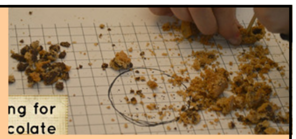
Chapter 19 - Earthquakes

Objectives

1. Define stress vs. strain as they apply to rocks.
2. Define faults.
3. Contrast types of seismic waves-3 types according to their type of movement, speed, location
4. Focus vs. epicenter
5. Explain how seismic waves give clues about Earth's interior.
6. Compare & contrast magnitude & intensity, and the scales to measure each
   A. Richter vs. Mercalli scale
7. Describe Earth's seismic belts
8. Locating an epicenter; Explain why data from at least 3 seismic stations is needed.
9. Mining of resources: Investigate the cost-benefit ratio, risks and impact on the environment.

Cookie Mining Intro Activity Discussion

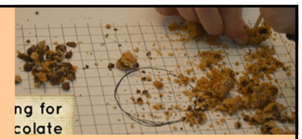


Natural resource = Material found in nature that is useful or necessary to humans

1.Cost-benefit ratio is a calculation used to determine if the resource can be mined at a profit. Costs of your Cookie Mining activity included:

A. Purchase of property on which to mine, (cookie),
B. Purchase of mining equipment (toothpick & paperclips)
C. Cost of removal of resource (time it took to get choc chip out of cookie)
D. Cost of reclamation – putting the land back into the condition it was found in.

Cookie Mining Intro Activity Discussion



2. Was yours mined at a profit, yes or no? Explain in the space below.

3. Was your reclamation successful? Explain including the following:
   - Were all your "scraps" able to fit in the original space?
   - Did the "property" look the same as it did originally?

4. Describe difficulties you think might occur with reclamation in real mining.

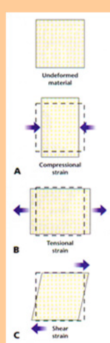
We will discuss again at the end of the unit with a different type of mining.

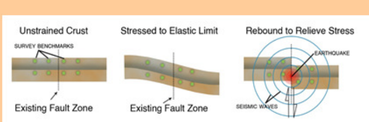
Sec 19.1 Forces within Earth

Sec 19.1 Forces within Earth

Stress: A force that acts on rock to change its shape or volume

Strain: Deformation (change) of material in response to stress

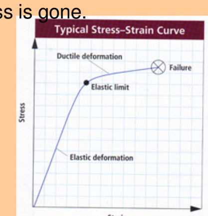




Strain & TT#44 Stress-Strain Curve

Types of Strain:

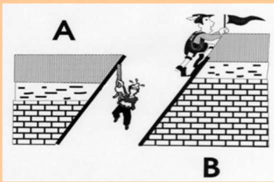
1. **Elastic strain:** Temporary deformation (bending, compression or stretching). Goes back to original shape when the stress is gone
   A. **Elastic limit:** Amount of stress a rock can withstand and still return to its original shape
2. **Ductile deformation:** Permanent deformation. Doesn't return to original shape after stress is gone.
3. **Failure** Material (rocks) break.



3 Types of Faults:

Faults: Fractures in Earth's crust along which movement occurs when stress causes failure.

- 3 subtypes: Depending on the plate boundary type.



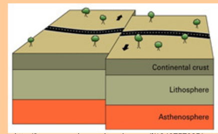
http://www.jsu.edu/dept/geography/mhill/phylabtwo/lab4/hngft.jpg

Transform Boundaries

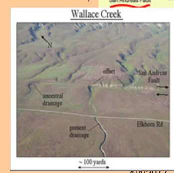
Transform Boundaries: 2 plates slide horizontally past each other

1. Crust is NEITHER consumed or created, only deformed and fractured
2. Causes earthquakes
   A. NO volcanoes
   B. No link to convection
3. Example locations: San Andreas Fault in California

http://geology.com/articles/san-andreas-fault.shtml



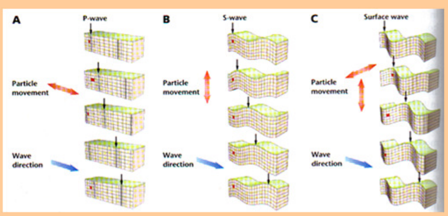
http://hoopmanscience.pbworks.com/f/1348757835/transform_20boundary.jpg



Earthquake Waves

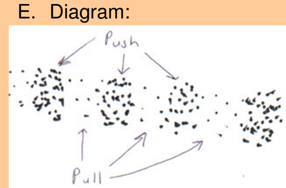
Earthquake Waves:

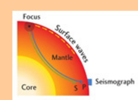
- Caused when failure is reached and rocks fail or break. Due to pressure build-up when rocks snag & lock.
- 3 Wave Types Exist in EVERY Earthquake



Primary Waves

1. **Primary Waves**: Rock particles move back & forth in the same direction that the wave travels
   A. AKA P-wave: "Push-Pull" wave
   B. Location: Underground (Body wave-starts at focus)
   C. Can travel through rock & liquid , but slowed & bent in liquid
   D. Fastest wave. Arrives at seismograph station 1st
   E. Diagram:

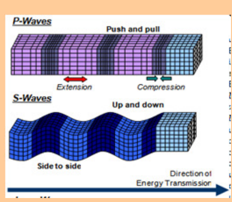




http://bc.outcrop.org/images/earthquakes/press4e/figure-19-05-1.jpg

Secondary Waves

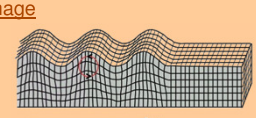
2. **Secondary Waves**: Rock particles move at right angles to the direction the wave travels
   A. AKA S-wave: "Side to Side" wave
   B. Location: Underground (Body wave-starts at focus)
   C. Can ONLY travel through SOLIDS. Therefore some seismograph stations don't receive S waves.
   D. Medium speed wave.
   E. Diagram:



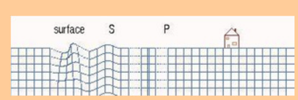
http://theconstructor.org/wp-content/uploads/2010/09/image77.png

Surface Waves

3. **Surface Waves**: Rock particles move in several directions at once: backward, rolling motion & side to side swaying motion
   A. No nickname
   B. Location: Surface (Starts at epicenter, NOT focus)
   C. Causes most of the damage
   D. Slowest wave.
   E. Diagram:

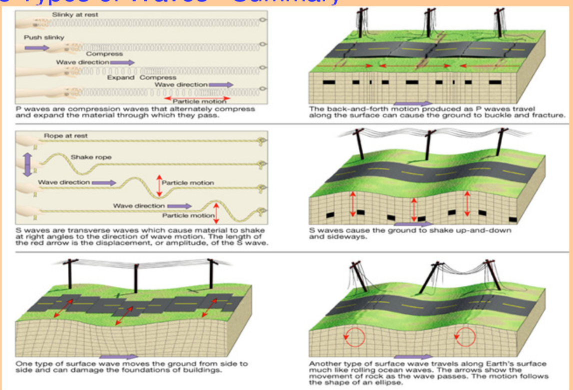


http://www.sjvgeology.org/oil/Rayleigh_surface_waves2.gif



http://www-rohan.sdsu.edu/~rmellors/lab8/l8awav2.jpg

3 Types of Waves - Summary



https://allanawheeler.files.wordpress.com/2011/05/semic-waves.png

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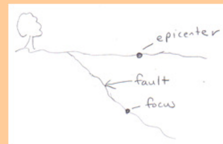
Focus & Epicenter

Focus: Point where earthquake originates (rocks break) & S & P seismic waves begin

Epicenter: Point on earth's surface directly above the focus



https://earthquakesandplates.files.wordpress.com/2008/05/eqfocus.gif?w=300

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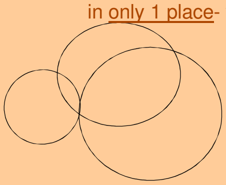
Locating an Earthquake

1. **Epicentral distance** = The distance between the seismic station and the epicenter
2. Must have a minimum of 3 seismic station readings to determine the epicenter location. Why?
   - A. If there is only 1 station, the epicenter could be anywhere on the circle (distance is the radius of circle)
   - B. If there are 2 stations, the epicenter could be in 1 of 2 places
   - C. If there are 3 stations, the epicenter could be in only 1 place- where all 3 circles meet



http://www.aeic.alaska.edu/input/west/guides/amato_faulting/eq_loc2.jpg

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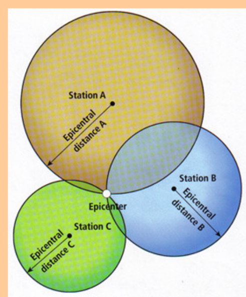
TT #57 (Fig 19-14) Locating Earthquakes



http://i.ytimg.com/vi/694yaY2ylTg/hqdefault.jpg

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Seismic Belts

3. Most earthquakes occur in **seismic belts** along tectonic plate boundaries

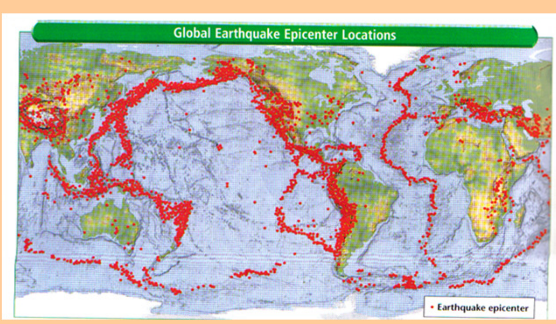

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Fig 19-9 Wave Travel Time Curves

What is the distance between the seismic station & the epicenter if the difference in arrival time for P-waves & S-waves is 6 minutes?

Answer: 4500km

Time of an earthquake can also be calculated by subtracting the minutes of travel from the known arrival time of the wave using this graph.

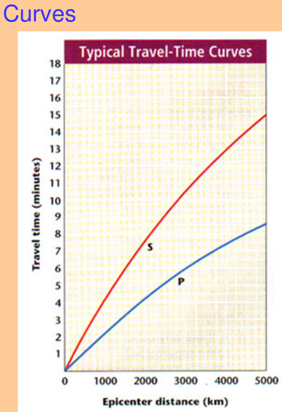

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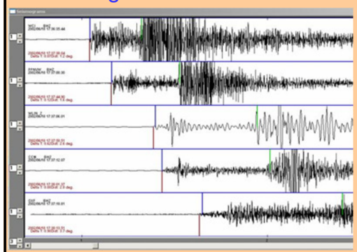
Fig 19-9 Wave Travel Time Curves & Seismograms for Distance Comparison



http://web.ics.purdue.edu/~braile/edumod/eqlocate/tutorial_files/image041.jpg

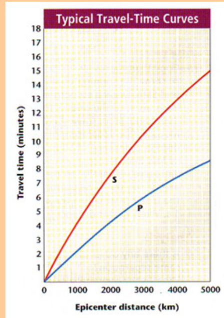


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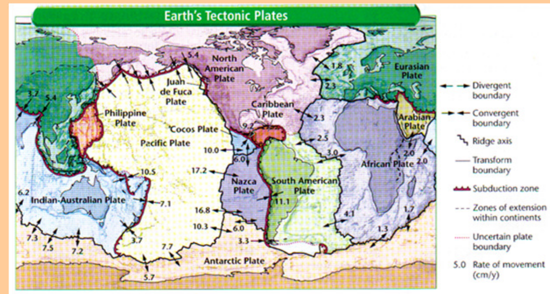
Fig 17-13 Tectonic Plate Boundaries



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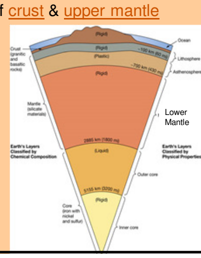
Earth's Interior

1. **Inner Core**: Solid, dense. Made mainly of iron.
2. **Outer Core:** Liquid, mainly iron.
3. **Mantle:** Largest layer of earth. 3 parts of mantle based on phase:
   - Lower (Inner) Mantle: Very viscous & solid-like
   - Asthenosphere: Plastic-like layer the tectonic plates float on
   - Upper (Outer) of the Mantle: Made of solid rock
4. **Crust:** Outermost layer. Continental crust is thicker than oceanic crust.
5. **Lithosphere plates:** Rigid combination of crust & upper mantle

http://scienceblogs.com/startswithabang/files/2011/09/Earth layers.gif



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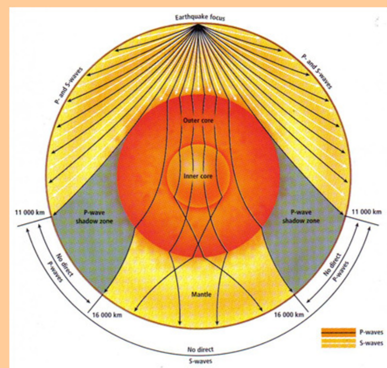
TT #56 (Fig 19-10) Refraction of P-Waves



Link to Model of Earth & Waves Simulation

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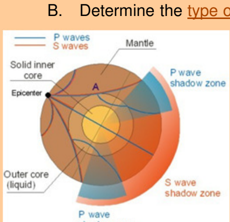
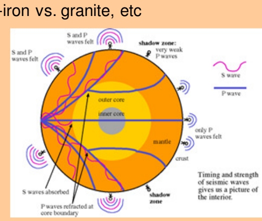
Clues To Earth's Interior

When waves hit Earth's core:

1. **Shadow Zones:** Areas of Earth that do not detect seismic waves because
   - **A. P-Waves** are refracted (bent) & slowed by the liquid outer core
   - **B. S-Waves** do NOT enter the liquid core. They disappear and are lost.
2. Wave speeds can be used to map Earth's internal structure and determine:
   - A. Whether it is liquid or solid
   - B. Determine the type of material-iron vs. granite, etc





http://www.astronomynotes.com/solarsys/seismicb.gif

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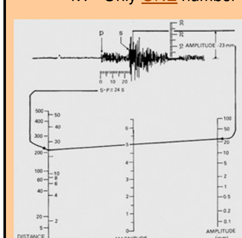
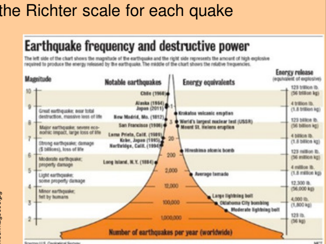
Section 19.3 Measuring & Locating Earthquakes

1. **Seismologist**: Scientist who studies earthquakes
2. **Magnitude:** Amount of energy released during an earthquake. Based on:
   - **A. Richter scale:** Measures strength (magnitude) of an earthquake
     - i. Based on size of the largest seismic waves on a seismogram
     - ii. No upper limit
     - iii. Most earthquakes are too small to be felt by humans (<3.0)
     - iv. Only ONE number on the Richter scale for each quake



http://www.earth2class.org/er/teachers/lessonplans/Docs/...



http://cdn.kizaz.com/wp-content/uploads/2013/12/Theyre-Not-Measured-On-The-Richter-Scale.jpg

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Richter Scale vs. Energy of TNT & Bombs

Magnitude	TNT equivalent	Example
0.00	15 g	100 firecrackers
0.20	30 g	hand grenade
0.50	85 g	
1.00	480 g	
1.20	1.1 kg	stick of dynamite
1.50	2.2 kg	
2.00	15 kg	
3.00	480 kg	1-ton bomb
3.87	9.5 metric tons	Explosion at Chernobyl in 1986
4.00	15 metric tons	
5.00	480 metric tons	
6.00	15 kilotons	Little Boy Atomic bomb dropped on Hiroshima
7.00	480 kilotons	
7.50	2.7 megatons	Equivalent to all bombs used in WW2
8.00	15 megatons	
8.35	50 megatons	Tsar Bomb Largest thermonuclear weapon ever tested
9.00	480 Megatons	
9.50	2.7 gigatons	Largest earthquake ever recorded - Chile, 1960
10.00	15 gigatons	Thought to be impossible
12.55	100 teratons	Approximate energy of the Yucatan Peninsula Impact killing the dinosuars 65 million years ago. 31,554 times more powerful than a 9.5 earthquake.

http://snowbrains.com/wp-content/uploads/2013/04/Richter-Scale-Chart.jpg

Magnitude	Description	Earthquake effects	Frequency of occurrence
Less than 2.0	Micro	Micro earthquakes, not felt.[16]	Continual
2.0–2.9	Minor	Generally not felt, but recorded.	1,300,000 per year (est.)
3.0–3.9		Often felt, but rarely causes damage.	130,000 per year (est.)
4.0–4.9	Light	Noticeable shaking of indoor items, rattling noises. Significant damage unlikely.	13,000 per year (est.)
5.0–5.9	Moderate	Can cause major damage to poorly constructed buildings over small regions. At most slight damage to well-designed buildings.	1,319 per year
6.0–6.9	Strong	Can be destructive in areas up to about 160 kilometres (99 mi) across in populated areas.	134 per year
7.0–7.9	Major	Can cause serious damage over larger areas.	15 per year
8.0–8.9	Great	Can cause serious damage in areas several hundred kilometres across.	1 per year
9.0–9.9		Devastating in areas several thousand kilometres across.	1 per 10 years (est.)
10.0+	Massive	Never recorded, widespread devastation across very large areas; see below for equivalent seismic energy yield.	Extremely rare (Unknown/May not be possible)

http://wordlesstech.com/wp-content/uploads/2012/05/What-does-earthquake-magnitude-mean-1.jpg

RICHTER SCALE of earthquake energy:

Each level is **10 times stronger** than the previous level

	Description	Occurrence	In Population	Movement
1	SMALL	DAILY	every minute	small
2	SMALL	DAILY	every hour	small
3	SMALL	DAILY	every day	small
4	SMALL	DAILY	every week	moderate sudden
5	MODERATE	MONTHLY	every 10 years	strong sudden
6	MODERATE	MONTHLY	every 30 years	strong sudden
7	MAJOR	MONTHLY	every 50 years.	severe sudden
8	GREAT	YEARLY	every 100 years	very severe
9	GREAT	YEARLY	every 300 years	very severe
10	SUPER	RARELY	every 1000 years	extreme

https://ginoraidy.files.wordpress.com/2010/02/earthquake_richter_scale.jpeg

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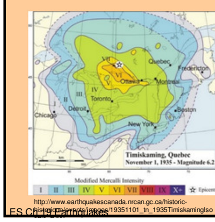
Intensity & Modified Mercalli Scale

3. Intensity: Amount of structural & geologic damage

A. Modified Mercalli Scale: Measures intensity in a specific location

i. Roman numerals I to XII
ii. I (low) is not felt vs. XII is total destruction
iii. Damage is caused by surface waves
iv. Multiple numbers for each quake, as different locations have different amounts of damage
v. Dependent on: magnitude, depth of quake, type of rock or surface material, structure design & distance from epicenter



http://www.earthquakescanada.nrcan.gc.ca/historic-...19351101_tn_1935Timiskamingiso

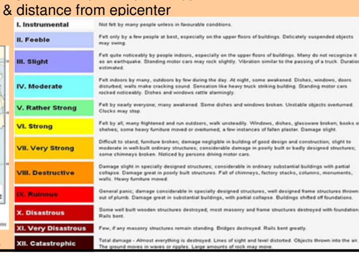


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Table 19-1 Mercalli Scale & Fig 19-13 Photo-Estimate Damage

Table 19-1 Modified Mercalli Intensity Scale

I.	Not felt except under unusual conditions.
II.	Felt only by a few persons. Suspended objects may swing.
III.	Quite noticeable indoors. Vibrations are like the passing of a truck.
IV.	Felt indoors by many, outdoors by few. Dishes and windows rattle. Standing cars rock noticeably.
V.	Felt by nearly everyone. Some dishes and windows break, and some plaster cracks.
VI.	Felt by all. Furniture moves. Some plaster falls and some chimneys are damaged.
VII.	Everybody runs outdoors. Some chimneys break. Damage is slight in well-built structures but considerable in weak structures.
VIII.	Chimneys, smokestacks, and walls fall. Heavy furniture is overturned. Partial collapse of ordinary buildings occurs.
IX.	Great general damage occurs. Buildings shift off foundations. Ground cracks. Underground pipes break.
X.	Most ordinary structures are destroyed. Rails are bent. Landslides are common.
XI.	Few structures remain standing. Bridges are destroyed. Railroad ties are greatly bent. Broad fissures form in the ground.
XII.	Damage is total. Objects are thrown upward into the air.

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Section 19.4 Earthquakes & Society - Tsunamis

Tsunami: Large ocean wave created by the vertical motion of ocean floor during a quake

1. At sea the wave is less than 1 meter high
2. As the wave enters shallow water, the wave height may increase to over 30m (100ft)
3. Speeds of 500-800km/hr
4. Spreads in all directions across the entire ocean

Video Link – CNN Japan Quake – The Force Behind Tsunamis
https://www.youtube.com/watch?v=qRqTTrlWldU

http://traversg.weebly.com/uploads/2/9/9/9/29999427/5361633_orig.jpg

http://www.go-green.ae/uploads/tsunami.jpg

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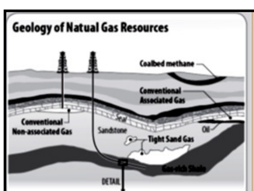
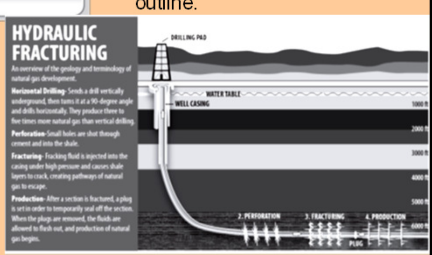
Earthquakes & Society - Fracking



Fracking: Answer the **Questions for Reading of the "Fracking Background Essay"** on the last page of your note outline.



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Earthquakes & Society – Fracking Discussion

Animation – How Fracking is Done: http://www.nytimes.com/interactive/2011/02/27/us/fracking.html?_r=1&

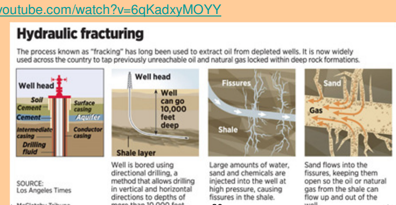
Video (3min) "What is Fracking?" https://www.youtube.com/watch?v=lo8o2nTXhb0

Video (6min) "Fracking – Health Concerns" https://iptv.pbslearningmedia.org/resource/envh10.sci.phys.energy.fracking/fracking/#.WN2O3Ms2yuU

Video (3 min) "Communities Divided over Natural Gas Drilling" https://www.youtube.com/watch?v=oMboTKOWeAs&feature=youtu.be

Video (2.5 min) "Does Fracking Cause Earthquakes?" https://www.washingtonpost.com/video/national/does-fracking-cause-earthquakes/2016/11/07/3a76252c-a51b-11e6-ba46-53db57f0e351_video.html

Extra Video (2 min) "What is Fracking?" by Nat'l Geo, includes wastewater https://www.youtube.com/watch?v=6qKadxyMOYY



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Bellwork #1

1. Compare and contrast focus and epicenter.
2. Compare stress and strain.
3. Compare surface vs. interior rocks in their response to stress;
   A. How does brittleness vs. ductility compare?
   B. How does their ability to withstand stress prior to failure compare?

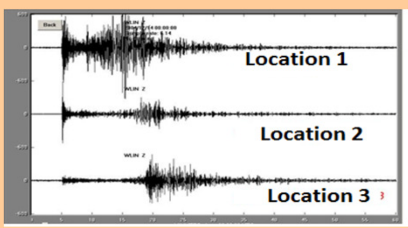
Bellwork #2

4. Are the following parts of the Richter or Mercalli scale?
   A. 8
   B. VIII
   C. Based on seismogram wave height?
   D. More than 1 number is possible for a given earthquake
5. How is it possible to have:
   A. A low Mercalli number with a high Richter number?
   B. A high Mercalli number with a low Richter number?

Bellwork #3

6. Label the P and S-waves at all 3 locations below.

7. Use the difference in arrival times of P and S waves to determine which reading was taken farthest from the earthquake's epicenter. Explain how you know.



Lab: Locating an Epicenter (Graph-Figure 1)