causes rock to start moving on both sides of the fault.

Energy is released in all directions causing an earthquake.



When the elastic strain is released the rocks on both sides of the fault will **"snap-back"** to their unstrained positions.



<u>Sample Problem</u>

Earthquakes commonly occur at plate boundaries, with reference to elastic rebound, what causes an earthquake?

Answer:
There is a build up of stress (energy) within the tectonic plates, where it reaches the elastic limit. The plates then rupture (snap) and the stored energy is released. Plates then move (snap) back to unstressed positions releasing the stored energy as seismic waves. This is what we call an earthquake.

<u>Questions to Answer:</u> *(9 marks)*

1. What is an Earthquake? Under what circumstances do earthquakes occur? *(2)*

____

____

____

____

2. How are faults, foci and epicenters related? *(2 marks)*

____

____

____

____

____

3. Who first explained the mechanism that generated earthquakes? *(1 mark)*

____

4. Explain what is meant by elastic rebound. *(2 marks)*

____

____

5. Faults that are experiencing no active creep may be considered ‘safe’. Is this statement true? Why or why not? *(2 marks)*

____

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<u>Part 2 -Seismic Waves</u>

The source of an earthquake is called the *focu*s and the *epicenter* is the point on Earth’s surface directly above the focus. Seismic waves originate at the focus and travel outward in all directions.

These energy waves are classified as:

1) Body Waves:

- Primary Wave

- Secondary Wave

2) Surface Waves:

- Love Wave

- Rayleigh Wave

Reference – *Textbook: Pages 444-447*

Body Waves

Originate from the focus and travel in all directions through the body of the Earth.

Two types of body waves:

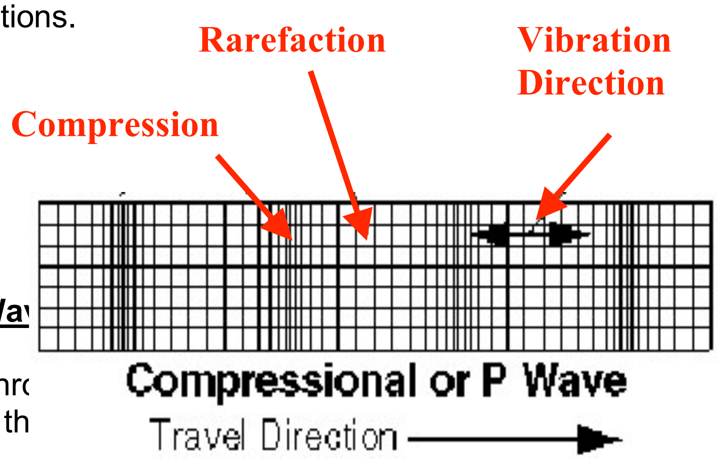
1) Primary Wave (P-Wave)

P-waves move by compressing and expanding (push-pull motion) the material as it travels. Much like sound waves.

These waves can pass through solids, liquids, and gases.

Vibrate in the same direction as wave motion.

These waves have the greatest velocity (6 km/sec) and are the first to reach the seismograph stations.



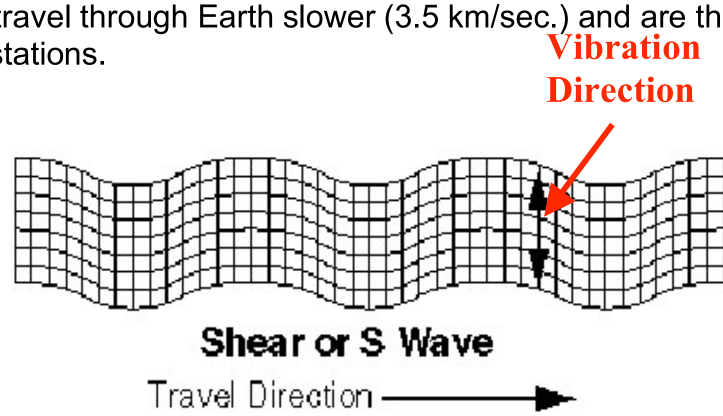
2) **Secondary Wa**

S-waves travel thr ... in the direction perpendicular to th

Because liquids and gases have no shape, these waves do not pass through liquids only trough solids.

These waves are much like the waves on the ocean.

These waves travel through Earth slower (3.5 km/sec.) and are the second to reach seismograph stations.



Surface Waves

Surface waves differ from body waves in that they do not travel through Earth, but instead travel along paths nearly parallel to the surface of Earth.

Surface waves behave like S-waves in that they cause up and down and side to side movement as they pass, but they travel slower than S-waves.

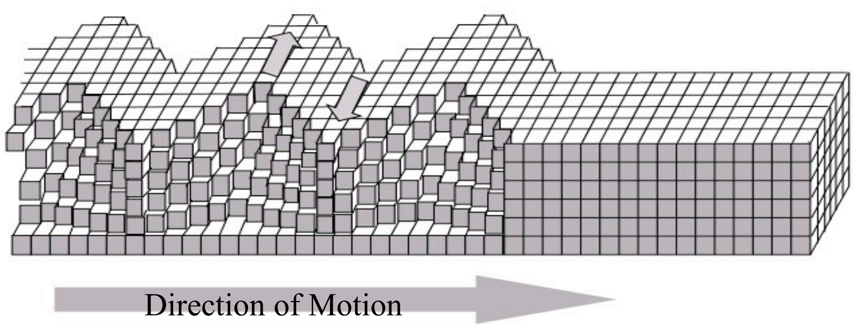
Two types of surface waves:

1) Love Wave

Surface waves that cause horizontal shearing of the ground. They move in much the same way as a snake slithering across the ground.

Vibrate in a perpendicular direction compared to that of wave motion.

Surface waves are the most destructive and cause the most damage.

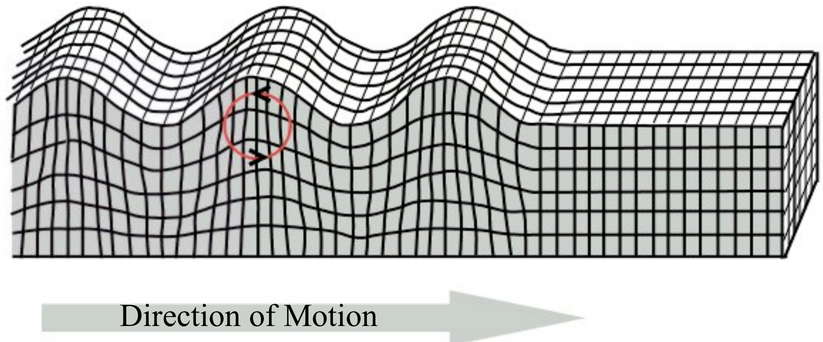


2) **Rayleigh Wave**

Surface waves that cause both horizontal (side-to-side) and vertical (up and down) movement within the ground.

Vibrate in a rolling motion in the same direction as wave motion.

Most of the shaking felt from an earthquake is due to these waves and these waves are the most destructive and cause the most damage.



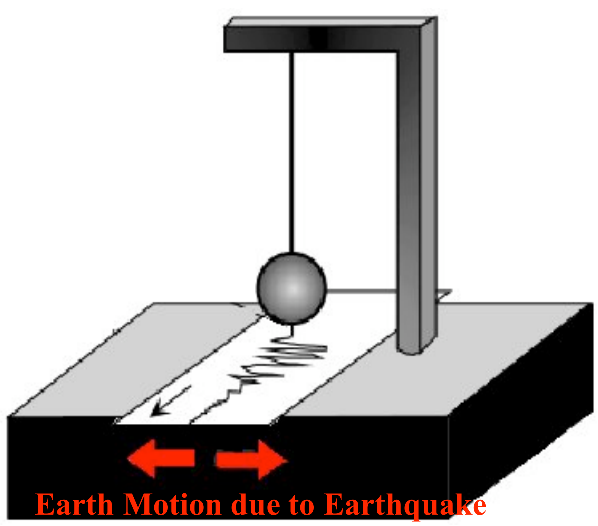
Seismograph

An instrument used to record seismic waves and the resulting graph that shows the vibrations is called a *seismogram*.

The seismograph must be able to move with the vibrations, yet part of it must remain nearly stationary.

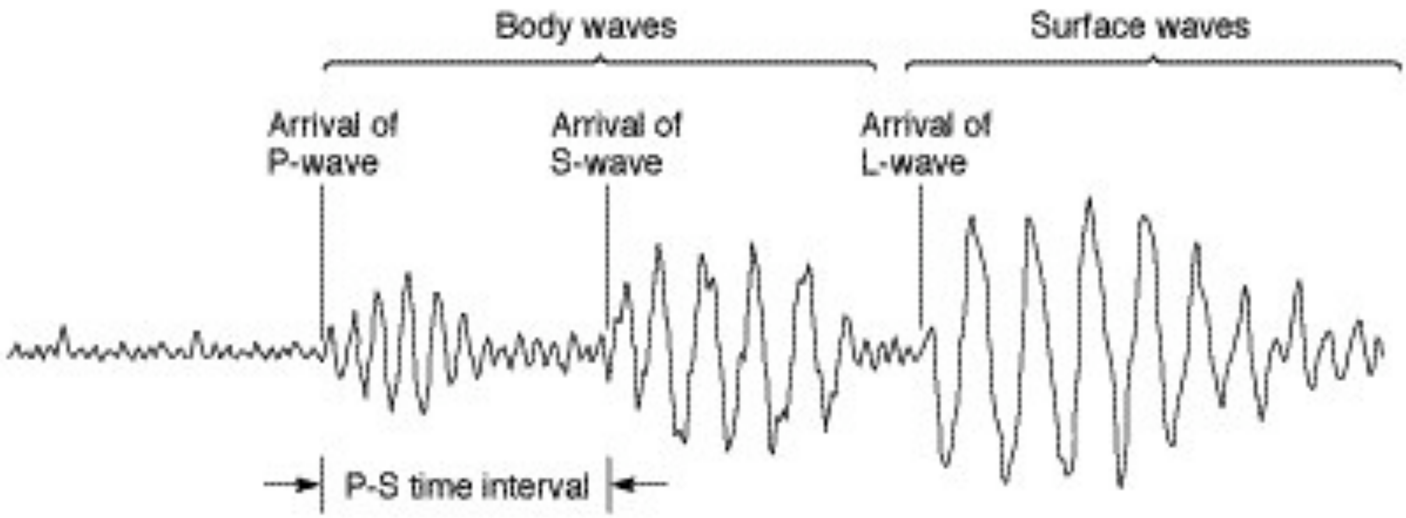
This is accomplished by isolating the recording device (like a pen) from the rest of the Earth using the principal of inertia.

For example, if the pen is attached to a large mass suspended by a spring, the spring and the large mass move less than the paper which is attached to the Earth, and on which the record of the vibrations is made.



Seismograph and Seismogram

P-waves, S-waves, and Surface waves are all recorded on the seismogram as seen below:



These paper records are important when seismologist wants to locate the position of the epicenter of an earthquake.

Seismologist can determine the difference in arrival times between the P-wave and the S-wave.

NOTE: *Now the Earthquake Lab (Core Lab #5) should be done.*

Sample Problem

Contrast the characteristics of Primary and Secondary waves.

Answer:

P - wave
Push - pull waves which vibrate in the same direction in which they move. Fastest earthquake wave and is the first to arrive at seismograph stations. Pass through all states of matter, solids, liquids, and gases.

S - wave
Shake the particles which cause them to vibrate in a perpendicular direction to their motion. Slower than P - wave and is the second earthquake wave to arrive at seismic stations. Pass only through solids.

Questions to Answer: *(11 marks)*

1. Describe the principle of a seismograph. *(2 marks)*

2. List the major differences between P and S waves. *(2 marks)*

3. P waves move through solids, liquids and gases but S waves move only through solids. Explain. *(3 marks)*

4. Which type of seismic wave causes the greatest destruction to buildings? *(1)*

5. Use figure 16.11 in your textbook to determine the distance between an earthquake and a seismic station if the first S wave arrives 3 minutes after the first P wave. *(1 mark)*

6. In what zone on the globe do most strong earthquakes occur? *(1 mark)*

7. Deep focus earthquakes occur several hundred kilometers below what prominent features on the deep ocean floor? *(1 mark)*

Part 3 - Richter and Mercalli Scales

An earthquake is the vibration of earth caused by a rapid release of energy.

Slippage along pre-existing faults and sudden movement within a subduction zone are commonly the cause of earthquakes.

Seismologist use two scales when classifying earthquakes.

1) Modified Mercalli Scale

2) Richter Scale

Reference – *Textbook: Pages 453- 454*

Mercalli Scale

Measures the *Intensity* of an earthquake on a twelve (XII) point scale.

In 1902 G. Mercalli developed a fairly reliable intensity scale which assesses the damage to various types of structures at a specific location.

Note that earthquake intensity is determined by several factors including:

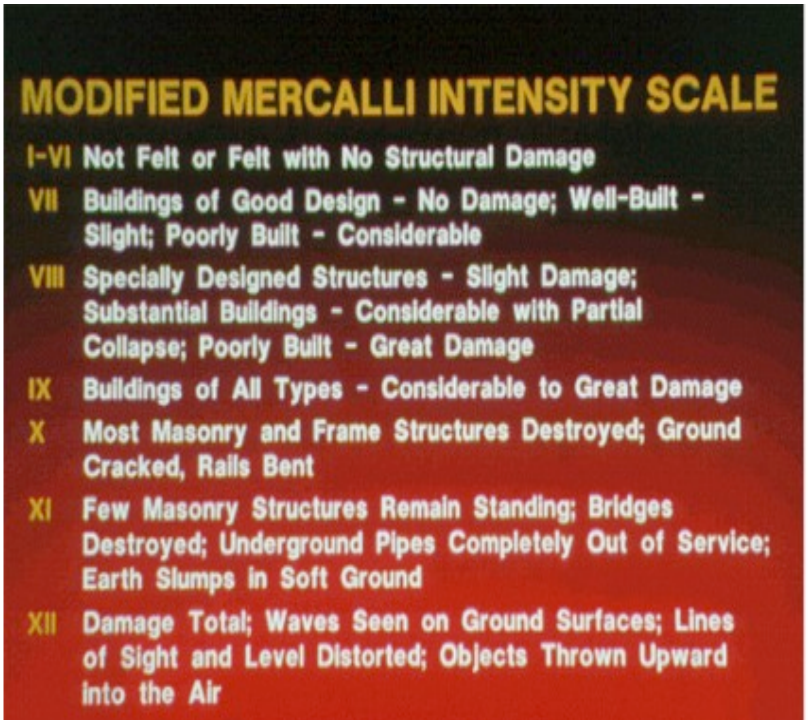
1) Strength of earthquake

2) Distance from epicenter

3) Nature of surface materials

4) Building design

The Mercalli scale does not give a true indication of the actual strength of an earthquake because the amount of damage done to different places will largely depend on, the type of materials used and the degree of construction of buildings and structures.


MODIFIED MERCALLI INTENSITY SCALE

I-VI	Not Felt or Felt with No Structural Damage
VII	Buildings of Good Design - No Damage; Well-Built - Slight; Poorly Built - Considerable
VIII	Specially Designed Structures - Slight Damage; Substantial Buildings - Considerable with Partial Collapse; Poorly Built - Great Damage
IX	Buildings of All Types - Considerable to Great Damage
X	Most Masonry and Frame Structures Destroyed; Ground Cracked, Rails Bent
XI	Few Masonry Structures Remain Standing; Bridges Destroyed; Underground Pipes Completely Out of Service; Earth Slumps in Soft Ground
XII	Damage Total; Waves Seen on Ground Surfaces; Lines of Sight and Level Distorted; Objects Thrown Upward into the Air

Richter Scale

Measures the *Magnitude* of an earthquake on a ten (10) point scale.

In 1935, Charles Richter introduced the concept of earthquake magnitude.

Richter magnitude is determined by measuring the largest amplitude (wave height) recorded on the seismogram.

Largest recorded earthquake had a Richter magnitude equal to 8.6

Richter Magnitude	Effects Near Epicenter
< 2.0	Generally not felt, but recorded
2.0 - 2.9	Felt under special conditions
3.0 - 3.9	Felt by some
4.0 - 4.9	Felt by most
5.0 - 5.9	Damaging shock waves
6.0 - 6.9	Destructive in populated regions
7.0 - 7.9	Major earthquakes
> 8.0	Great earthquakes

Richter magnitude can be expressed in two ways:

1) wave amplitude increases ten fold (10X).

2) energy released increases thirty fold (30X).

While it is correct to say that for each increase in 1 in the Richter Magnitude, there is a tenfold (10X) increase in amplitude (height) of the wave;

It is **incorrect** to say that each increase of 1 in Richter Magnitude represents a tenfold (10X) increase in the size of the Earthquake.

A better measure of the size of an earthquake is the amount of ***energy released*** by the earthquake.

How they Work:

1) Wave amplitude

increases tenfold (10X) with each increase in Richter magnitude.

Each increase in 1 in Richter Magnitude represents a 10 fold increase in the wave amplitude (height).

Thus, a magnitude 7 earthquake measures 10 times more amplitude than a magnitude 6 earthquake.

A magnitude 8 earthquake measures 10 x 10 (or 100 times) more amplitude than a magnitude 6 earthquake. And so on.

2) Energy released

increases thirtyfold (30X) with each increase in Richter magnitude.

Each increase in 1 in Richter Magnitude represents a 30 fold increase in the energy released (size).

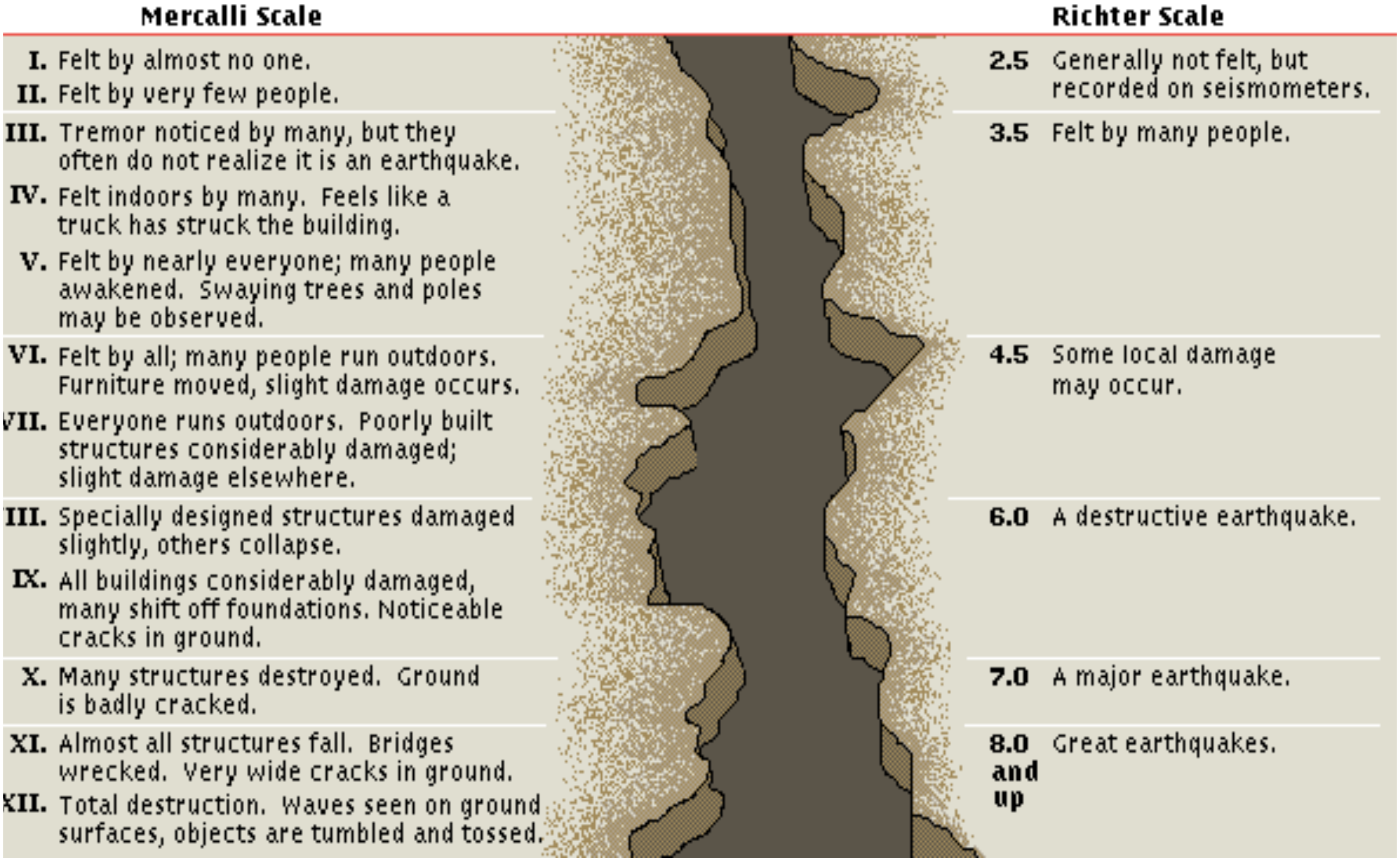
Thus, a magnitude 7 earthquake releases 30 times more energy than a magnitude 6 earthquake.

A magnitude 8 earthquake releases 30 x 30 or 900 times more energy than a magnitude 6 earthquake. And so on ….

Complete the following table: *(2 marks)*

Amplitude	Richter Magnitude	Energy Released
1	1	30
10	2	900
100	3	27 000
	4	
	5	
	6	
	7	
	8	
	9	

Richter and Mercalli Scales in Comparison



Sample Problem
In terms of magnitude, an earthquake measuring 7.2 on the Richter scale has a wave amplitude of how many times greater than an earthquake measuring 4.2 on the Richter scale?

Amplitude	Magnitude	Energy Released
	4.2	
	5.2	
	6.2	
	7.2	

Questions to Answer: *(20 marks)*

1. What are 4 differences between the Mercalli Scale and the Richter Scale? *(4)*

____

____

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____

2. For each increase of 1 on the Richter Scale, wave amplitude increases by _________ times. *(1 mark)*

3. An Earthquake measuring 7 on the Richter scale releases about _________ times as much energy as an earthquake with a magnitude of 6. *(1 mark)*

4. Give 3 reasons why the moment magnitude scale has gained popularity among seismologists. *(3 marks)*

____

____

____

5. List four factors that affect the amount of destruction caused by seismic vibrations. *(4 marks)*

____

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____

6. What factor contributed to the extensive damage that occurred in the central portion of Mexico City during the 1985 Earthquake (p 458)? *(2 marks)*

____

____

7. List 3 other types of destruction associated with earthquakes, other than the direct destruction created by an earthquake. *(3 marks)*

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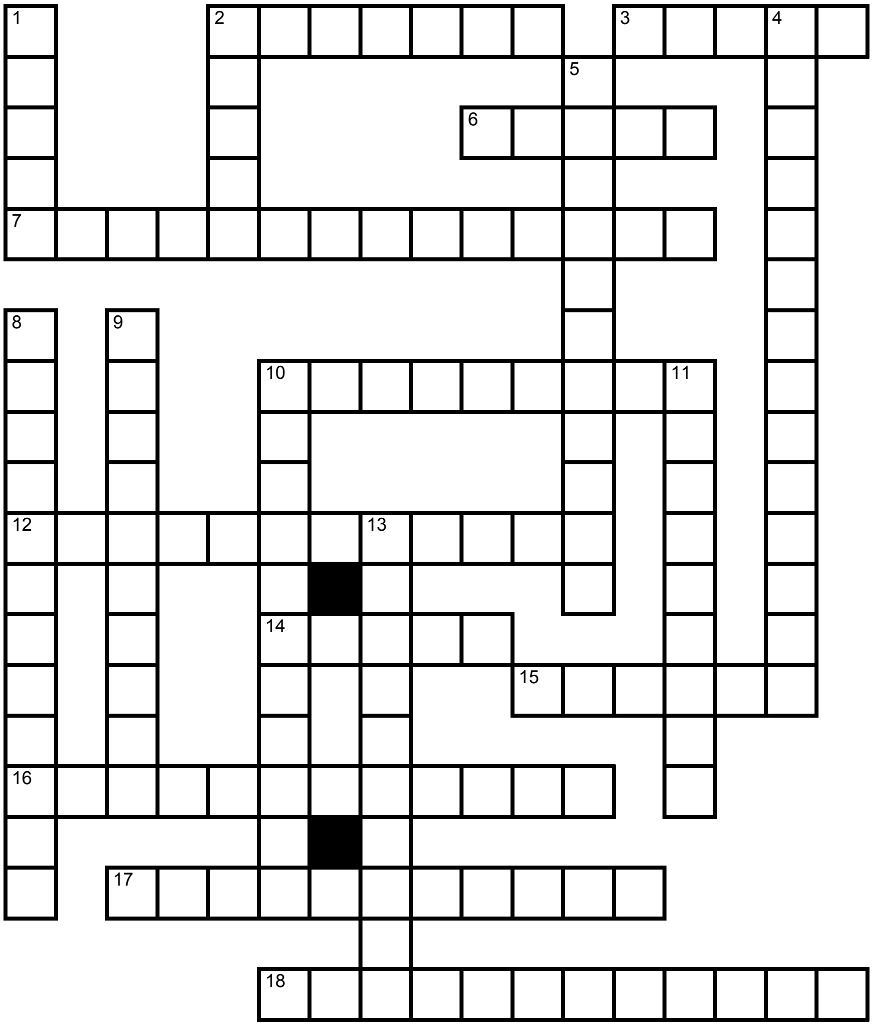
8. What are some reasons why a moderate magnitude earthquake might cause more damage than a high magnitude quake? *(2 marks)*

____

____

EARTHQUAKES

Name: ____________________________



Across

2 A sea wave that is created when the seafloor slips after an underwater earthquake. (7)

3 The outermost layer of the earth. The layer of the earth where earthquakes occur. (5)

6 A body wave that can penetrate the earth's core. (1,4)

7 Large, thin, plates that move relative to one another on the outer surface of the Earth. (8,6)

10 The height of a wave. (9)

12 Scale used to measure the magnitude of earthquakes. (7,5)

14 A body wave that doesn't penetrate the earth's core. (1,4)

15 The part of the earth between the core and the crust. (6)

16 Waves that travel at the surface such as Raleigh and long waves. (7,5)

17 A machine used to measure earthquake activity. (11)

18 A place where seafloor spreading occurs. (7,5)

Down

1 The fracture along which blocks of crust move relative to each other. (5)

2 City destroyed by earthquake in 1923. (5)

4 The place where two plates collide and one goes over top the other. (10,4)

5 Sudden stress changes in the earth that cause ground shaking. They occur at fault lines and near volcanic activity. (11)

8 City destroyed by earthquake in 1906. (3,9)

9 Also known as the focus. The place under the ground where the earthquake originates. (10)

10 Earthquakes that immediately follow a major earthquake shock. (11)

11 The place on the surface directly above the earthquake's focus. (9)

13 The area of earth that is unaffected by both P and S waves. (6,4)

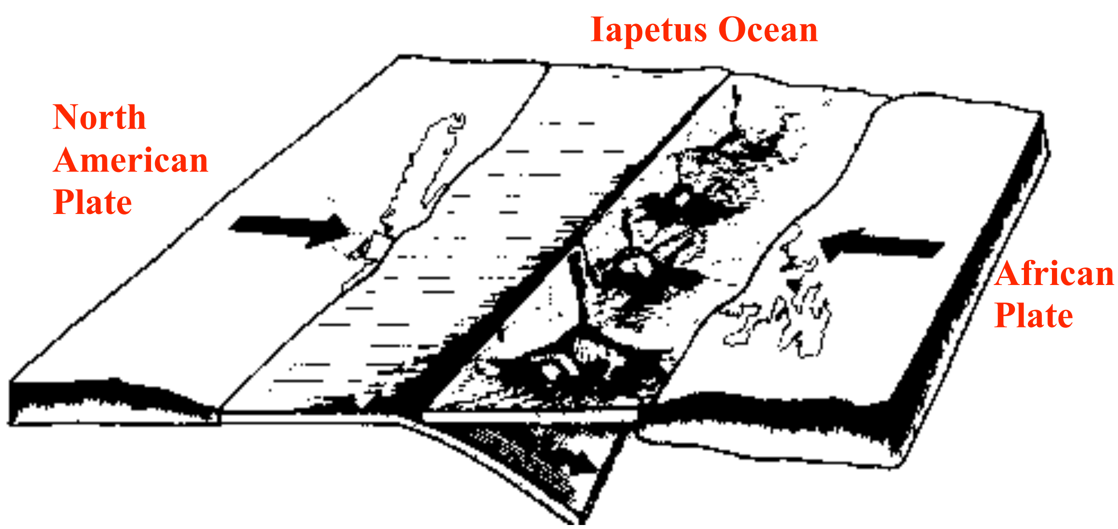
Earth Systems 3209 Unit 4 - Lesson 6: Plate Tectonics and Newfoundland

How old is Newfoundland and Labrador? You might think about John Cabot and say "about 500 years." But, using geology we find that the answer is much older. Remember: geology is the scientific study of Earth and its land-forms.

NL has a rich geological history, hundreds of millions of years old.

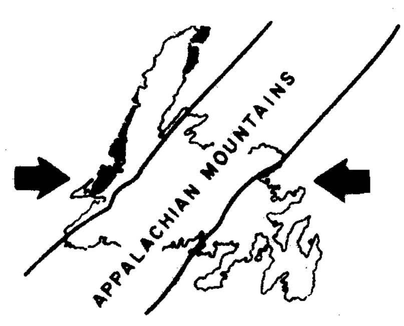
The Geological Formation of Newfoundland

~ 500 hundred million years ago, the central portion of North America was under a warm tropical sea called the Iapetus Ocean. Europe, Africa and North America bordered this body of water.



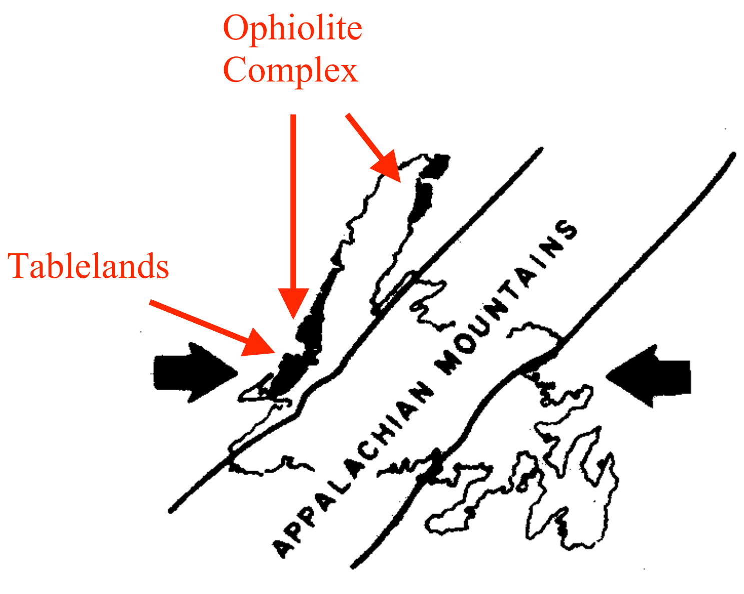
Over the next 150 million years, forces within Earth's mantle slowly carried these continents on a collision course. As the continents drifted together, the ocean floor was squeezed and then pushed upward to form the Appalachian Mountains.

This mountain range now exists throughout central and western Newfoundland and is the northernmost part of the Appalachians in North America. This range, continues through most of the British Isles and into Norway.

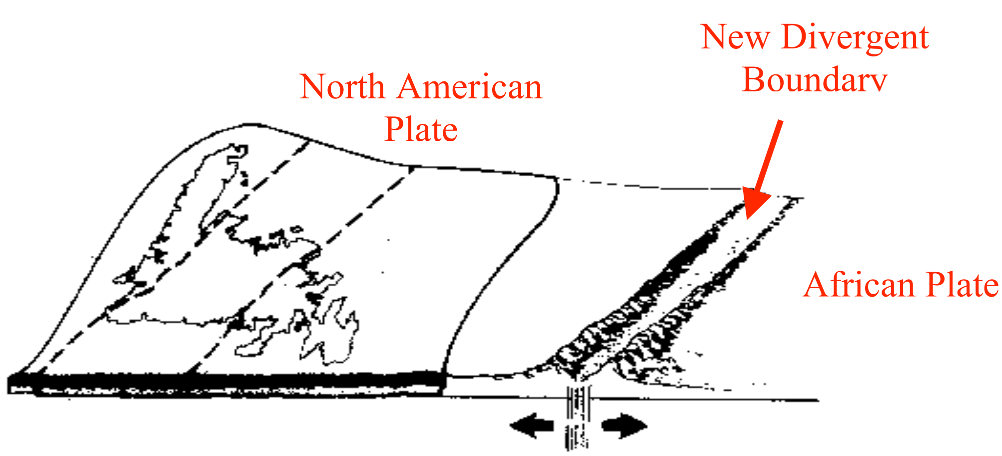


An area called the Tablelands in Gros Morne National Park has rocks that were once part of Earth's mantle but were pushed on top of Earth's crust during the collision of the continents many millions of years ago.

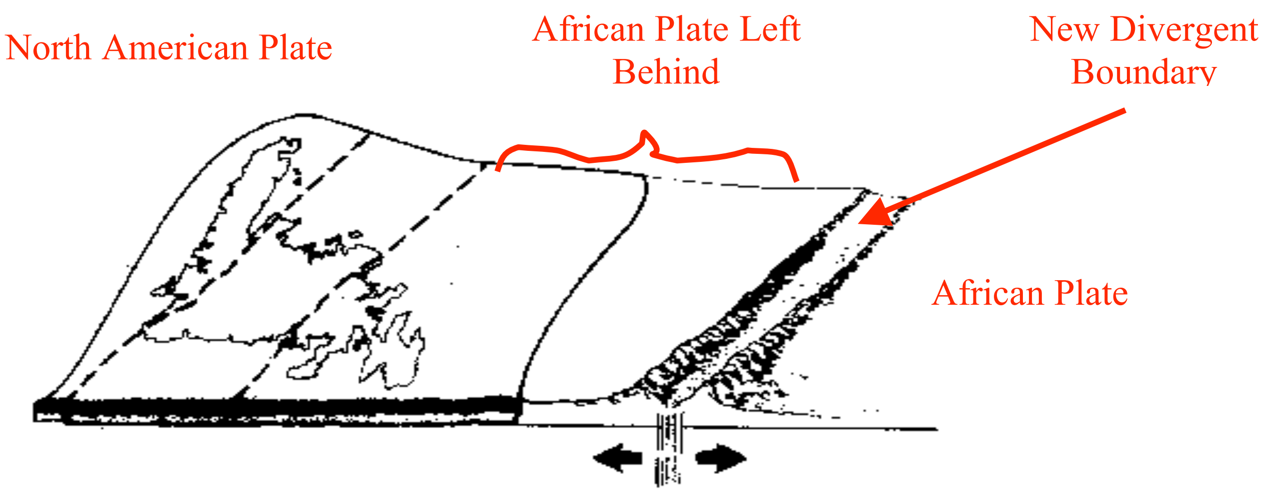
These sightings called   Ophiolite complexes are rarely seen on Earth's surface.



225 million years ago, the forces in Earth's mantle that brought the continents together reversed and slowly began to pull them apart. The divergent boundary responsible for the shifting of the plate rifted within the African plate and caused the plates to drift apart.



During this process a small bit of Africa got left behind! When you stand on Signal Hill in St, John's, you are standing on rocks that are identical to ones in the country of Morocco in north Africa! The eastern part of Newfoundland was once a part of the African plate.

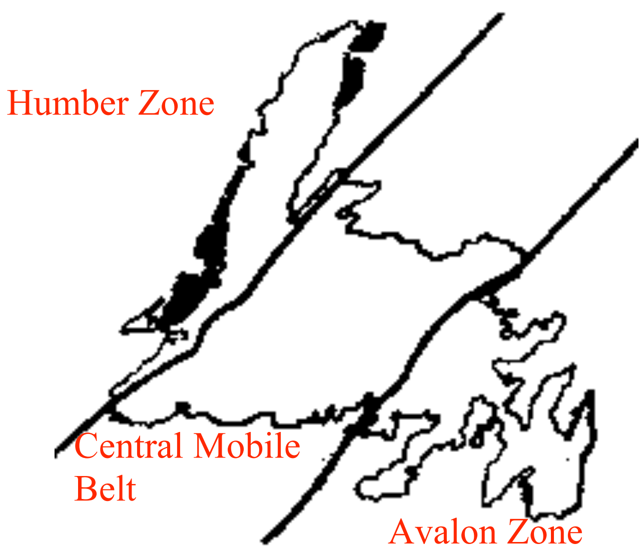


The Geological Layout of Newfoundland

Humber (Western) Zone - Has been a part of the North American plate for at least the last billion years.

Central (Zone) Mobile Belt   Remnants of volcanic arcs and the ancient Iapetus ocean floor.

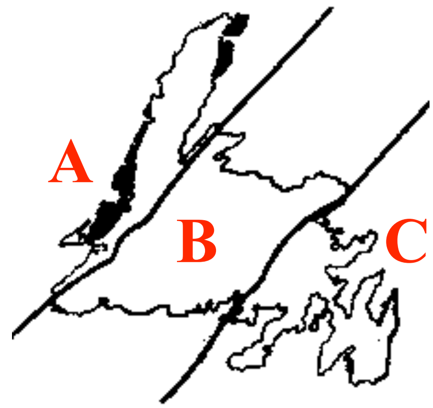
Avalon (Eastern) Zone   Once part of the African plate which remained attached as Pangaea split 200 million years ago.



Sample Problem

Use the diagram and your knowledge of the theory of Plate Tectonics to explain how the three geologic zones of the island portion of Newfoundland and Labrador were formed. Remember to Label each section.

Answer:



DO STSE #4 Next

Earth Systems 3209 Unit 4 - Lesson 7: Evidence For Plate Tectonics

The main evidence to support the idea of plate tectonics focuses on the different plate boundaries. The many different features seen at these boundaries provide overwhelming proof that the sea floor is indeed moving, in fact, it is being **recycled.**

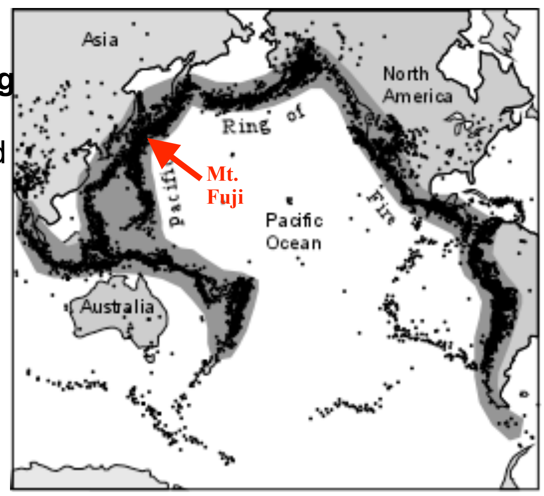
Evidence supporting Plate Tectonics Include:

1) Earthquakes and Volcanoes
2) Polar wandering
3) Magnetic Reversals and Seafloor Spreading
4) Ocean Drilling
5) Hot Spots

1) Earthquakes and Volcanoes

Earthquakes and volcanoes do not occur randomly throughout the world, but occur in rather limited belts. These belts mark the location of Plate Boundaries.

The largest active belt in the world surrounds the Pacific Ocean and is referred to as **"The Pacific Ring of Fire".** 90% of all the world's earthquakes occur there. Some of the more famous volcanoes are found surrounding the Pacific.



These boundaries are areas where compressional forces cause tectonic plates to move toward one another and stress builds up. When the stress is to great, fractures (faulting) may occur within the tectonic plates or the plates may slip abruptly and **earthquakes** result.

The boundaries are also places of high heat flow, where molten rock rises to the surface and forms **volcanoes**. Example: Mount Saint Helens in USA.

2) Paleomagnetism (Fossil Magnetism)

Defined as the permanent magnetism in rocks that indicate the direction of the magnetic field when the minerals became magnetized.

The most persuasive evidence to support the Plate Tectonic theory comes from the study of Earth's magnetic field. Polar wandering and magnetic reversals in the ocean floor provide this evidence.

Basaltic rocks contain iron-rich minerals that become magnetized in the direction of the magnetic field at the time when the rock solidified. If the rocks move or if the magnetic poles change the magnetism in the rocks retain its original magnetic alignment. Rocks that formed millions of years ago "remember" the location of the magnetic poles at that time.

3) Polar Wandering

This is the apparent movement of the magnetic poles as outlined from studying the magnetism fossilized in successive basaltic lava flows ranging in age over millions of years.

A plot of this magnetism showed that the magnetic pole appeared to change position considerably over the past 500 million years.

This was clear that either the magnetic pole had moved with time, an idea known as polar wandering, or the lava basaltic lava flows had moved, explained by continental drift.

Plate Tectonic theory is believed to be the best explanation for polar wandering. If the magnetic poles remain stationary, then their apparent movement of the poles was caused by the drifting of continents.

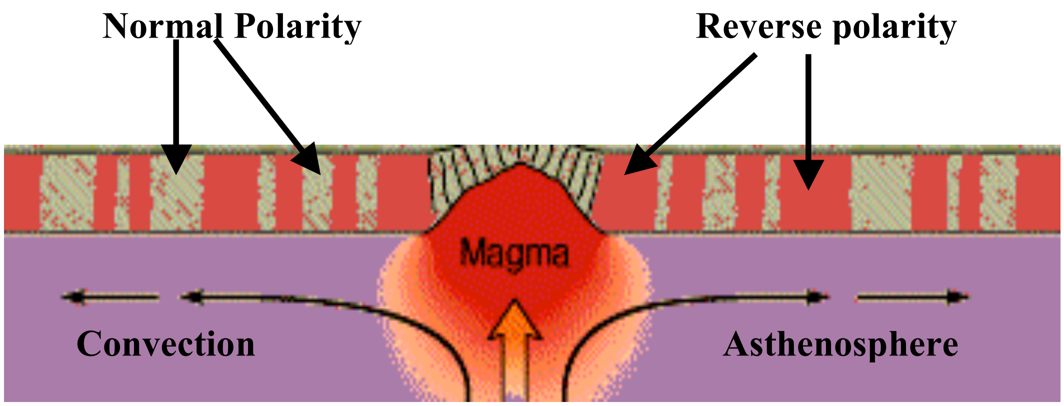
4) Magnetic Reversals and Seafloor Spreading

Paleomagnetism also provided evidence for the Plate Tectonic theory when scientist discovered that the magnetic field reverses polarity. Basaltic lavas solidifying during a time of reverse polarity would display opposite magnetism as rocks forming today.

Rocks with magnetism the same as our present magnetic field is said to have normal polarity, while rocks with opposite polarity is said to have reverse polarity.

This alternating magnetic polarity can be seen in; 1) successive lava flows making up a volcano and 2) the basaltic rock making up the ocean floor.

At oceanic ridges the plates move apart and new basaltic rock is added to each plate. The magnetism of these basaltic rocks appears to alternate to produce identical magnetic patterns on both sides of oceanic ridges. This proved to be the strongest evidence to support seafloor spreading and therefore Plate Tectonics.



5) Ocean Drilling

From 1968 to 1983, the Deep Sea Drilling Project collected convincing evidence confirming the seafloor spreading idea and the Plate Tectonic theory.

Drill core samples of the ocean floor and sediments on the ocean floor were collected with increasing distance from ocean ridges.

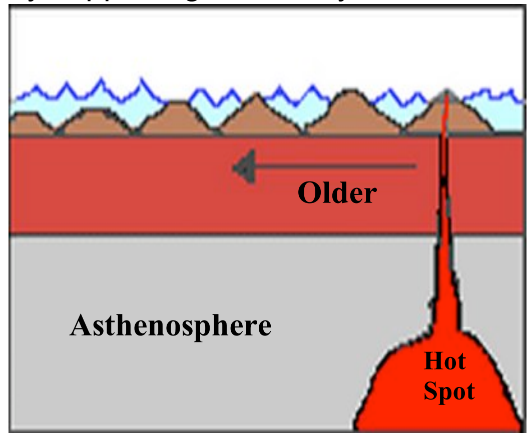
When the oldest sediment from each drill site was plotted against the distance from the ocean ridge, it was noted that the age of the sediment increased with increasing distance from the ridge.

This evidence also confirmed the idea that the ocean basins are relatively young, because no sediment older than 160 million years was found. Continents were dated to be 4.6 billion years.

6) Hot Spots

Mapping of the seafloor in the Pacific revealed a chain of volcanoes and seamounts that extend from the Hawaiian Islands to the Midway Islands and continue north to the Aleutian trench of the coast of Alaska.

Scientist proposed that a plume of magma presently exist beneath Hawaii and the Pacific plate moved over this stationary magma chamber. This confirmed that the tectonic plates do move in relation to earth's interior thereby supporting the theory of Plate Tectonics.



Radioactive age dates of the seamounts and volcanic islands confirm that the age increases the farther away you go from Hawaii, and the hot spot.

Questions

1. List and describe, with examples of each, the 5 pieces of evidence that support Plate Tectonic Theory.

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____

2. Explain how Paleomagnetism and Magnetic Reversals are similar when being used as evidence to support Plate Tectonic Theory.

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3. How can geologists account for the seemingly organized chain of chain of volcanoes and seamounts that extend from the Hawaiian Islands to the Midway Islands and continue north to the Aleutian trench of the coast of Alaska? *Using your textbook may help you with this question.*

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Earth Systems 3209 Name: ________________

Igneous Activity ***Chapter 4 - Nature of Volcanic Eruptions (Pg. 89-93)***

1. Compare volcanic eruptions of Mount St. Helens with Hawaii's Kilauea. P. 88-89

St. Helens:
Kilauea:

2. List three factors which determines if a volcano with erupt ***violently*** or ***gently***. P. 90

1.	2.	3.

3. Describe viscosity. P. 90

4. State whether the eruptions have High or Low viscosity Magmas.

Violent:	Gentle:

5. What percent silica is in the following magmas? P. 90

Mafic:	Intermediate:	Felsic:

6. Explain the relationship between silica content and the viscosity of a magma. P.90

7. What are gases in magma called? P. 90

8. Does dissolved gases increase or decrease the fluidity of magma? P. 90

9. What happens to the pressure of the gases in the magma the closer the magma gets to the surface? P. 90

10. Explain how the following magmas will erupt. P. 92

Fluid Mafic Magma:

Viscous Felsic Magma:

<u>Volcanoes</u> (Pg. 96-101)

11. Define volcano P. 96

Shield Cone Volcanoes

12. Briefly describe a **Shield Volcano** (size, shape, composition, explosiveness, etc.)? P.96-97

13. Where are shield volcanoes located (continents or oceans)? P. 97

14. Give two examples of shield volcanoes. P. 97

15. Which composition of magma feeds shield volcanoes? P. 97

16. Draw a diagram of a shield volcano. Label the diagram including relative size.

Cinder Cone Volcanoes

17. Briefly describe a **Cinder Volcano** (size, shape, composition, explosiveness, etc.)? P. 99 - 100

18. Which composition of magma feeds cinder cone volcanoes? P. 100

19. Is their much lava associated with cinder cone volcanoes? P. 100

20. Give two examples of cinder cone volcanoes. P. 100 - 101

21. Briefly describe the time frame by which cinder cones form? P. 100

22. Draw a diagram of a cinder cone volcano. Label the diagram including relative size.

Composite Cone Volcanoes

23. Briefly describe a **Composite Cone Volcano (Stratovolcano)** (size, shape, composition, explosiveness, etc.)? P. 101

24. Where are most of these volcanoes located? What is this zone called? P. 101

25. Where are the most active composite cone volcanoes found? P. 101

26. Which composition of magma feeds composite cone volcanoes? P. 101

27. Describe the lavas erupted from composite volcanoes? P. 101

28. Give two examples of cinder cone volcanoes. P. 101

29. Which eruption (gentle or explosive) is associated with composite cones? P. 101

30. Draw a diagram of a composite cone volcano. Label the diagram including relative size.