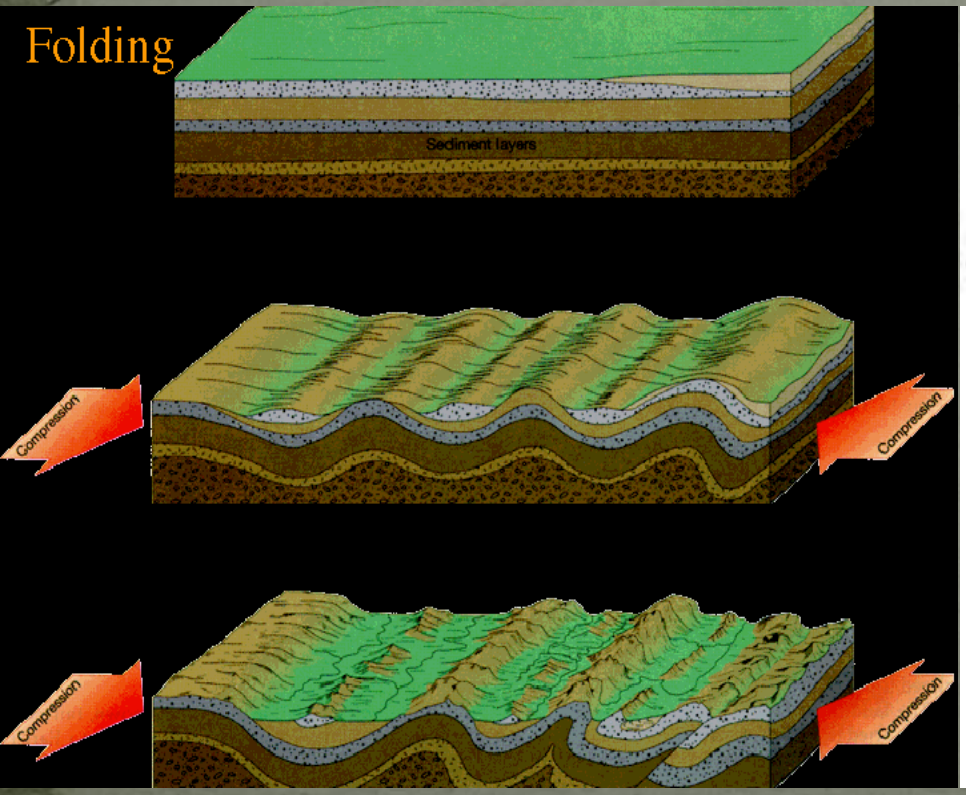
Faults & Earthquakes & Volcanoes

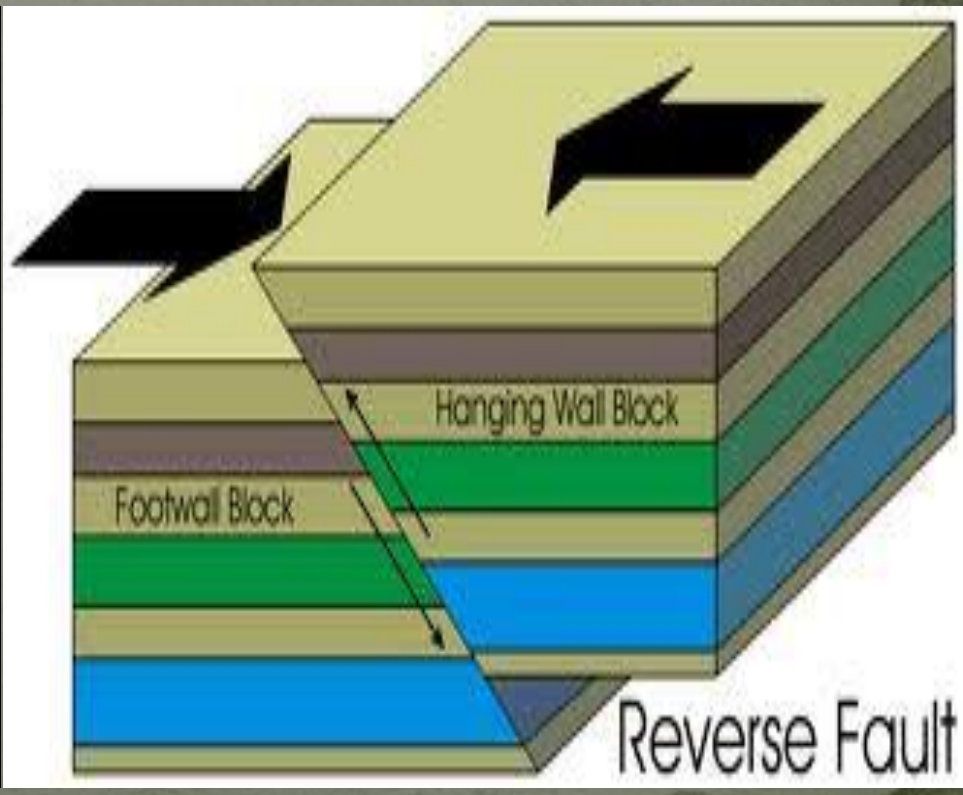
OH MY!

- What does the movement of plates create in the lithosphere?
- Moving plates create pressure and stress on the lithosphere.
- Types of Stress:
- Types of stress:
- Compression
- Compression: Stress pushing inwards (press in)
- Tension
- Tension: Stress pulling apart (wires, fights = tension)
- Shearing
- Shearing: Stress in opposite directions.
  (scissors are shears)

Stress on Rock

- What does stress do to rock?
- Stress can deform and break rocks apart.

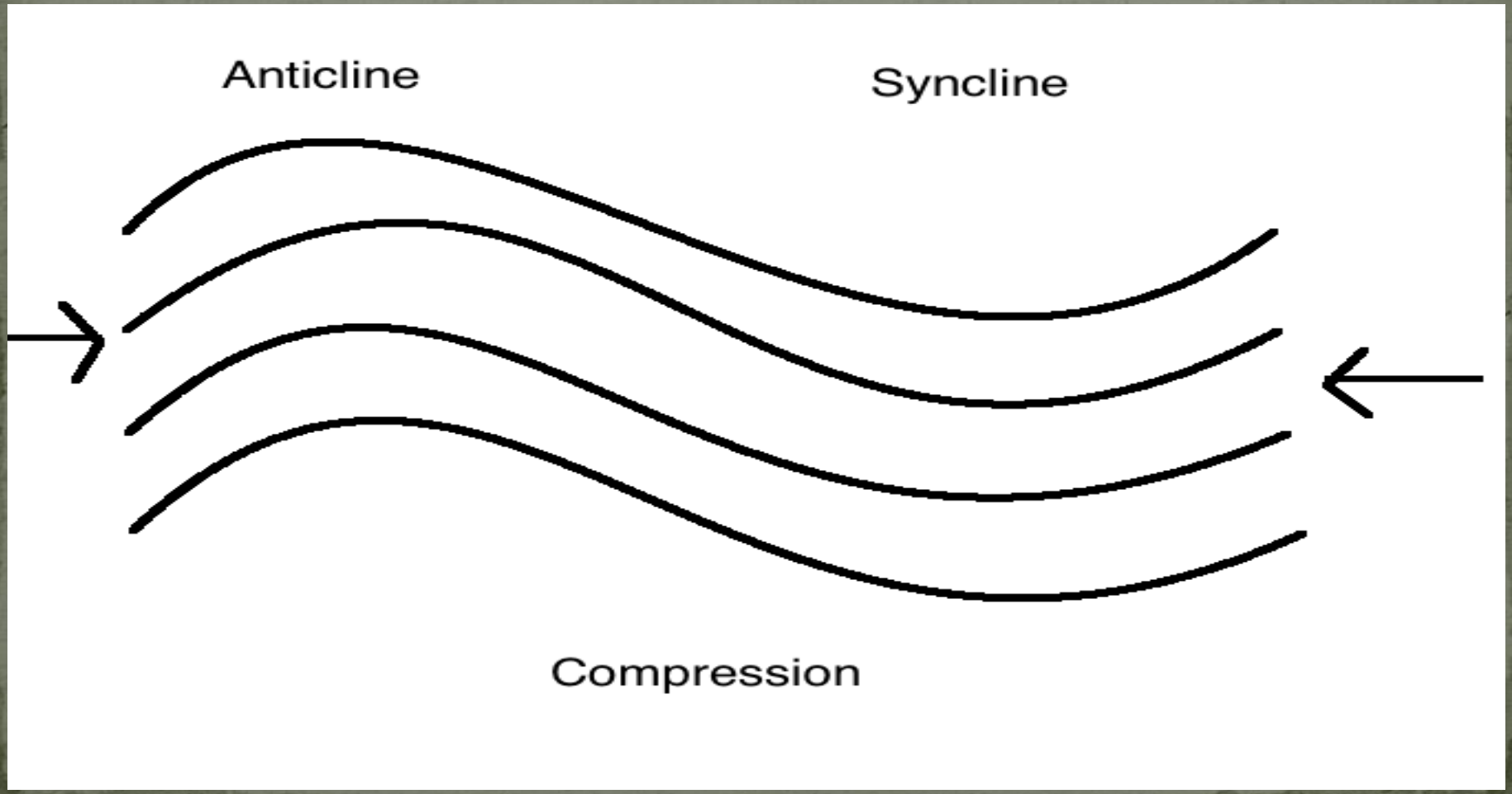




Stress

- What can stress do to rock?
- Stress can bend rock:
- Folding
- Or break rocks:
- Faulting
- What decides if a rock Folds or Faults?
- Pressure, temperature and material decide if a rock folds or faults.
- Upper level rock typically Faults.
- Low pressure and temperature (cold crayon)
- Rock deep below the surface typically Fold.
- High pressure and temperature (heated crayon)

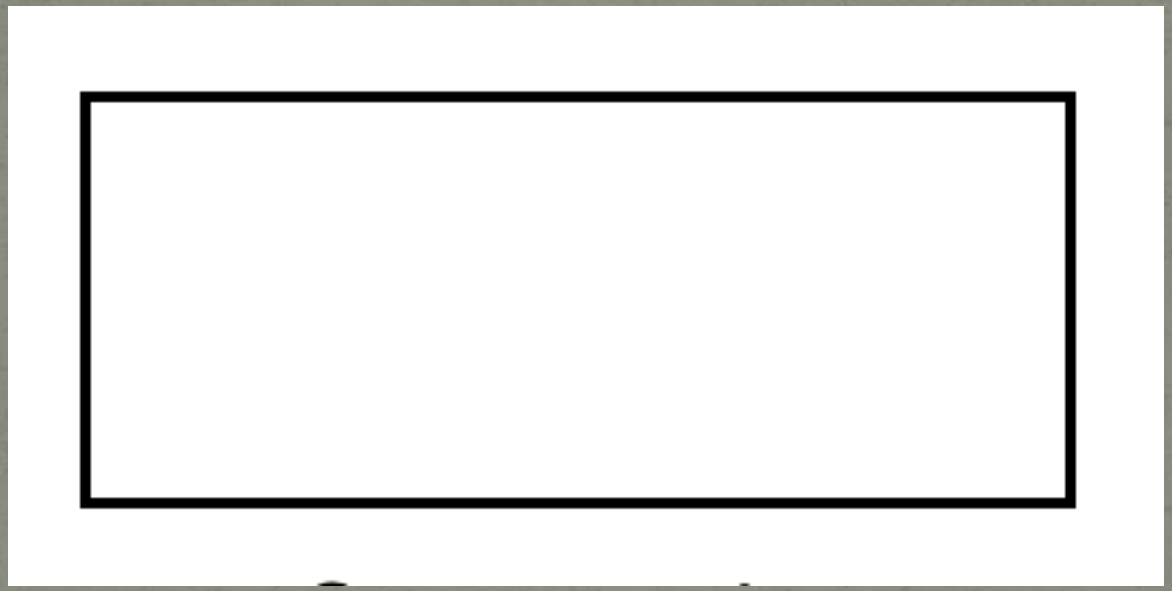
- Types of Folds

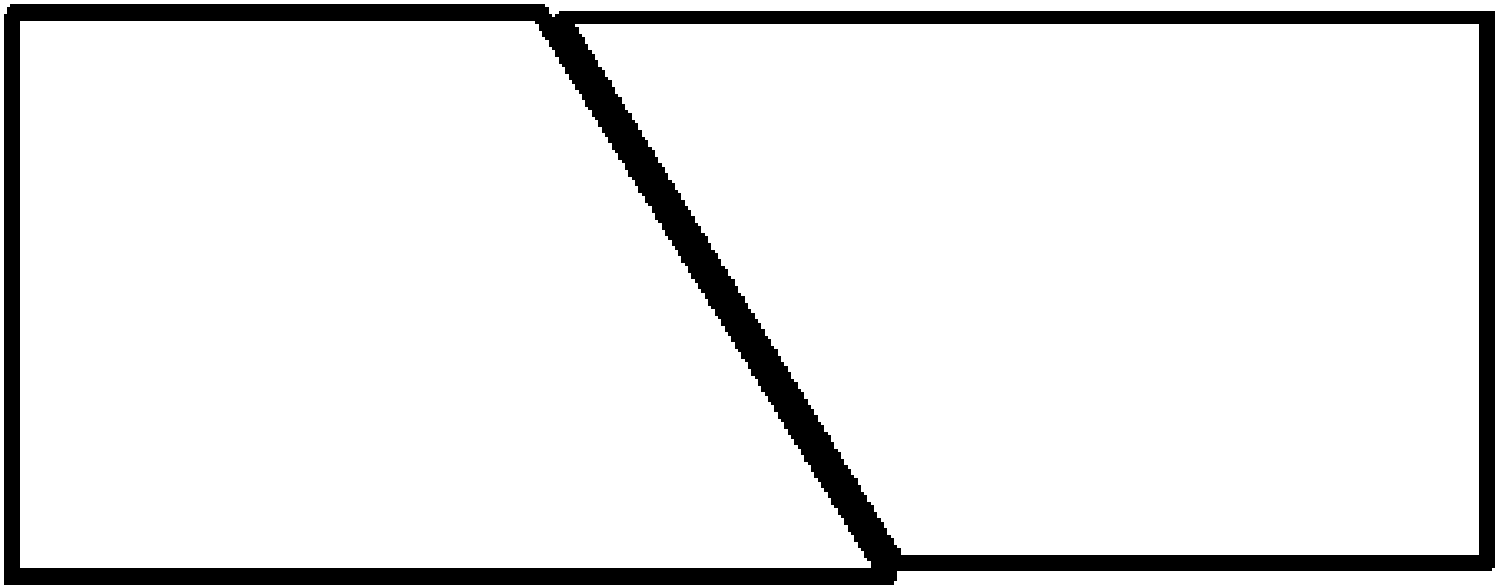


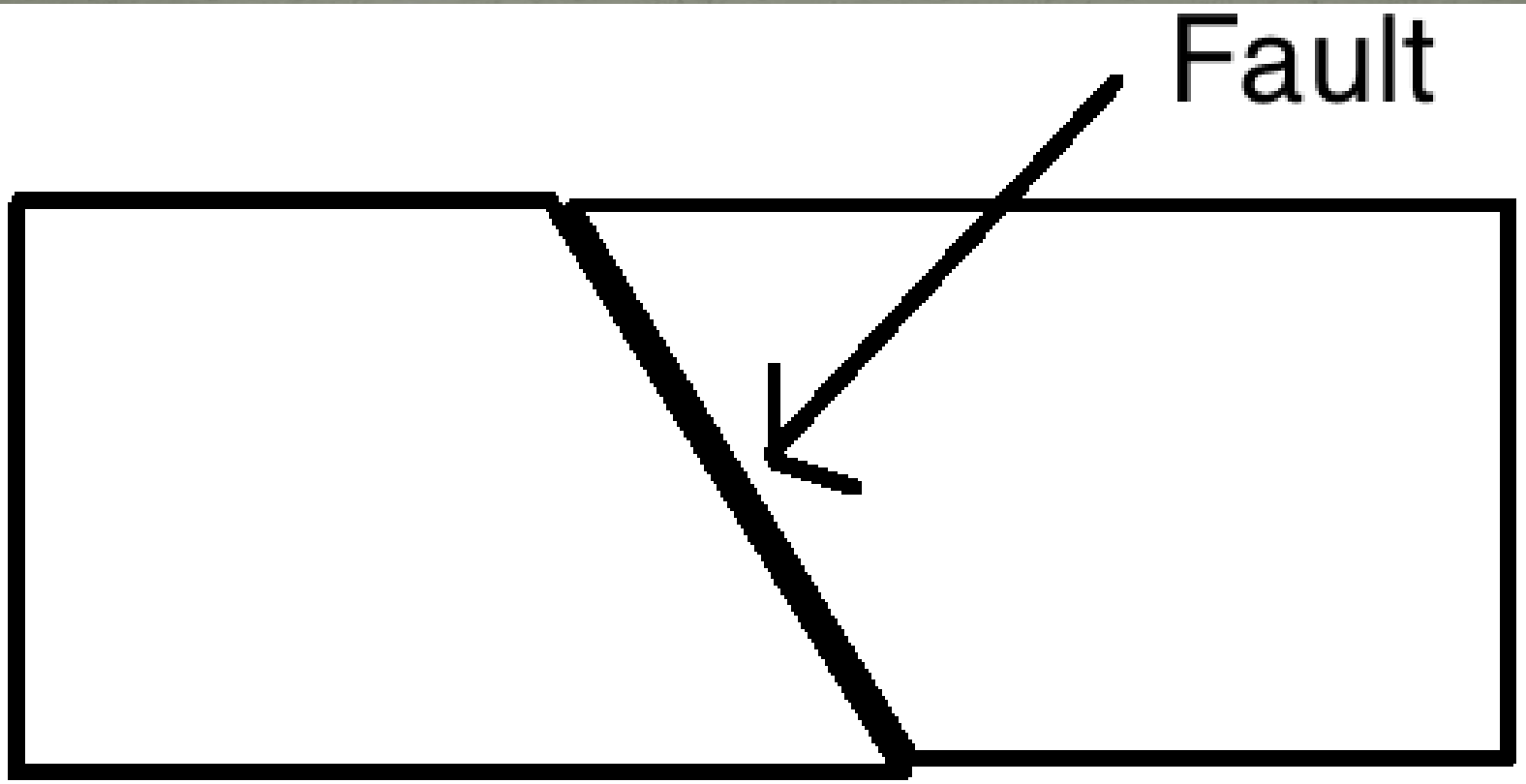
- Syncline: downward fold (sinking, sinister smile ☺)
- Anticline: Upward fold (arch, anti-smile = frown ☹ anthill)

Folded Mountain, Alaska Highway.

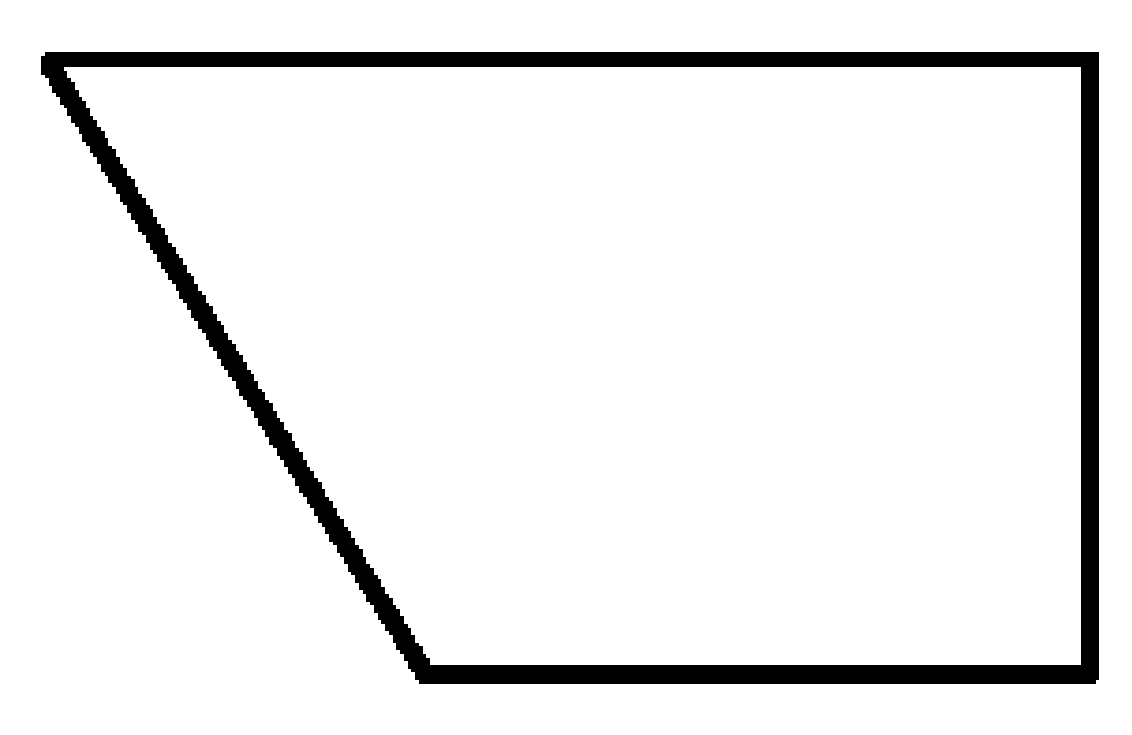
Fault – A break in a rock with movement





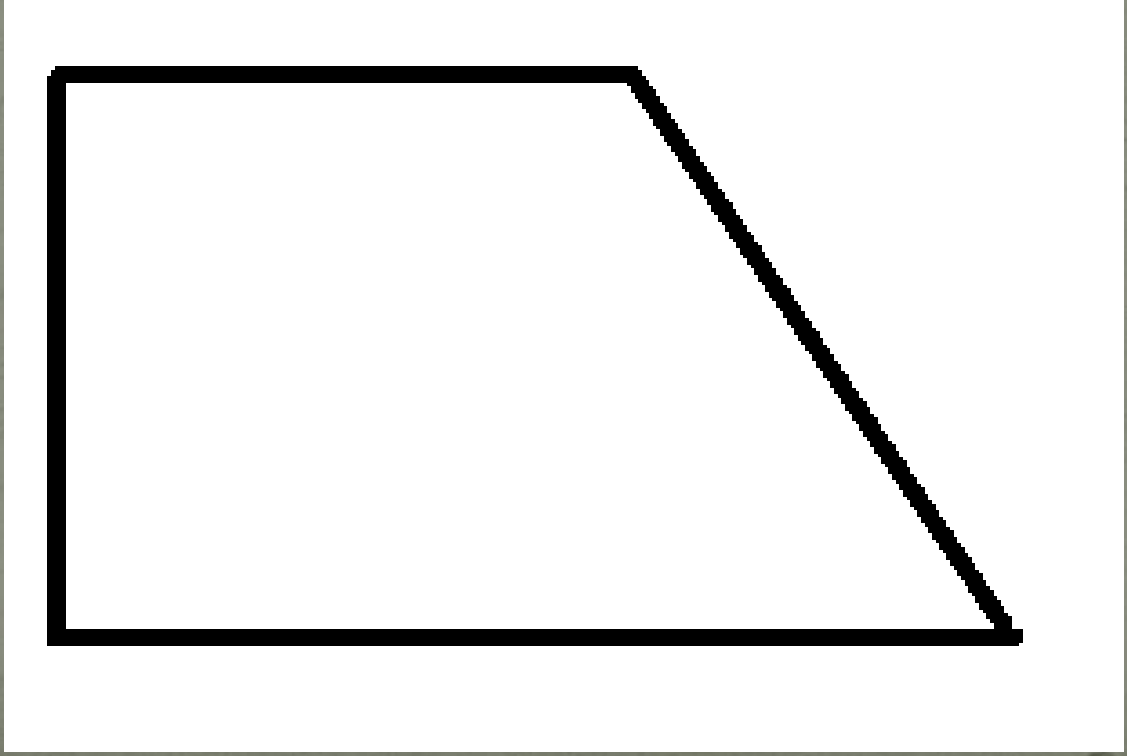

Fault

- What is a hanging wall?
- Hanging wall: Block above the fault.
- (You can hang things from it)

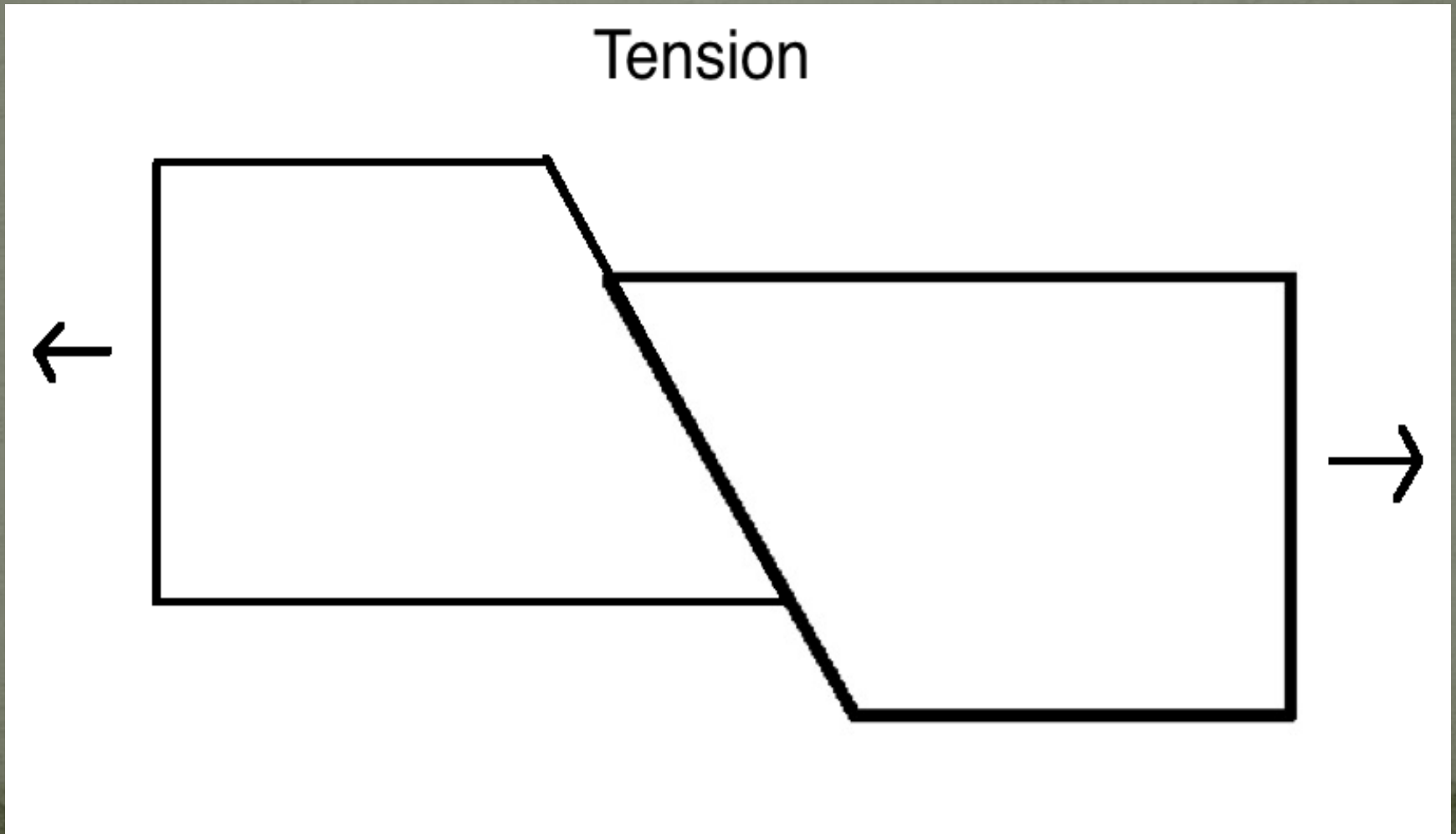


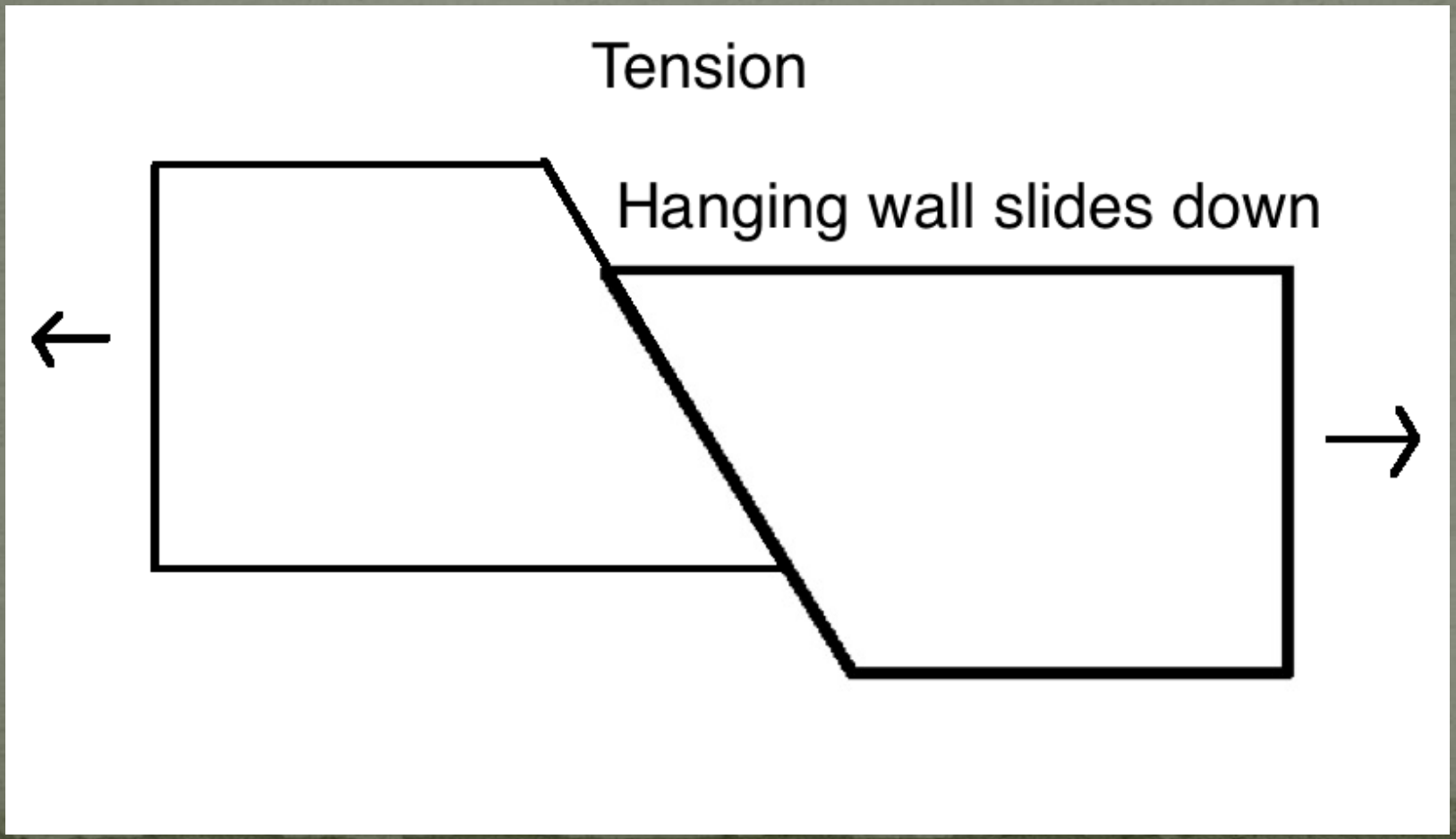

COME & BROWSE UNDERGROUND
COACH PARKING AREA ONLY
OPEN

- Footwall:
- Footwall: Block below the fault.
- (Walk up with your foot)



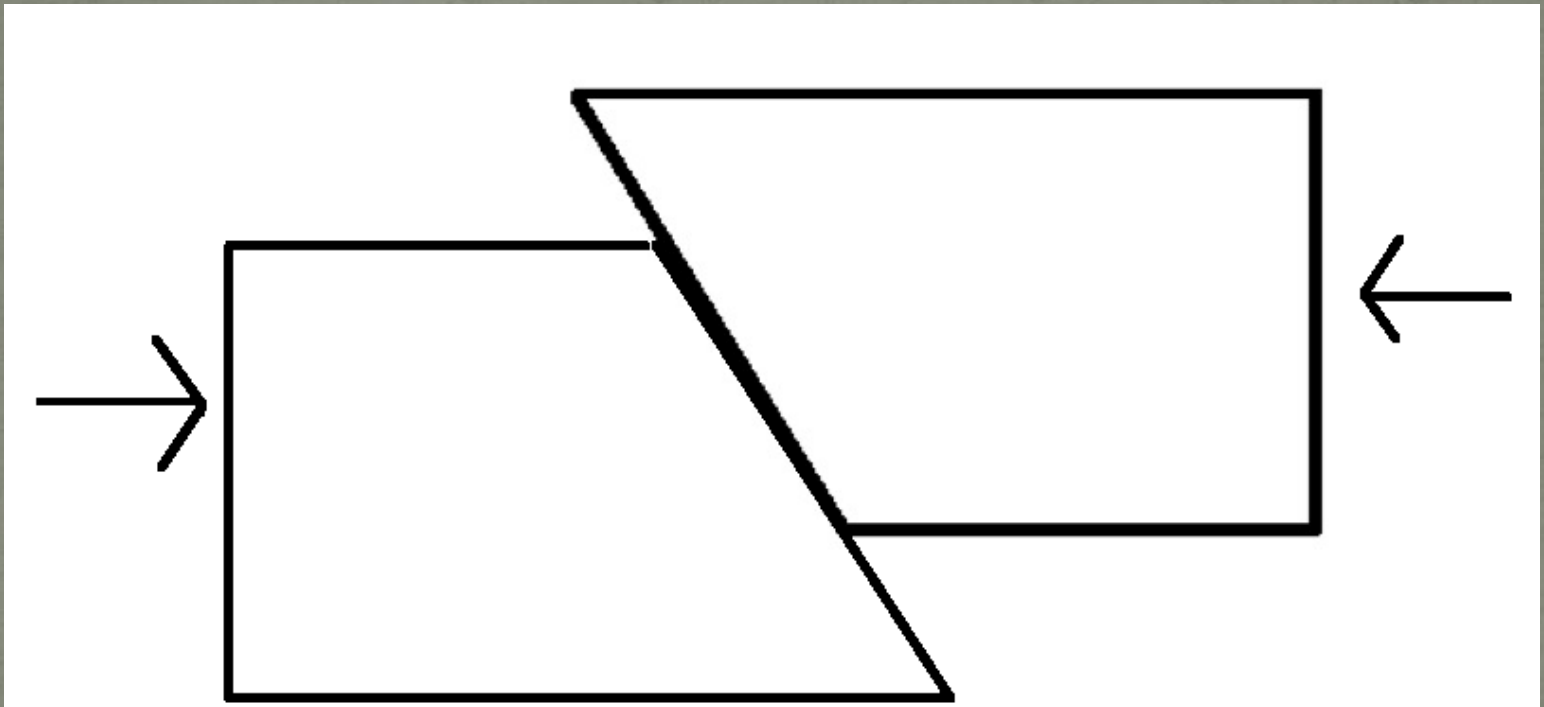
- Vertical faults: Blocks move vertically in relationship to each other
- 1) Normal Fault (vertical fault): makes a ramp - Walk up normally

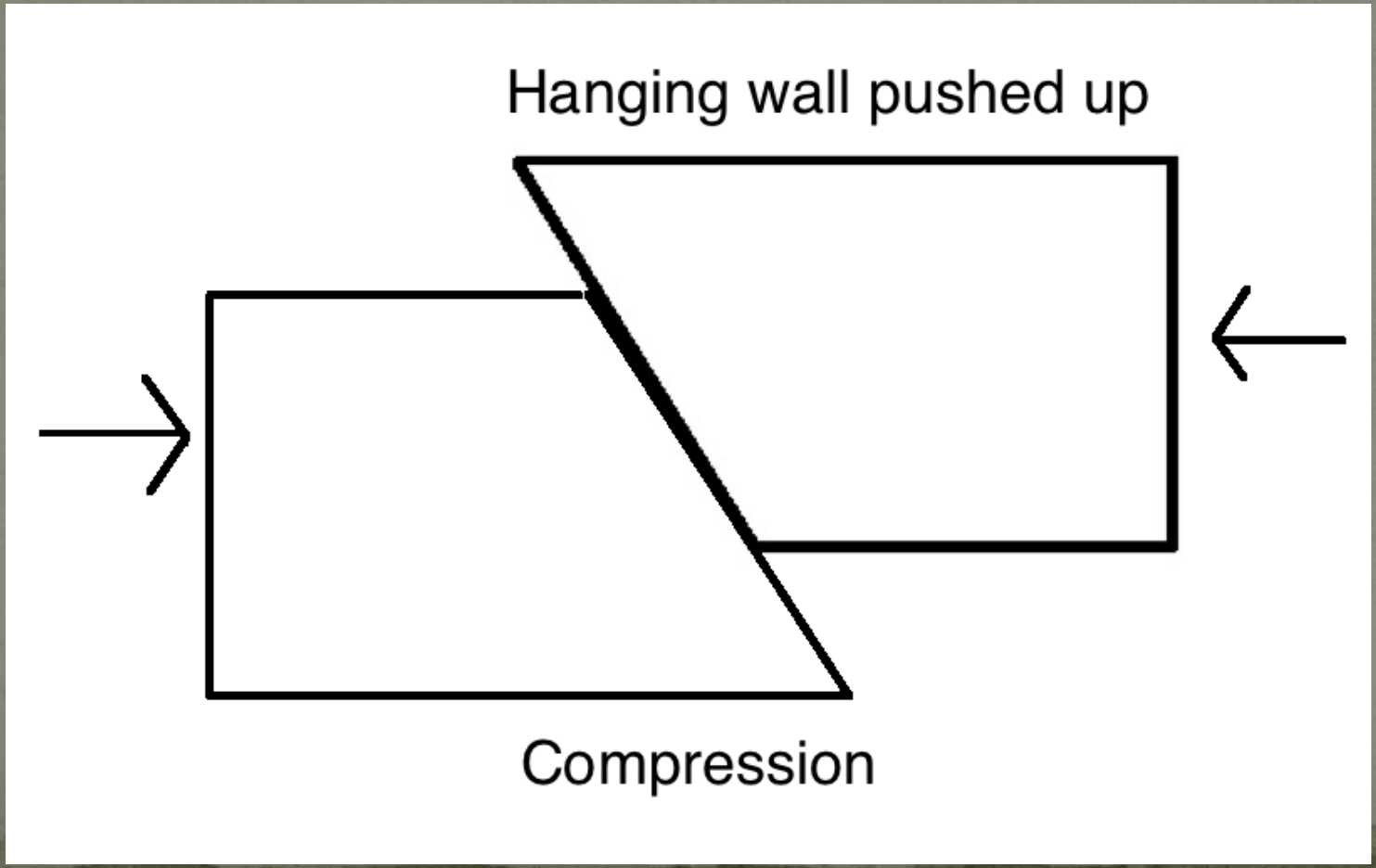



Tension
Hanging wall slides down

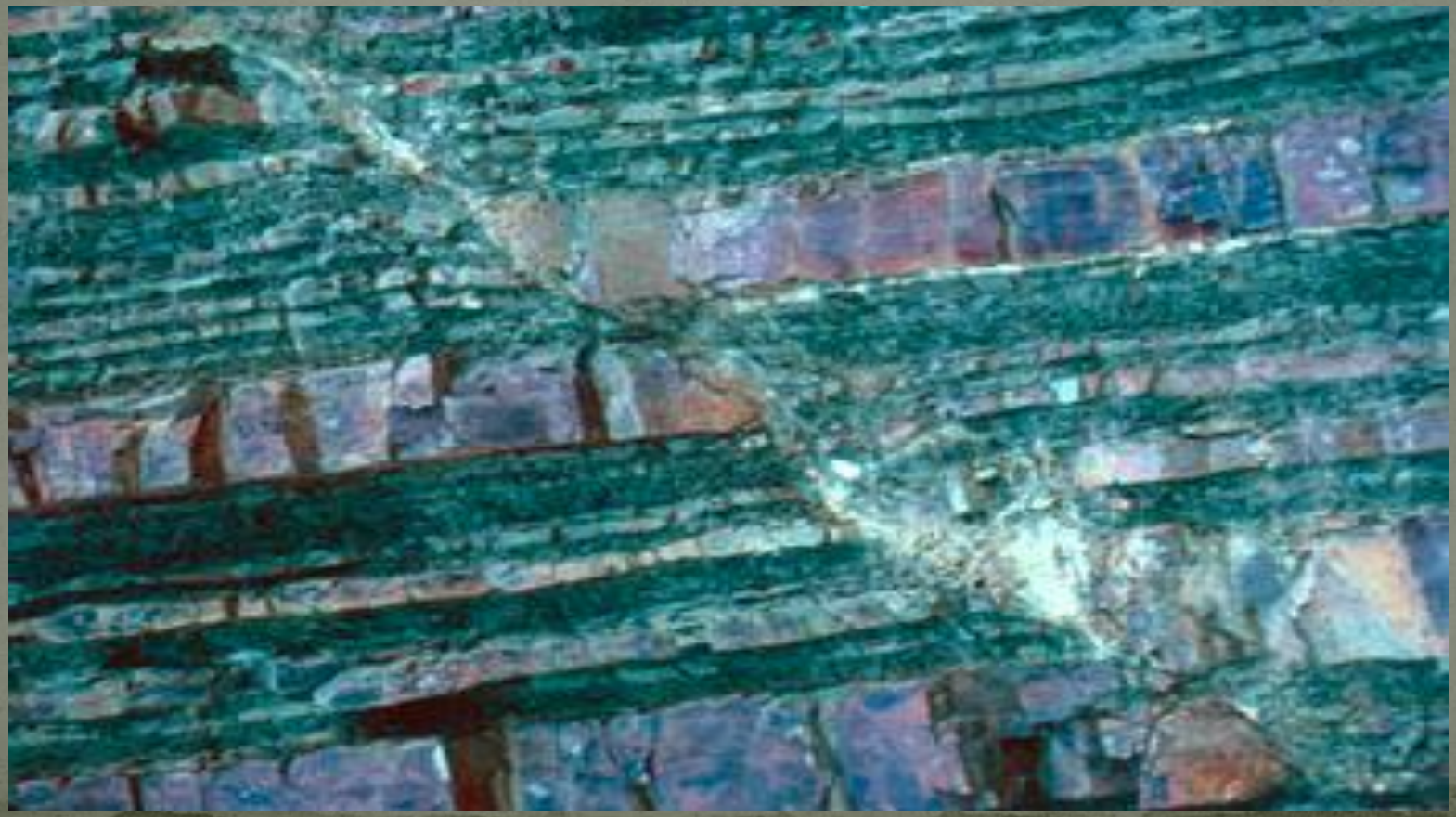
- Normal Fault: Tension pulls crust apart, Hanging wall slides down relative to the foot wall. Length of the crust grows.

- 2) Reverse Fault (vertical): over hangs
- (Have to go in reverse when you get to one)

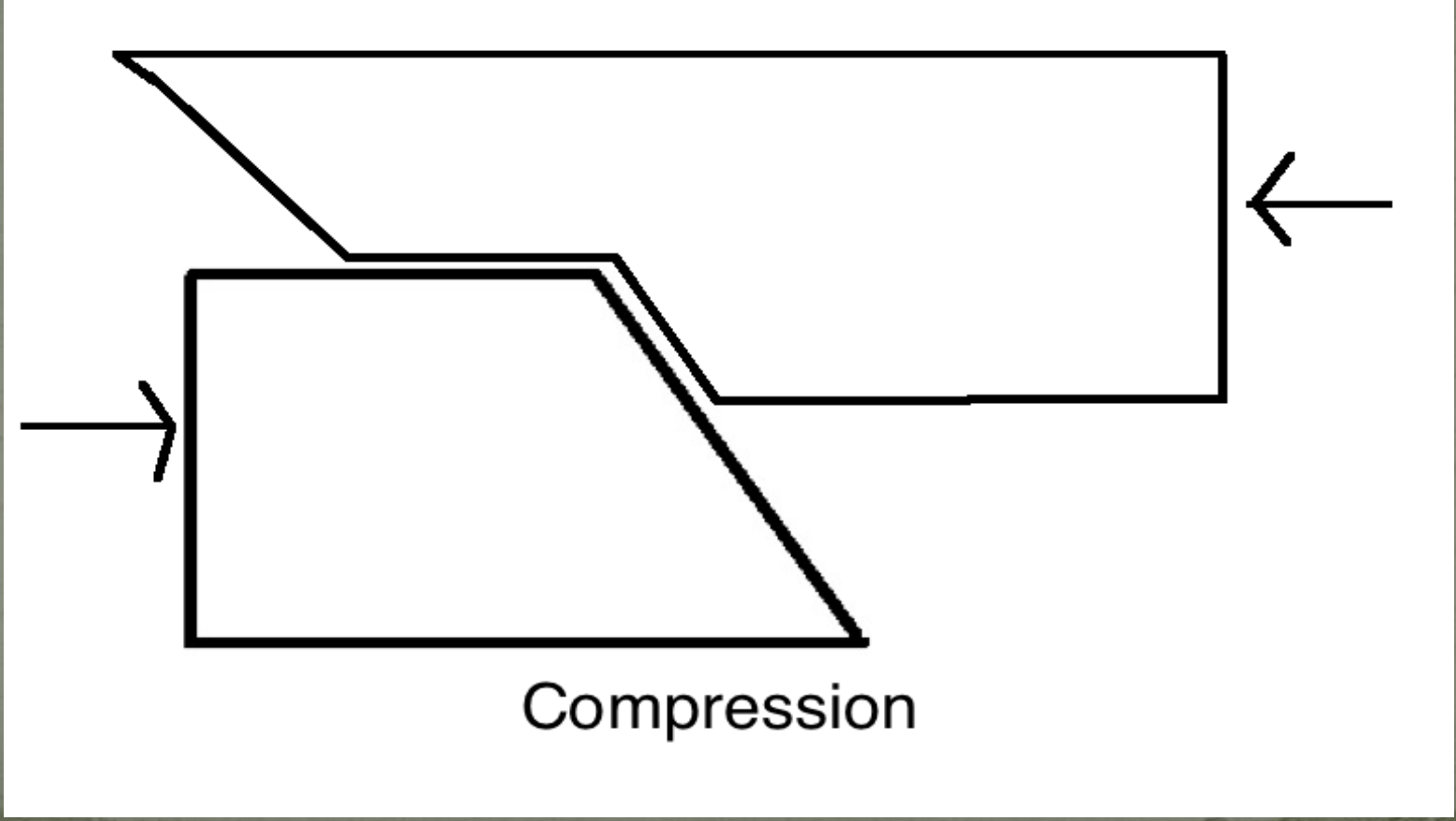


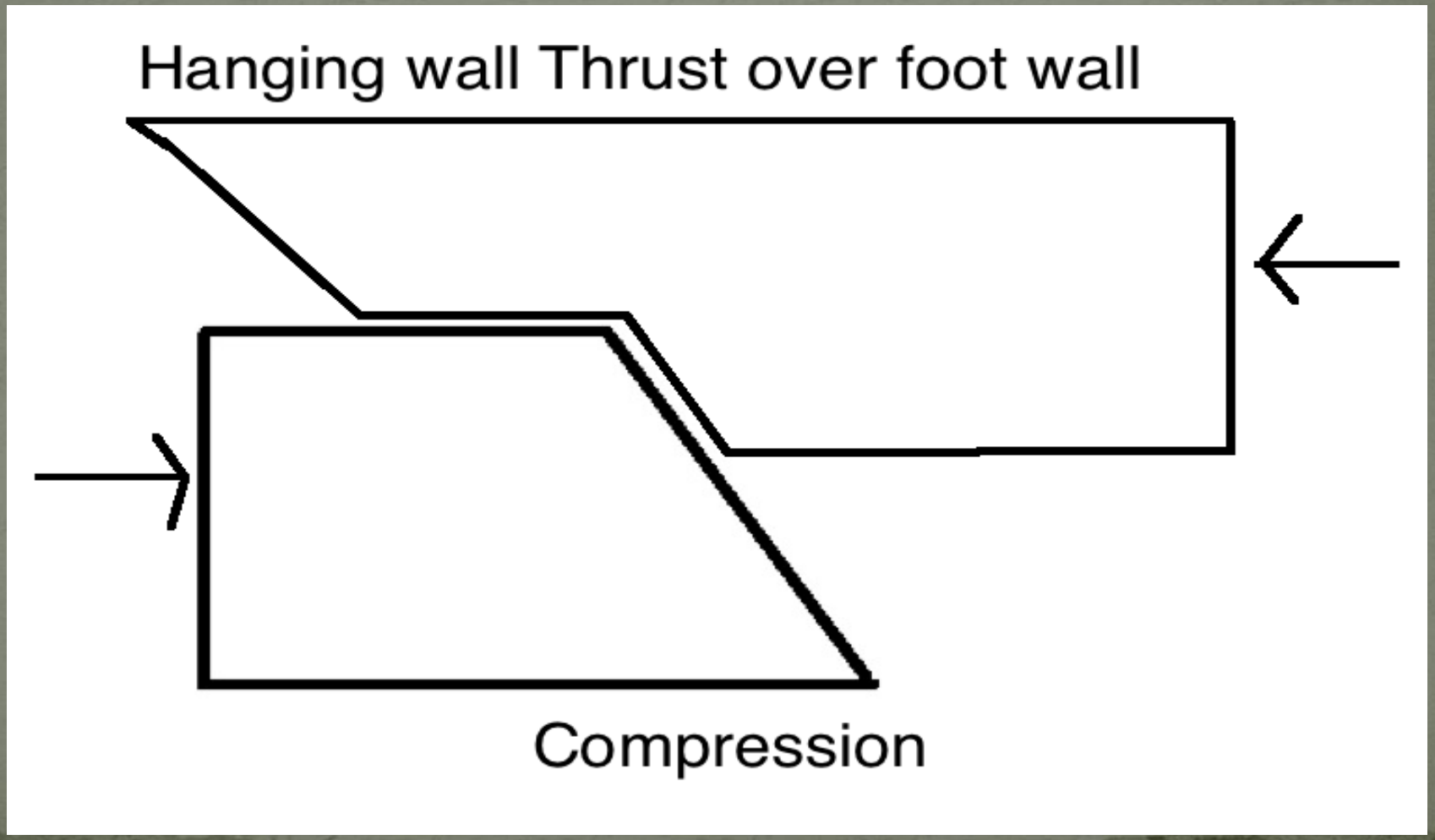

Hanging wall pushed up
Compression

- Reverse Fault: Compression pushes in, Hanging wall moves up and the length of the crust shortens.

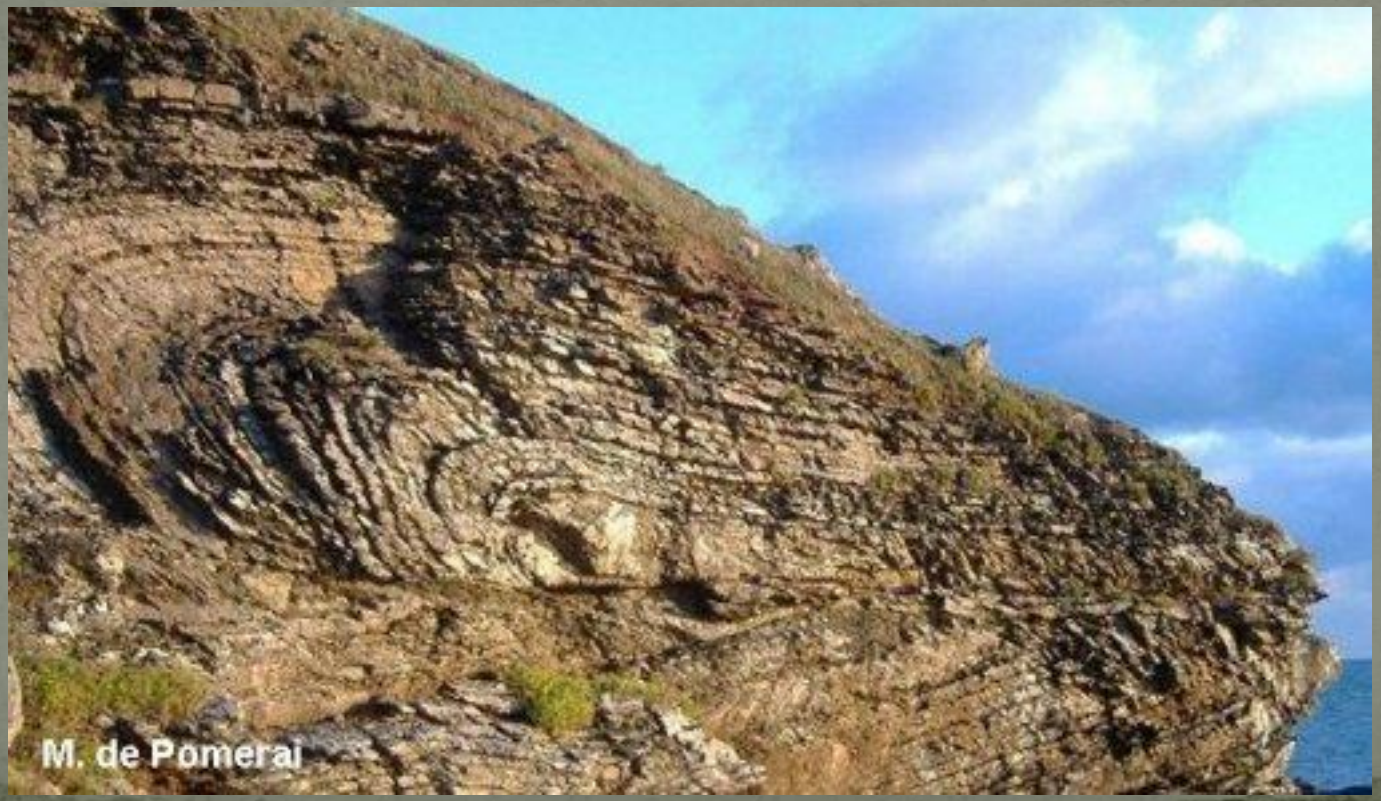


- 3) Thrust Fault (vertical): (super reverse)

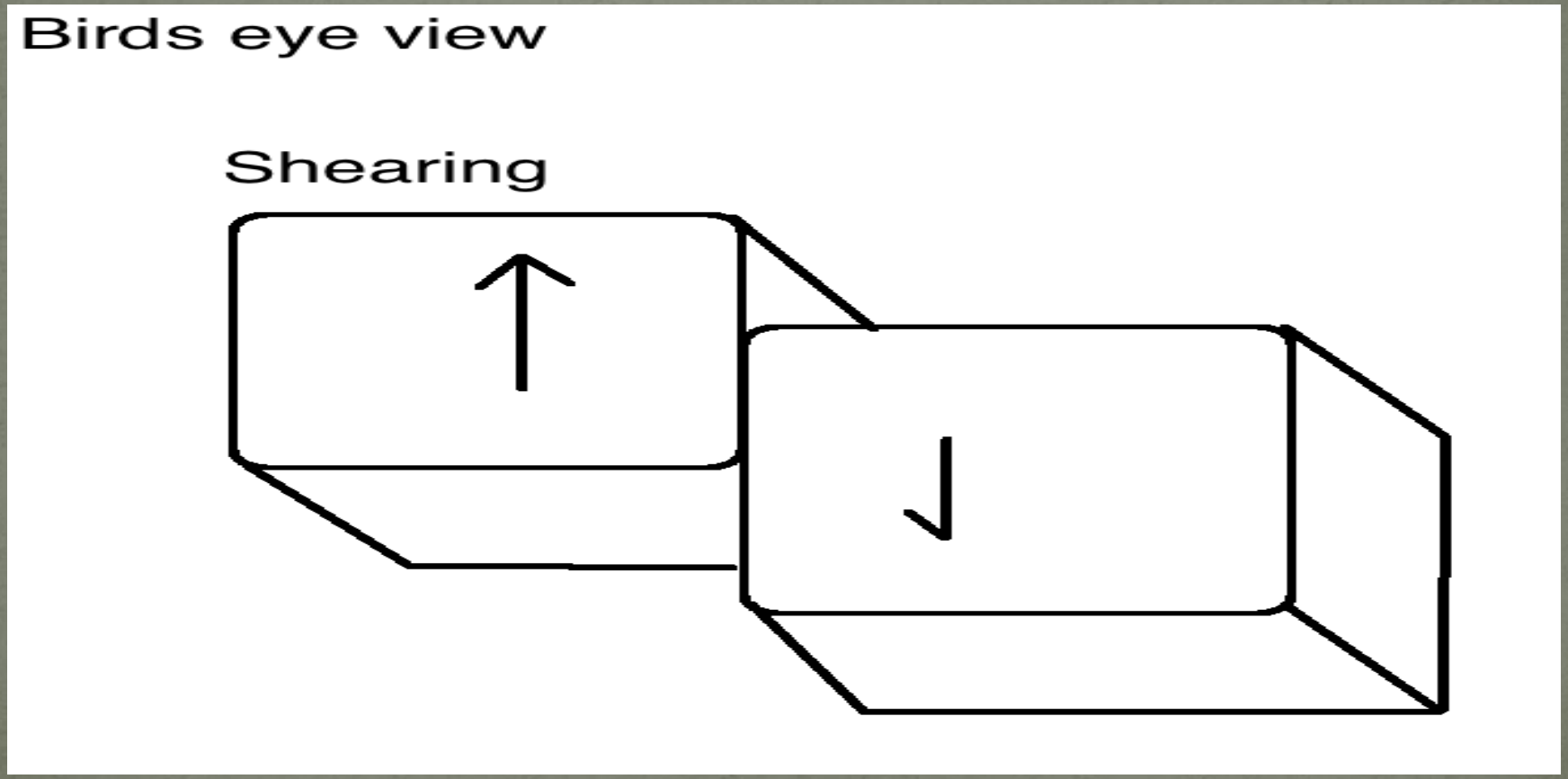



Hanging wall Thrust over foot wall
Compression

- Thrust fault: Compression thrusts hanging wall over footwall.

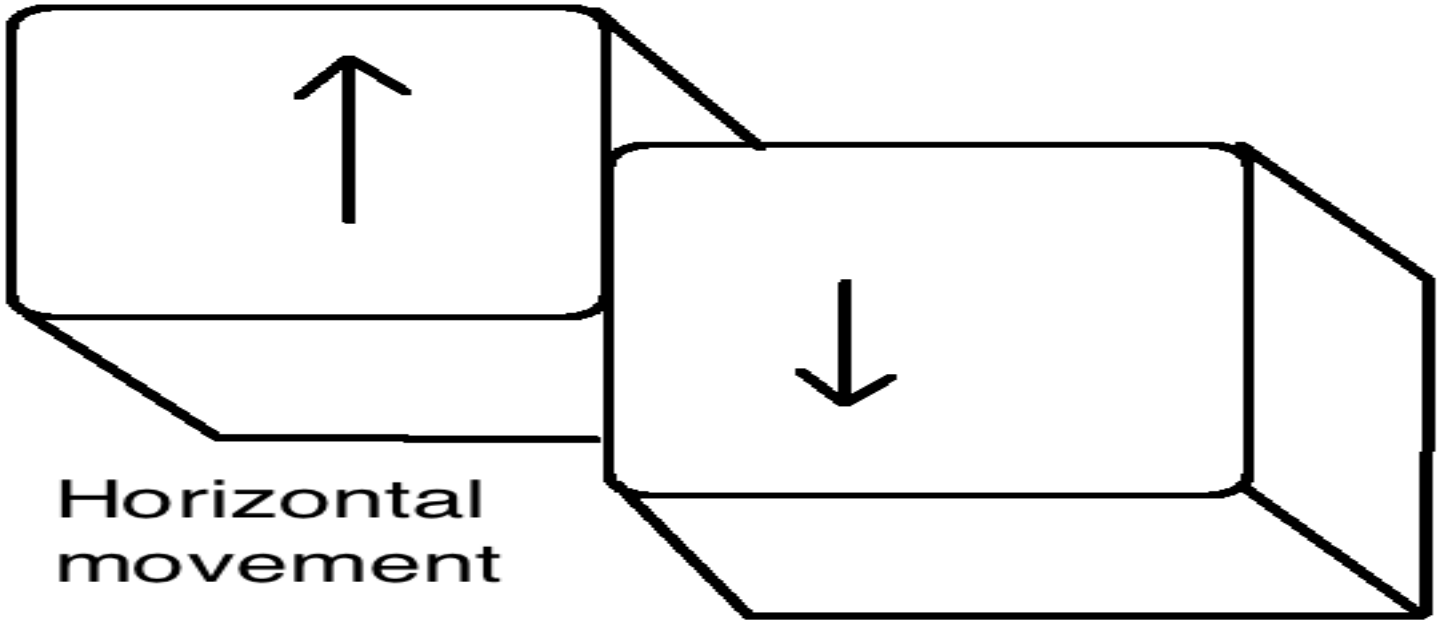


- Horizontal Fault – Blocks move horizontally or laterally past each other.
- 1) Strike-Slip fault (Lateral / Horizontal fault)



Birds eye view

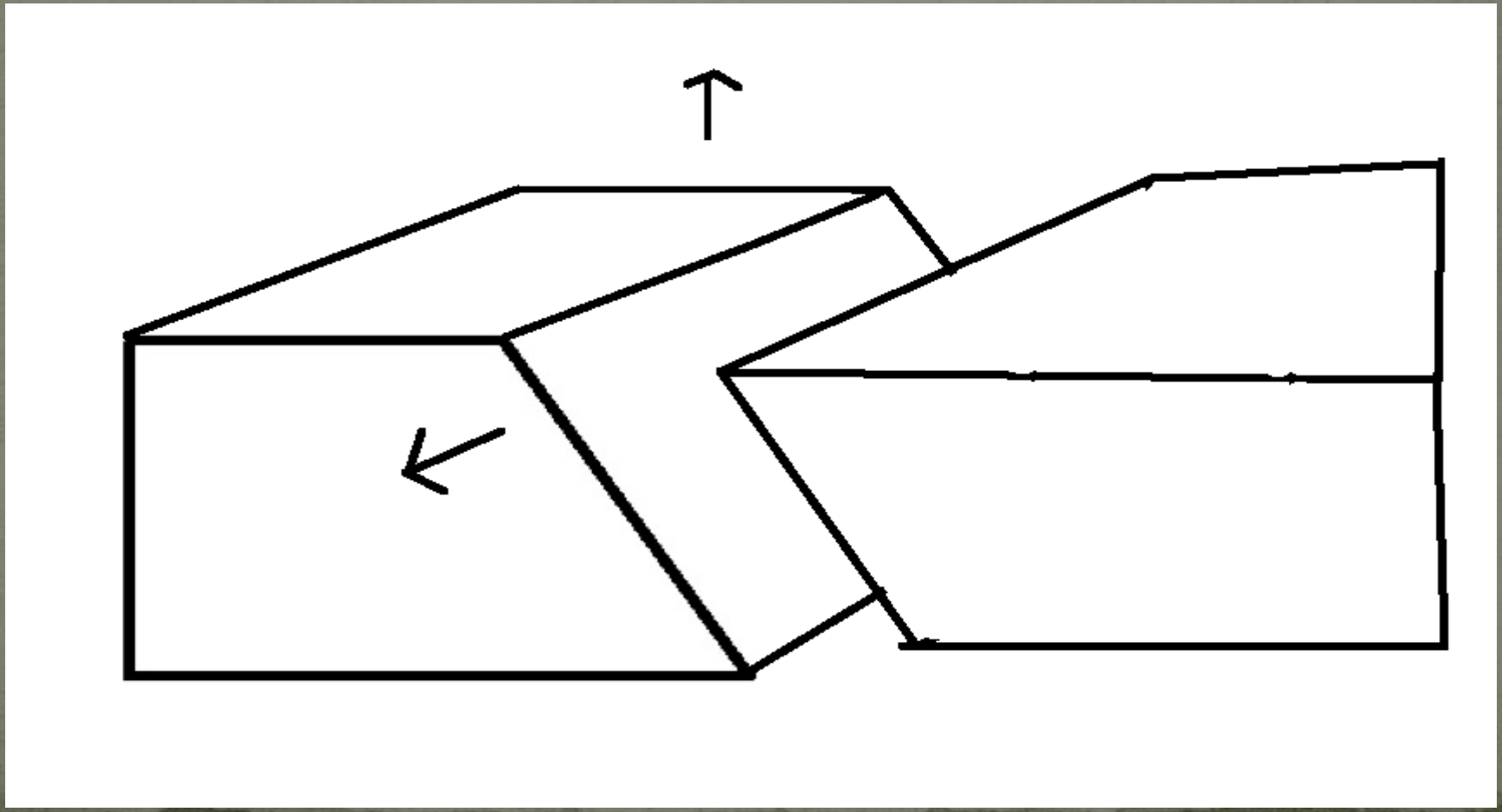
Shearing



Horizontal movement

- Strike-Slip (Lateral Fault): Blocks move horizontally past each other due to shearing.

- Oblique slip: Vertical & Horizontal



- Oblique Slip: Rock moves horizontally and vertically.

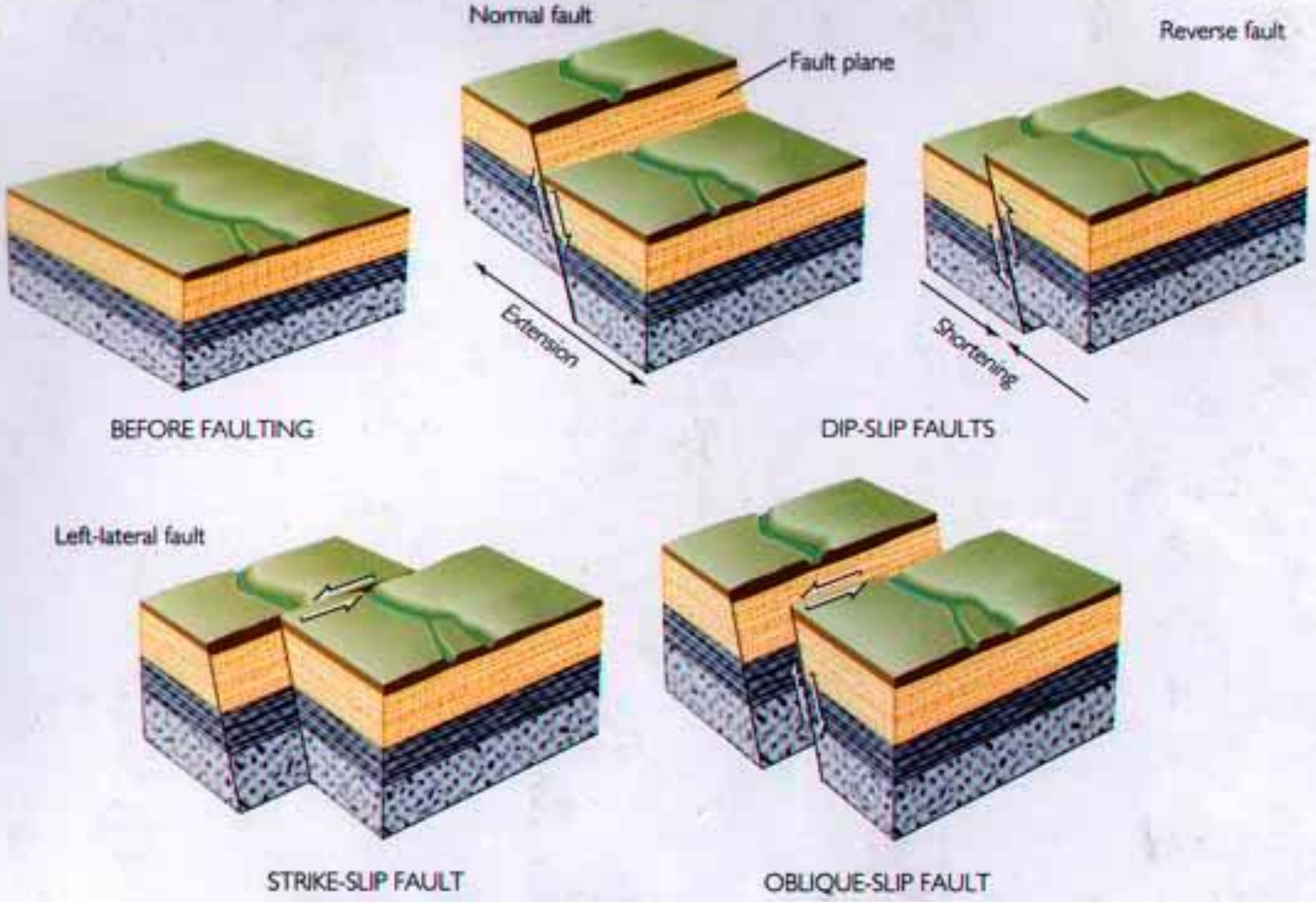
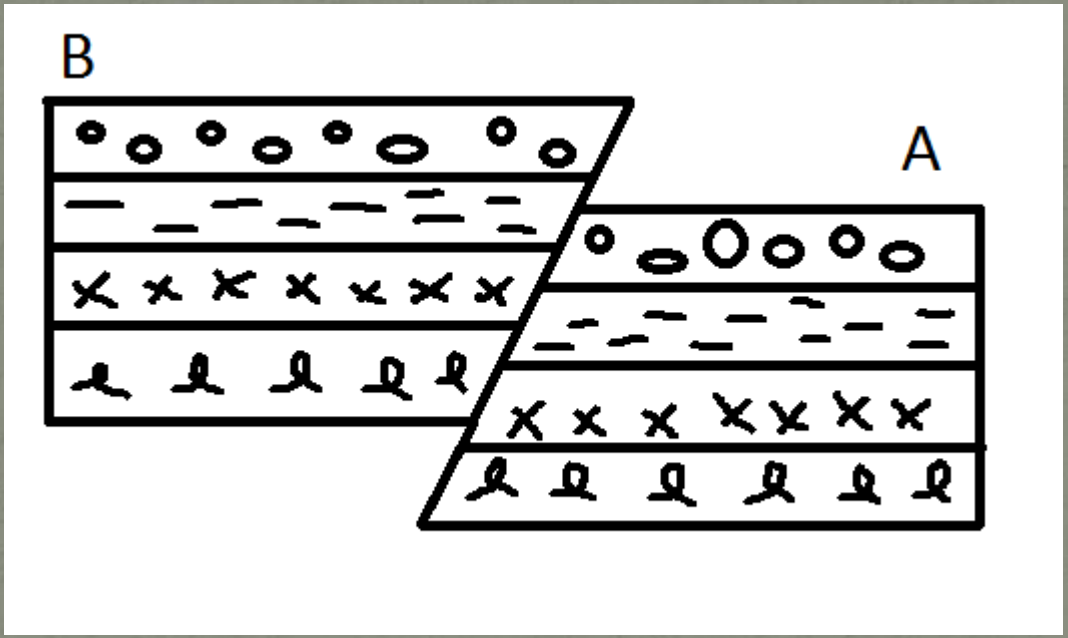
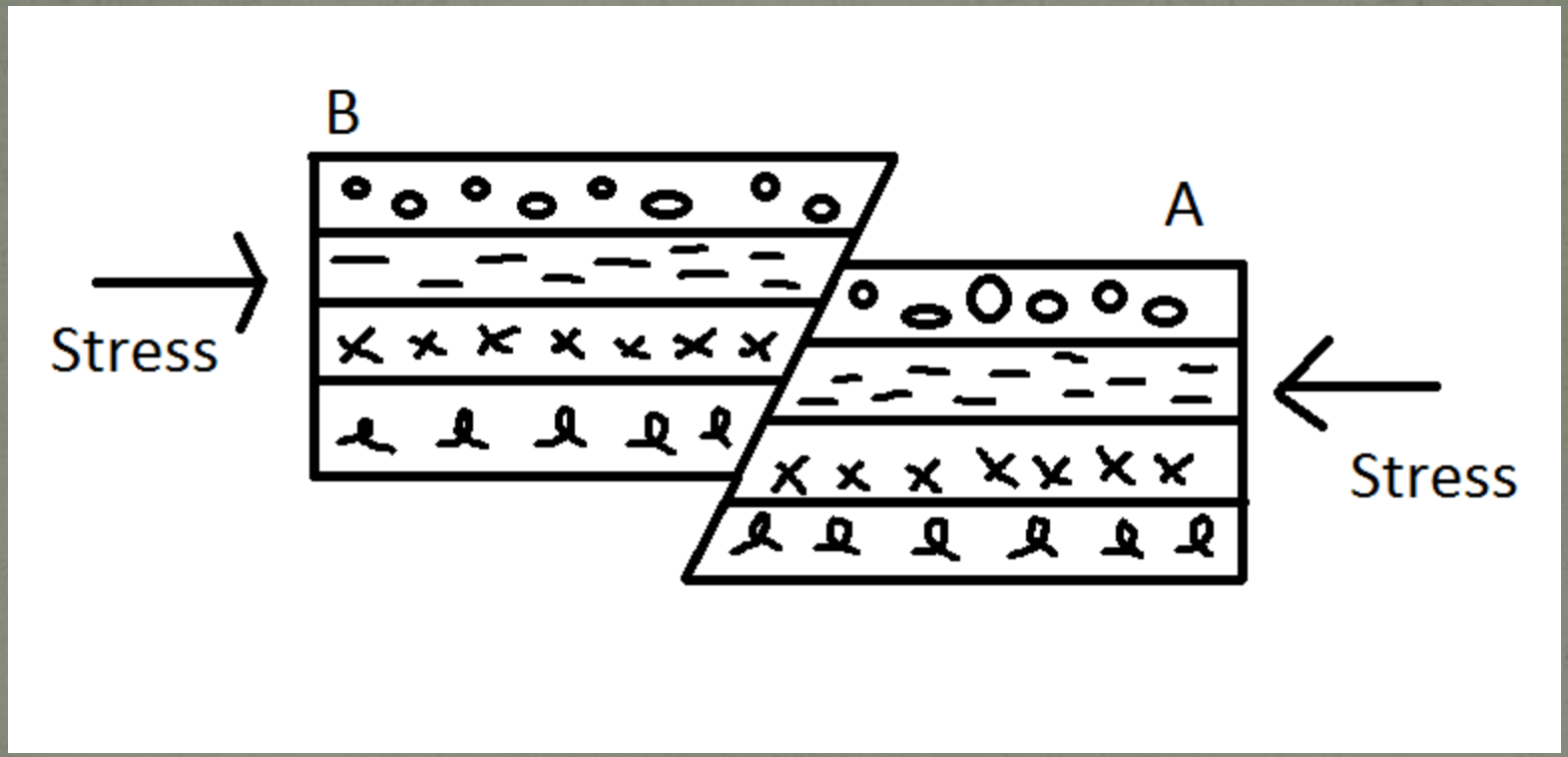
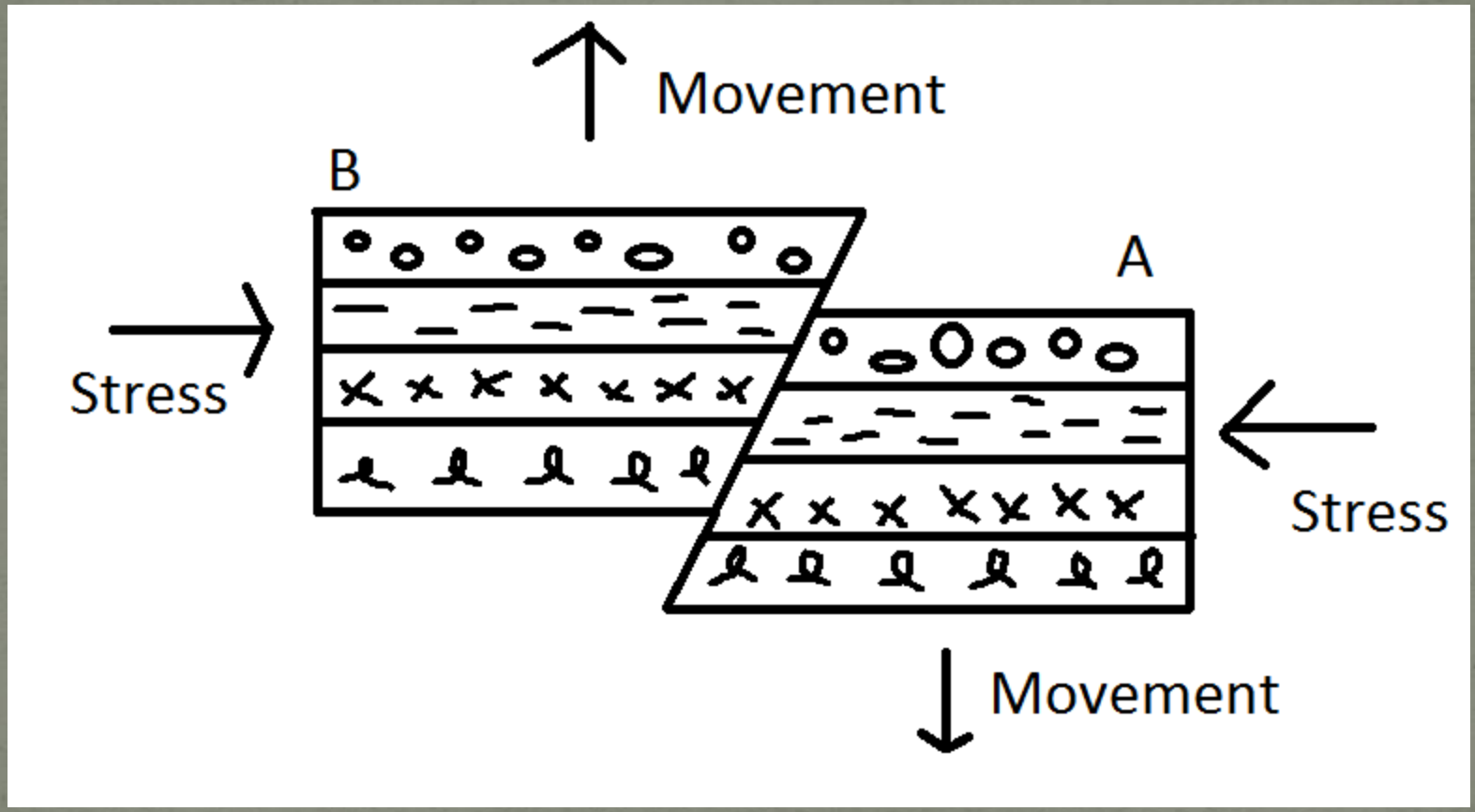


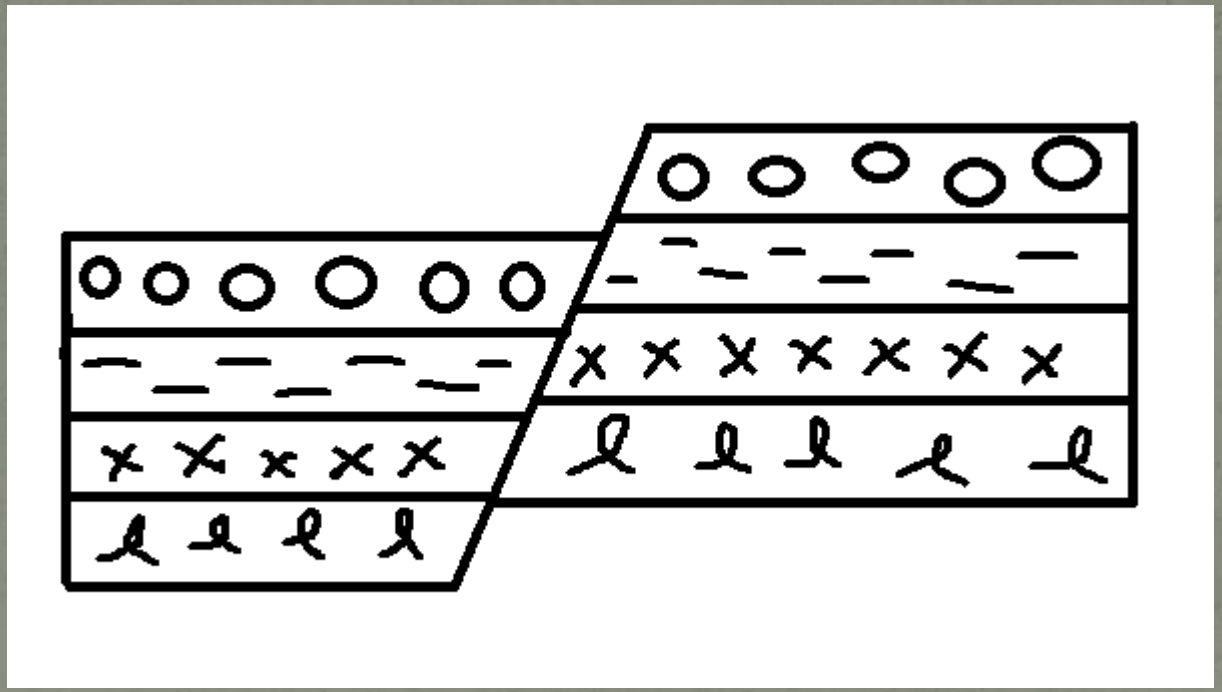
Figure 10.22
Press and Siever: ***Understanding Earth***

OHT 54


B
A


B
A
Stress
Stress


Movement
B
A
Stress
Stress
Movement



Fault Lab

- Purpose – Learn about folding and faulting
- Data – Faulting Diagram 1 & 2
  Question sheet

Conclusion –

3 types of stress

What is Folding

2 types of folds

What is Faulting

Hanging walls & Foot walls

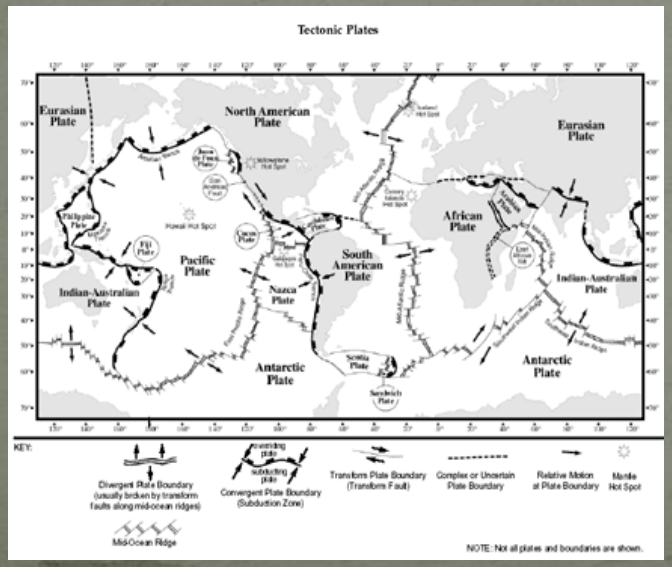
5 Types of Faults (diagram and explain them)

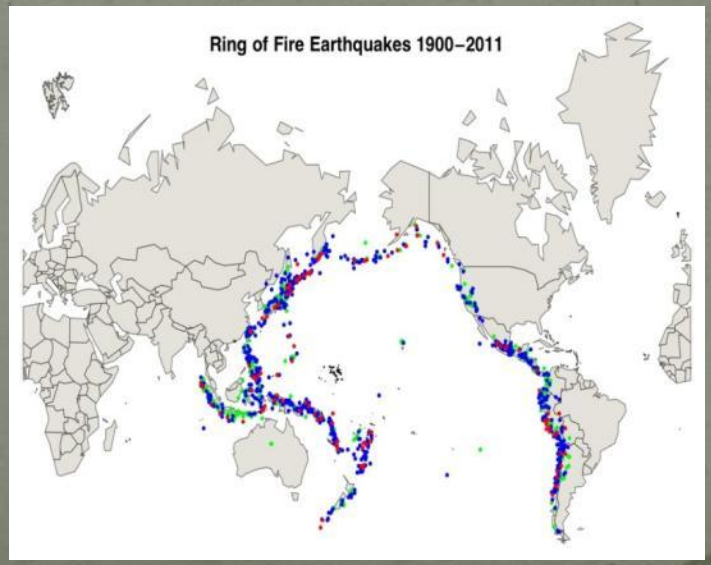
What affects whether a rock will fold or fault?

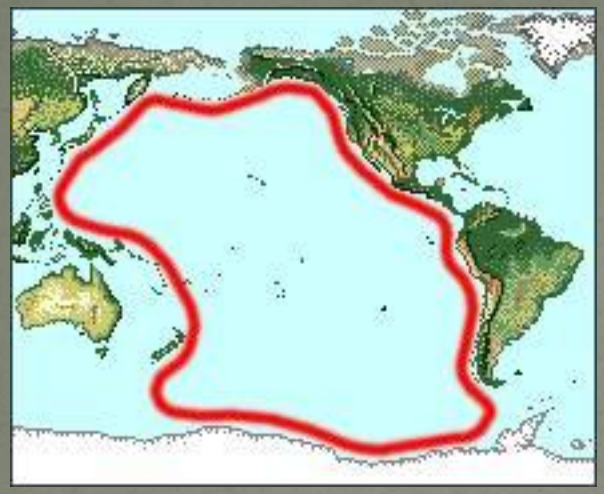
- What happens when a large amount of stress is released from the Earth and plates move?
- Earthquakes: sudden movement of the Earths crust caused by the release of stress at faults.
- Which are better, many small ones or few large ones?
- Frequent small quakes are better than rare large quakes as they release pressure slowly without any major problems.

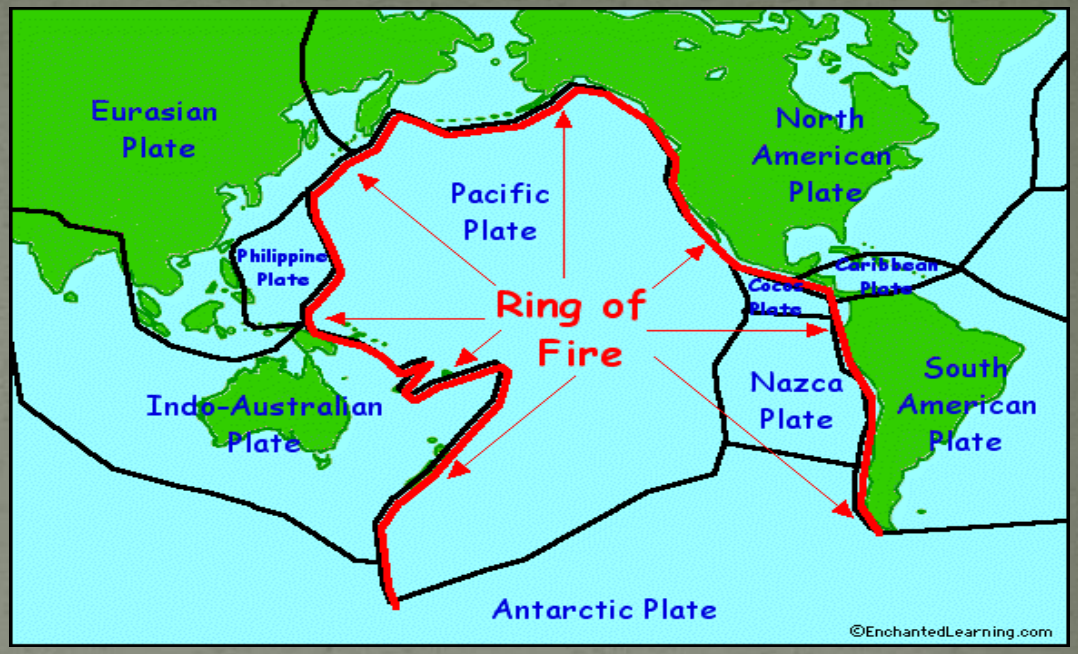
- Where do most Earthquakes happen?
- Most Earthquakes happen at plate boundaries.
- ~ 80% of major quakes occur at the ring of fire.

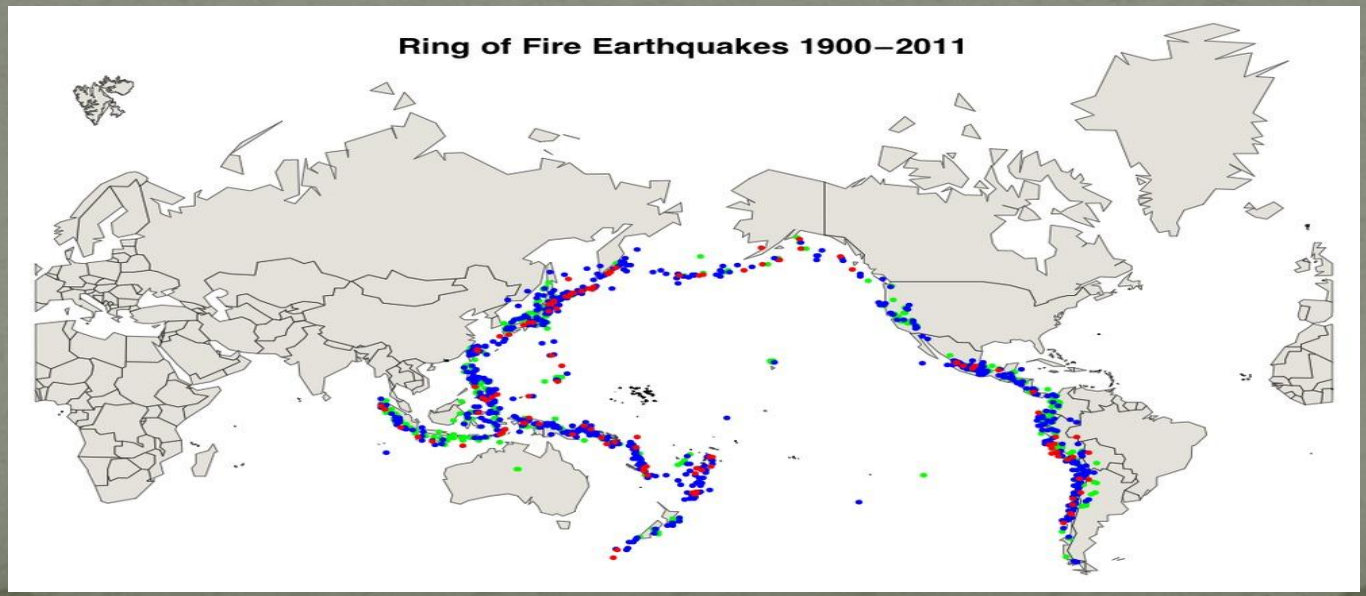
  (ring around the Pacific plate also filled with volcanoes)



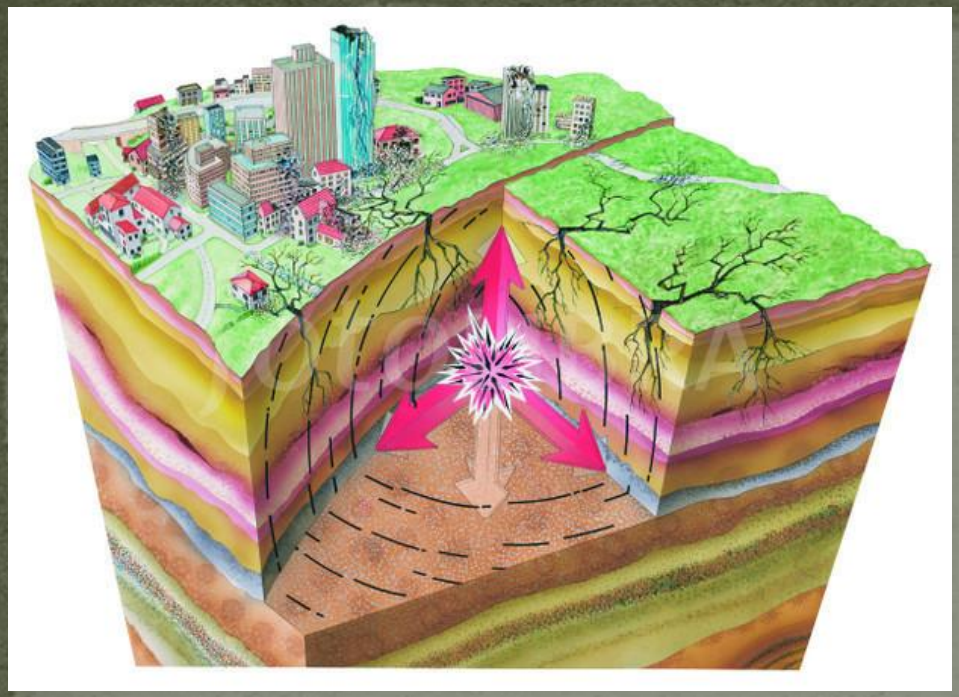


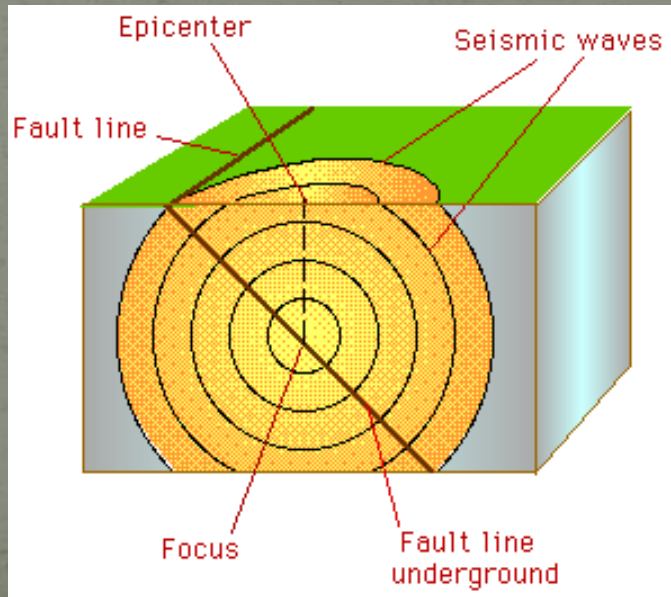



Eurasian Plate
North American Plate
Pacific Plate
Philippine Plate
Caribbean Plate
Cocos Plate
Ring of Fire
Nazca Plate
South American Plate
Indo-Australian Plate
Antarctic Plate
©EnchantedLearning.com


Ring of Fire Earthquakes 1900–2011

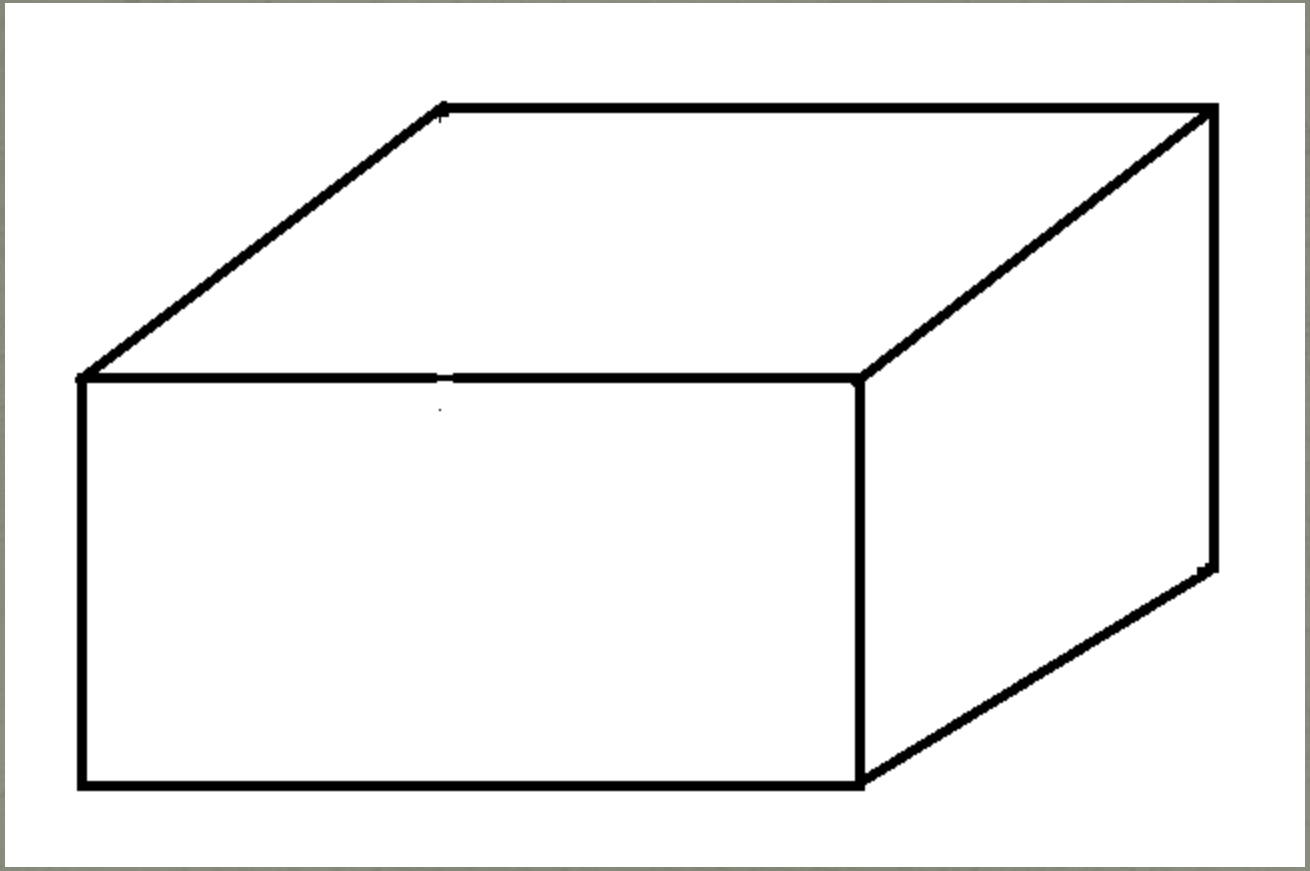
- World Earthquake Map
- http://earthquake.usgs.gov/earthquakes/map/

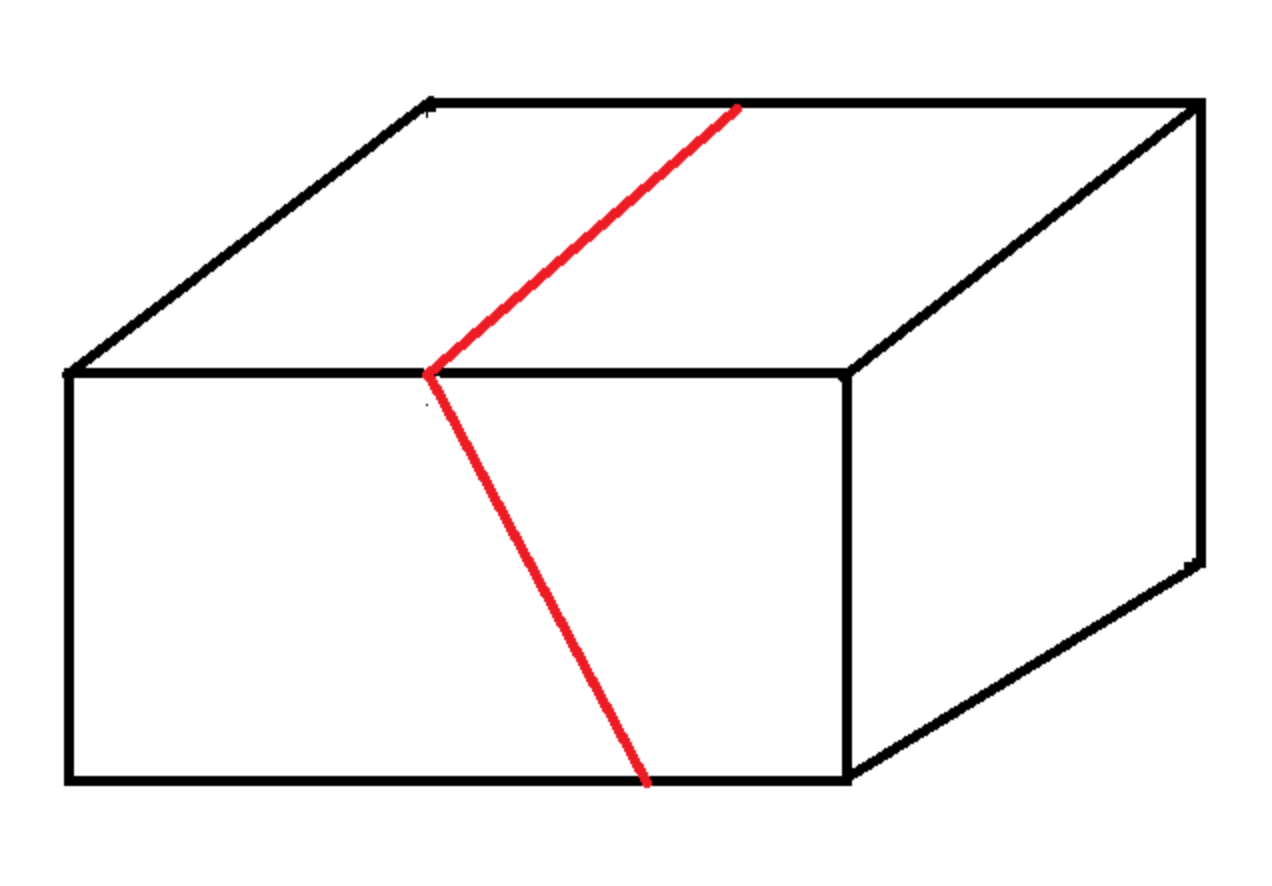


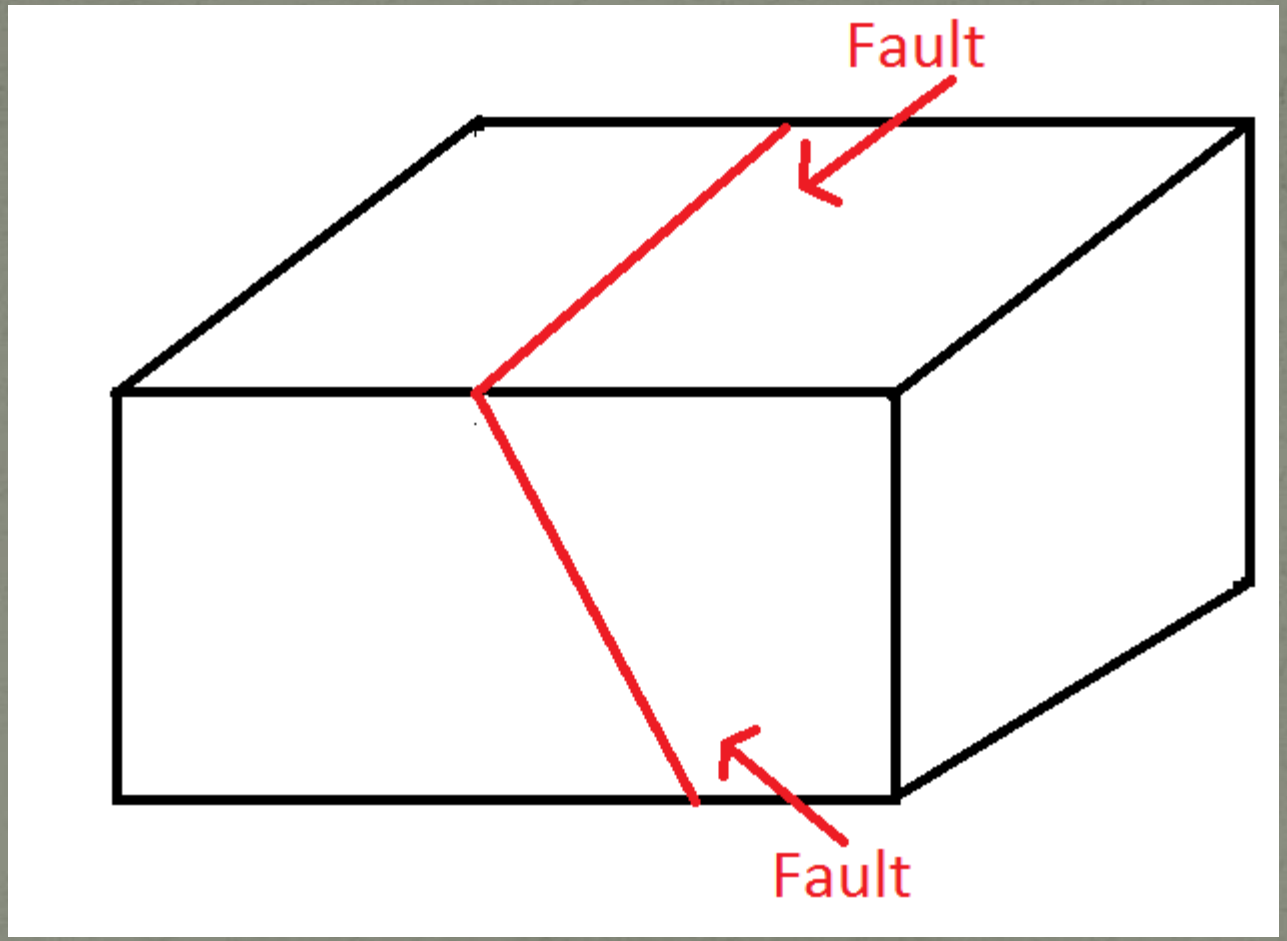


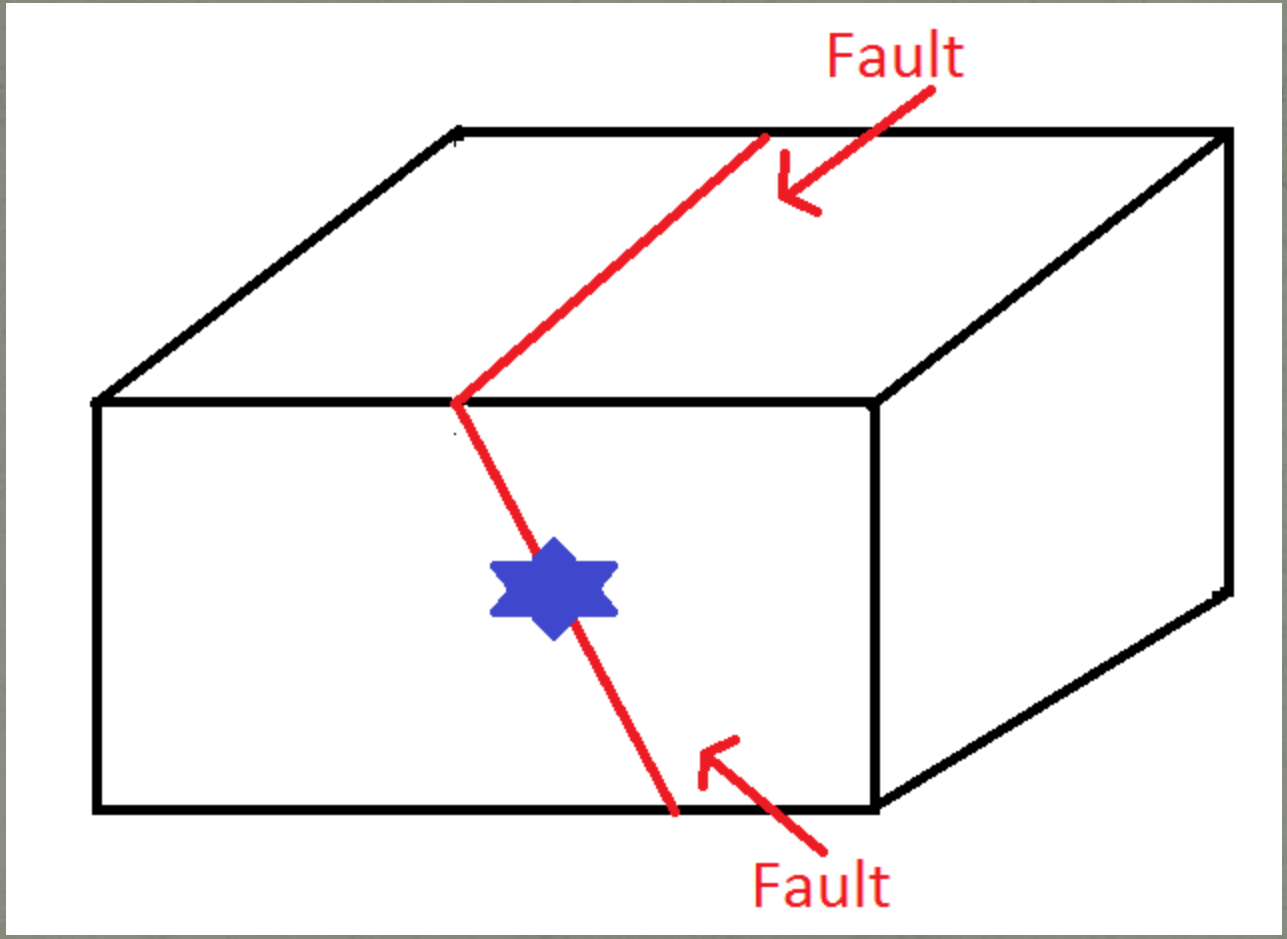
Earthquakes

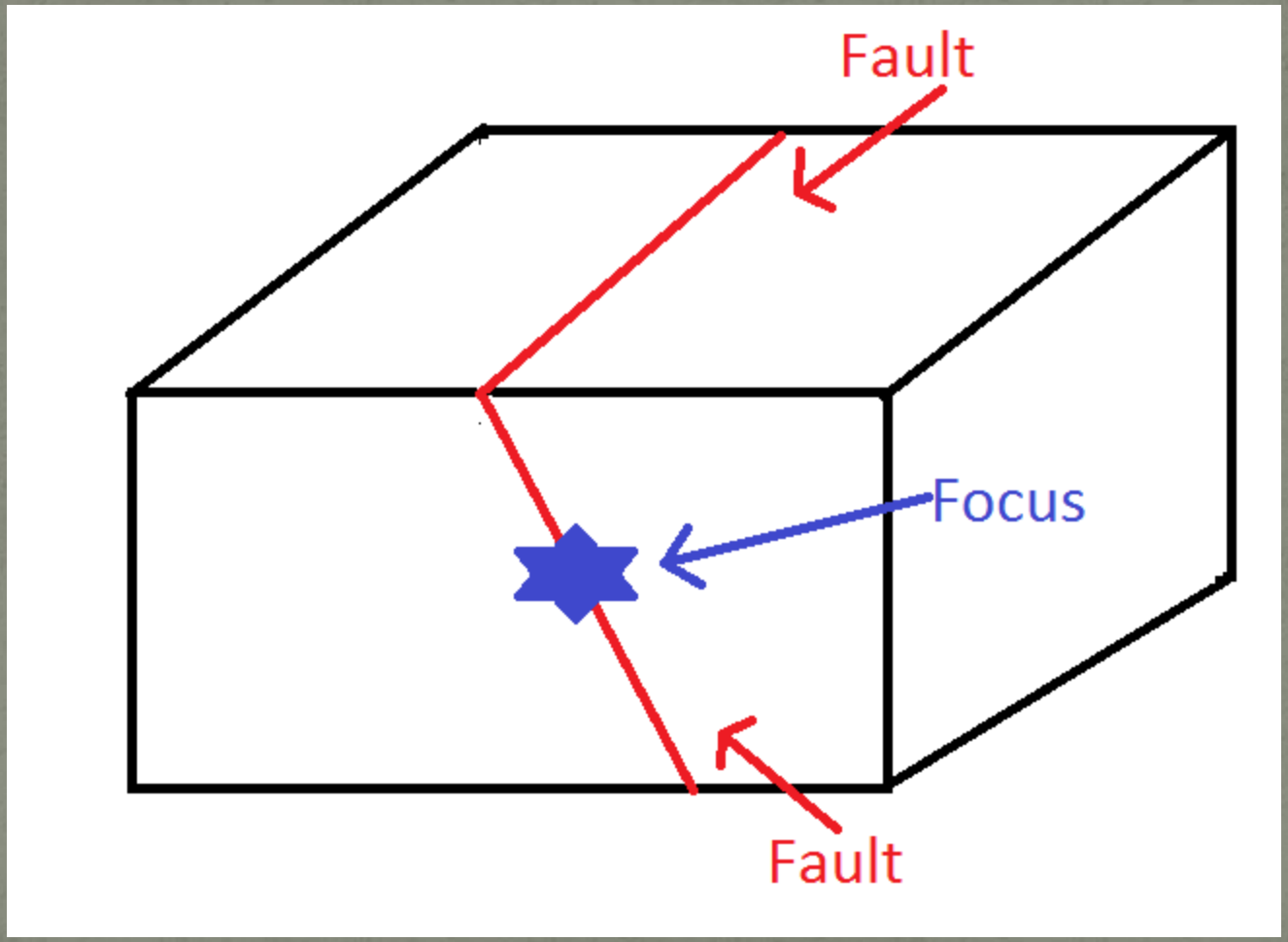
When the break line (the **fault**) between two blocks of rock suddenly moves, the movement causes vibrations (**seismic waves**) to race rapidly outward in all directions from the **focus**. The point at ground level directly above the focus is called the **epicenter**.

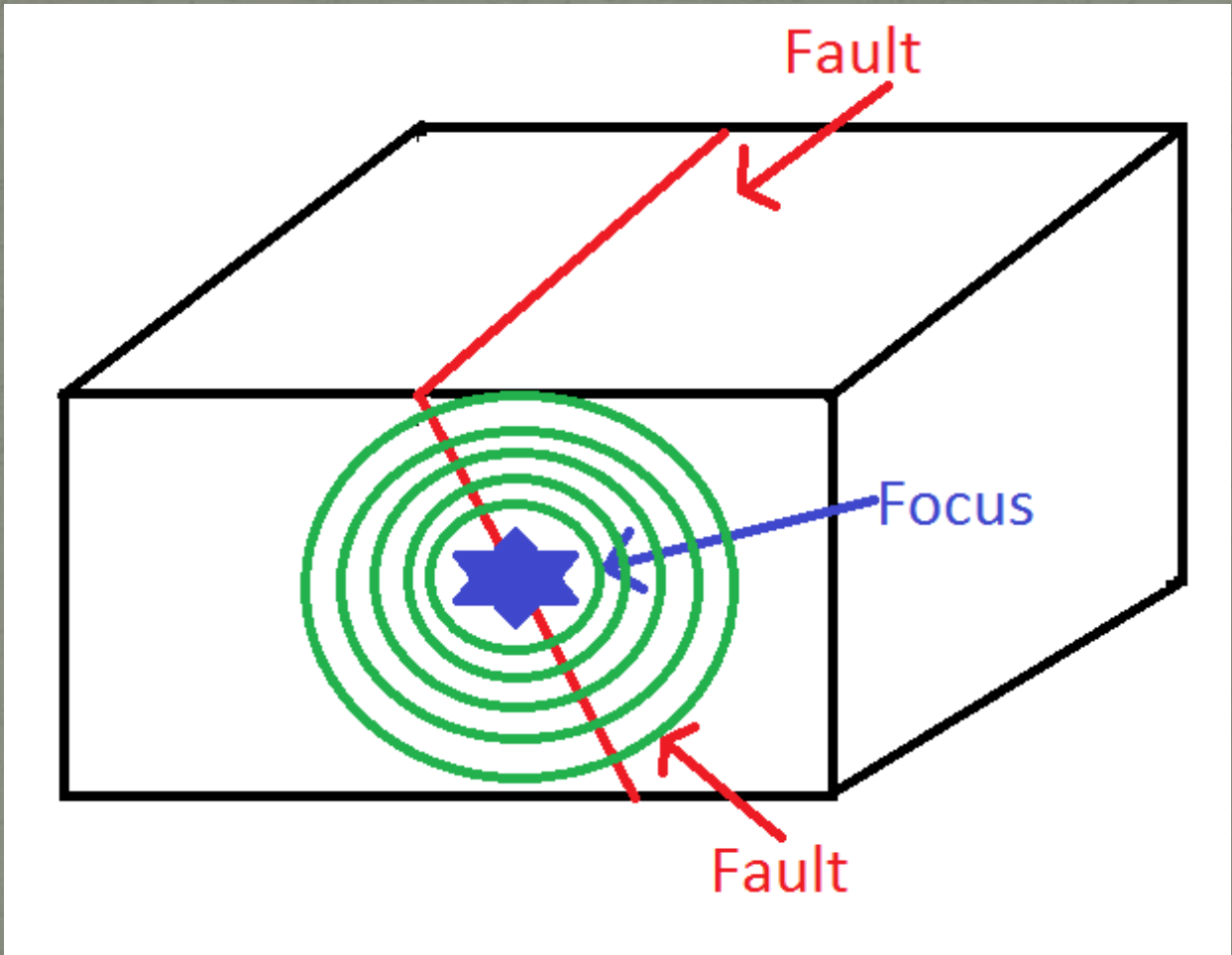


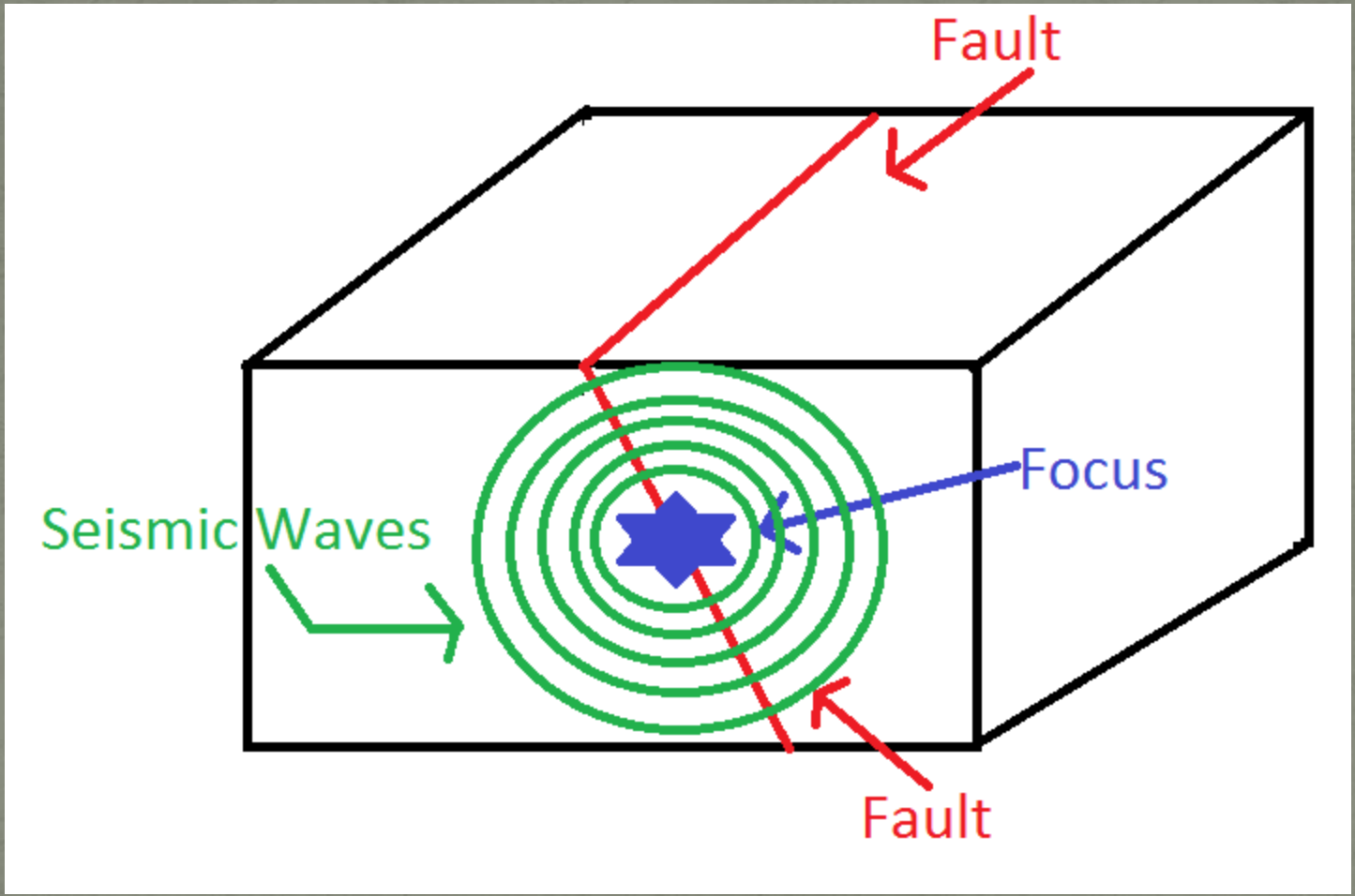


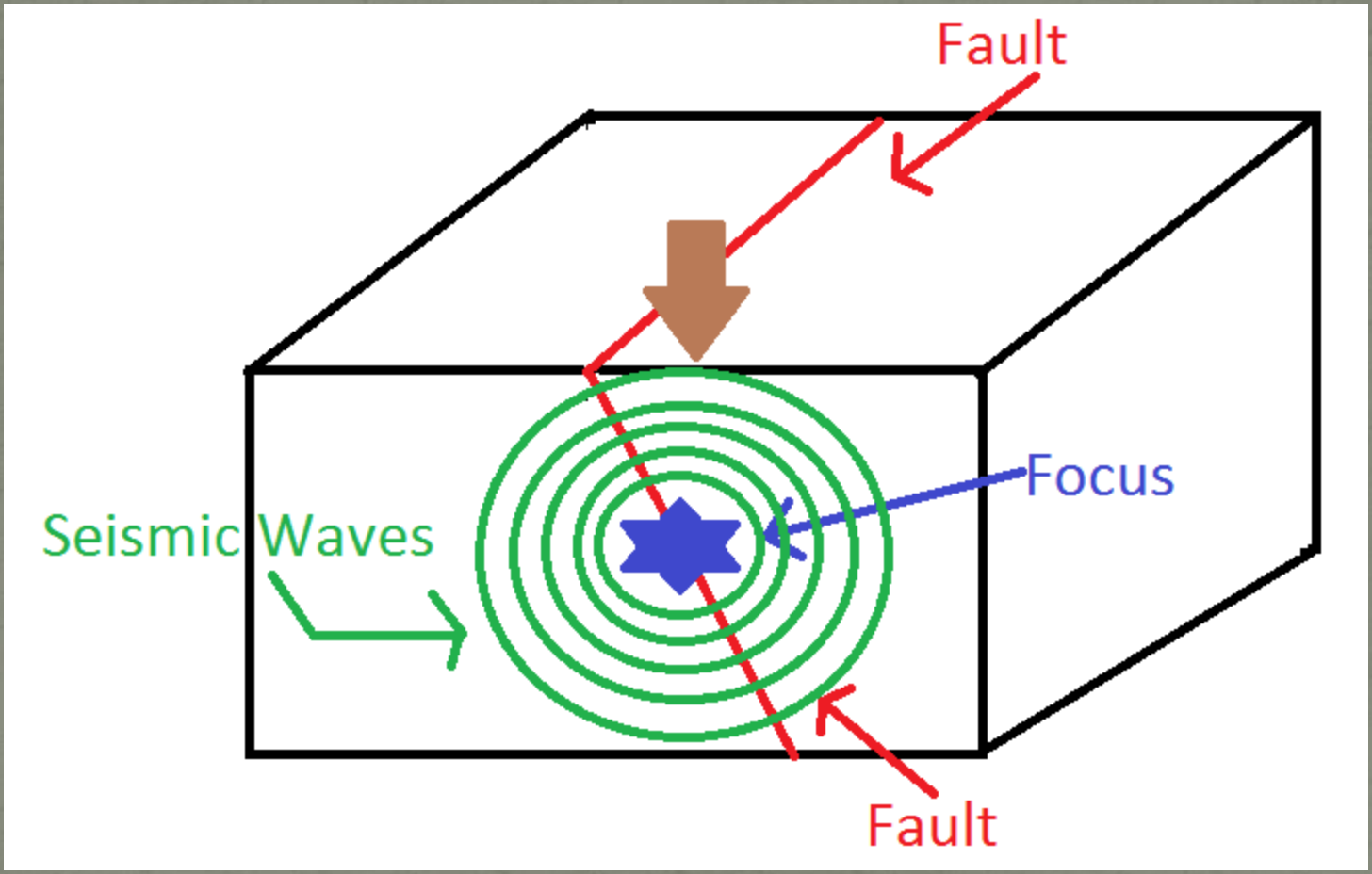

Fault
Fault

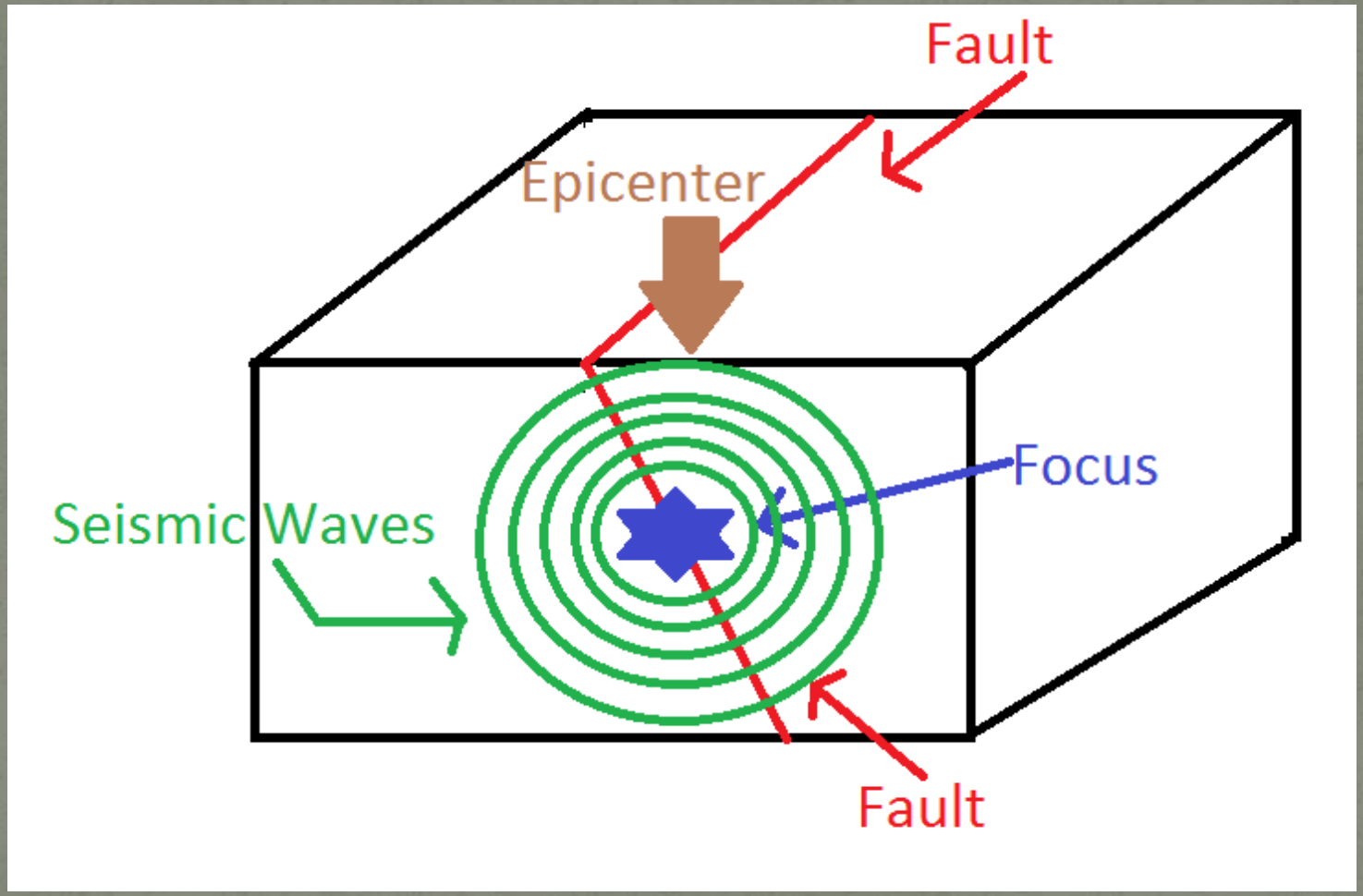

Fault
Fault


Fault
Focus
Fault


Fault
Focus
Fault


Fault
Focus
Seismic Waves
Fault


Fault
Focus
Seismic Waves
Fault


Fault
Epicenter
Focus
Seismic Waves
Fault

- Parts of an Earthquake:
- Focus:
- 1) Focus: Where the Earthquake originates.
- (Energy is Focused there)
- Fault:
- 2) Fault: Break in the Earths crust that moves.
- Seismic Waves:
- 3) Seismic Waves: Waves of energy sent out by an Earthquake. (2 types: body & surface waves)
- Epicenter:
- 4) Epicenter: Location on the surface directly above the focus.

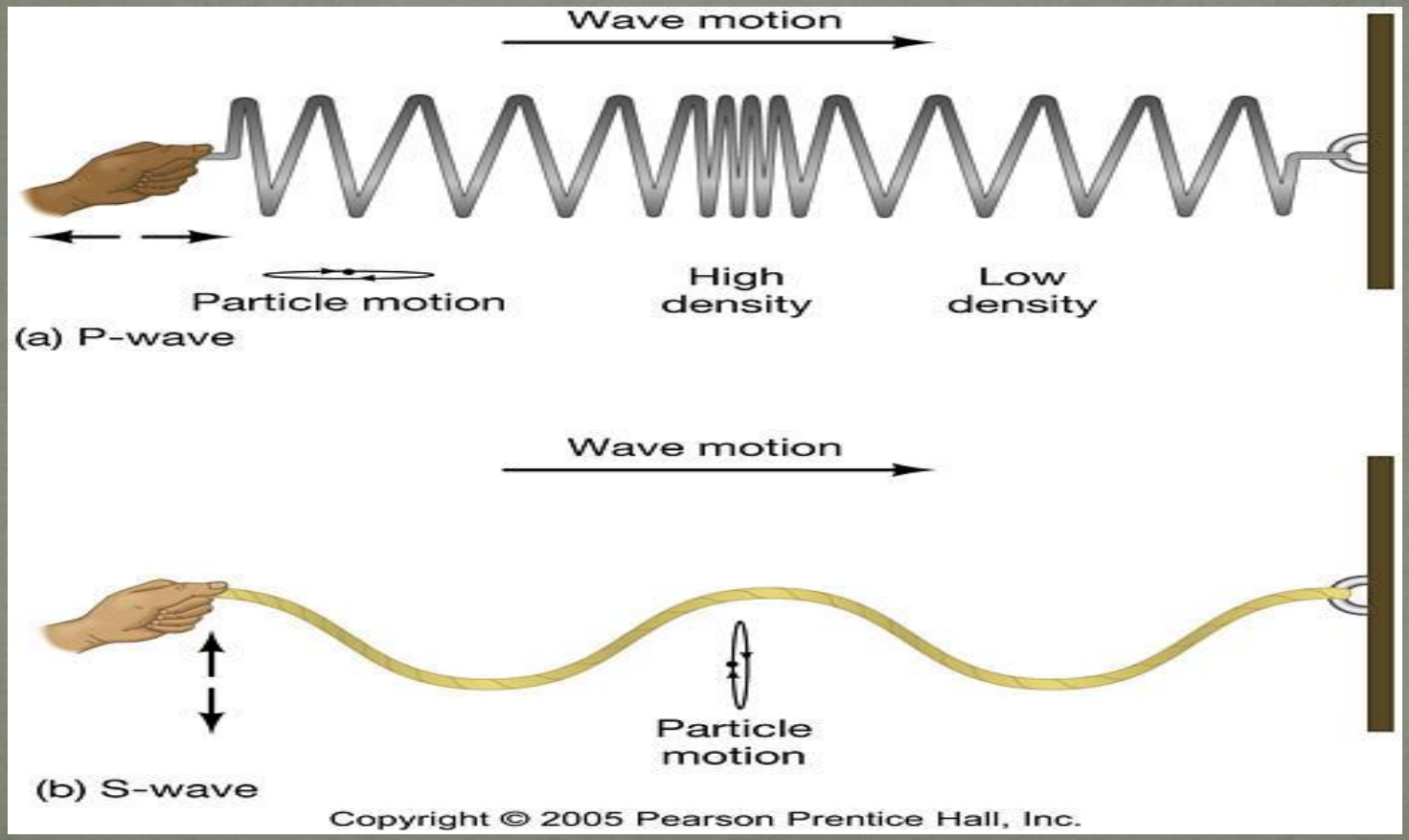
Epic Center (typically the hardest hit)

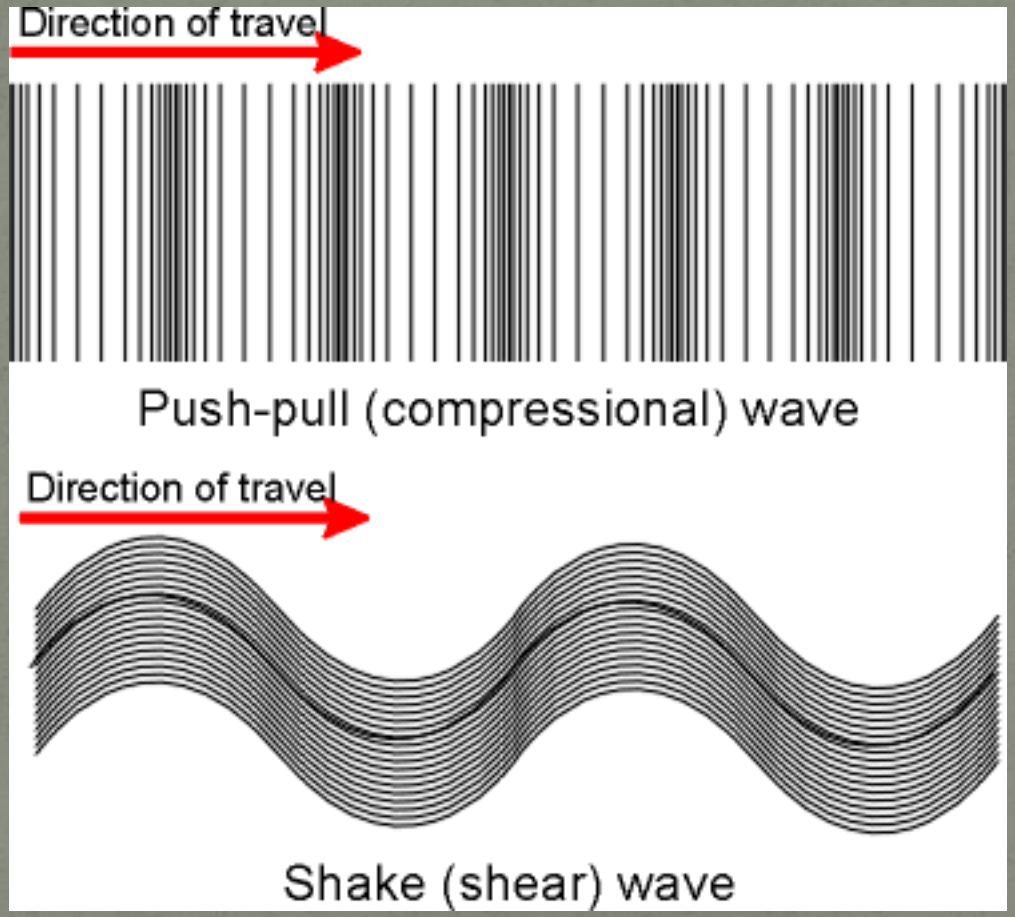
- What is worse, a deep focus Earthquake or shallow focus Earthquake?
- Shallow Earthquakes typically hit hardest as locations are closer to the focus.

- Body waves?
- Body waves: Travel through the body of the Earth.
- 2 types: P waves, S waves

Types of Seismic waves

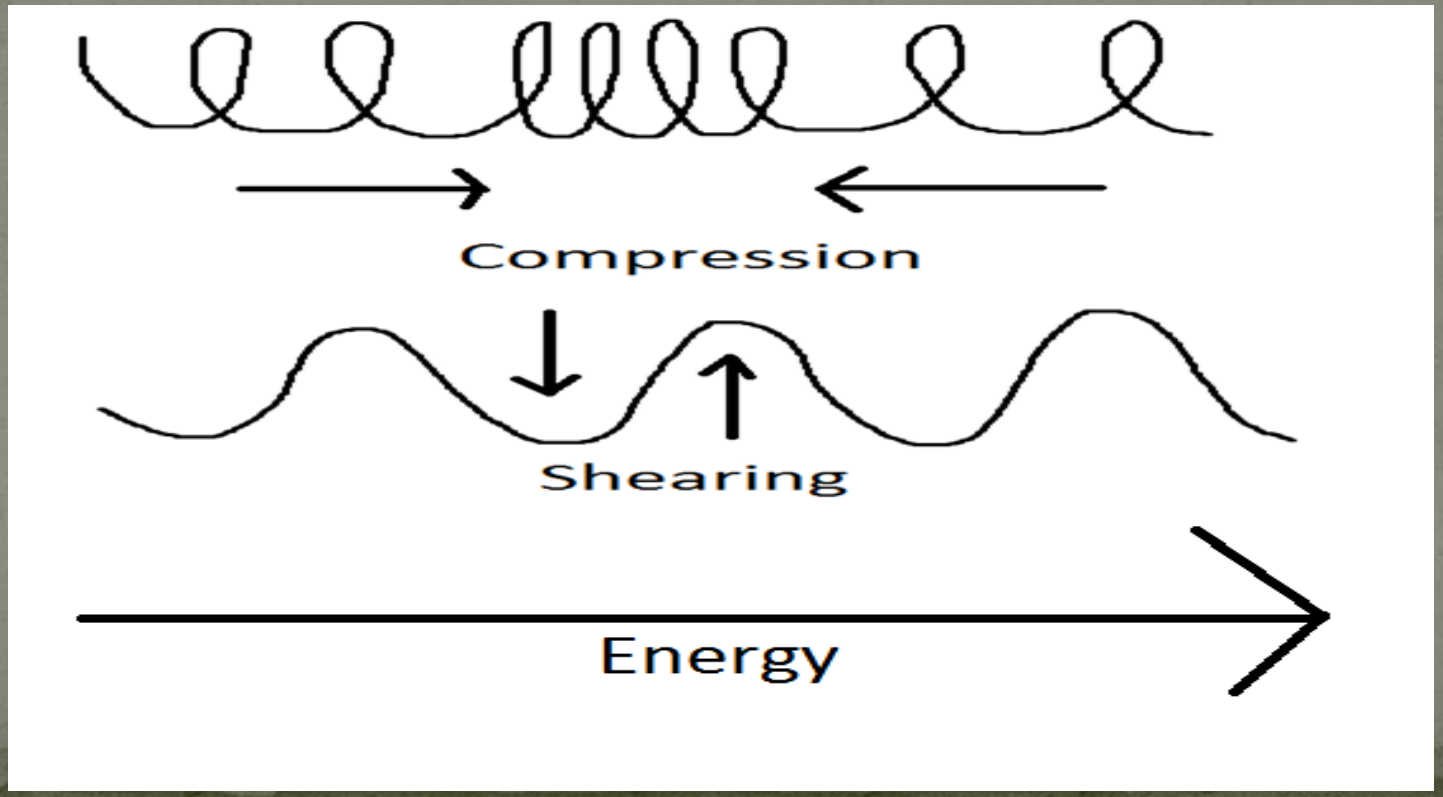
How can you send energy at someone using a slinky?




Direction of travel
Push-pull (compressional) wave
Direction of travel
Shake (shear) wave

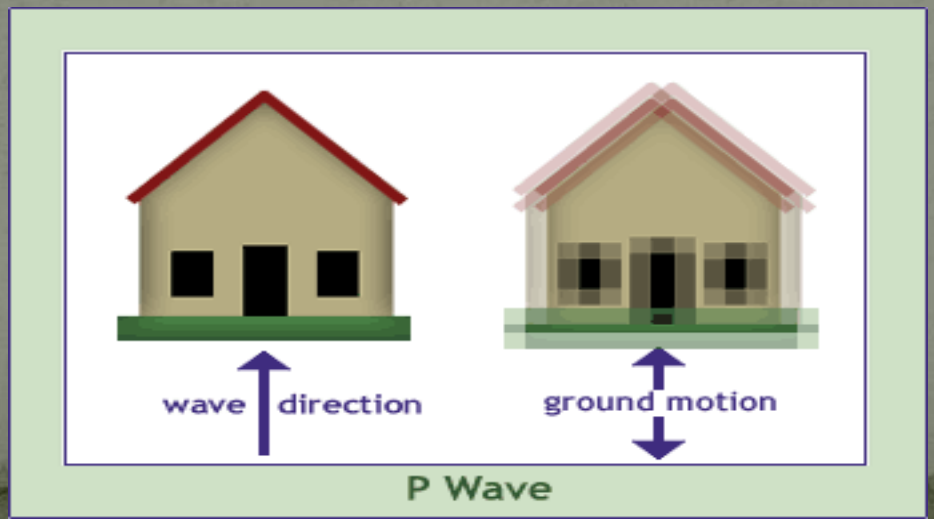
How to send energy:

1) Compression (push / pull)
2) Shearing (side to side)



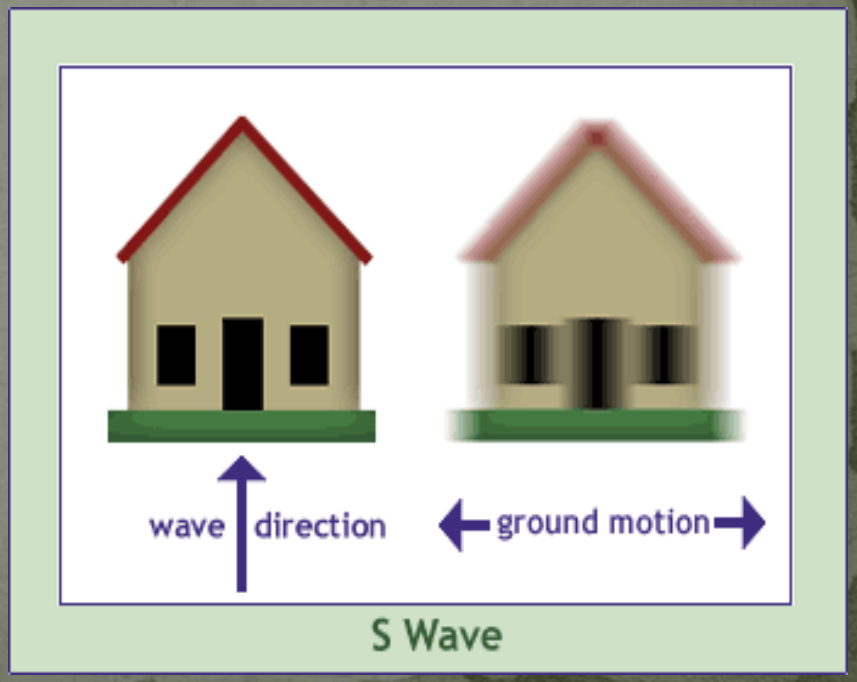
P waves

- P waves
- Primary waves (1st)
- Phastest waves
- Push / Pull (comPression)
- Pop - vertical
- Pretty much anything (liquid / solid) (travels through)



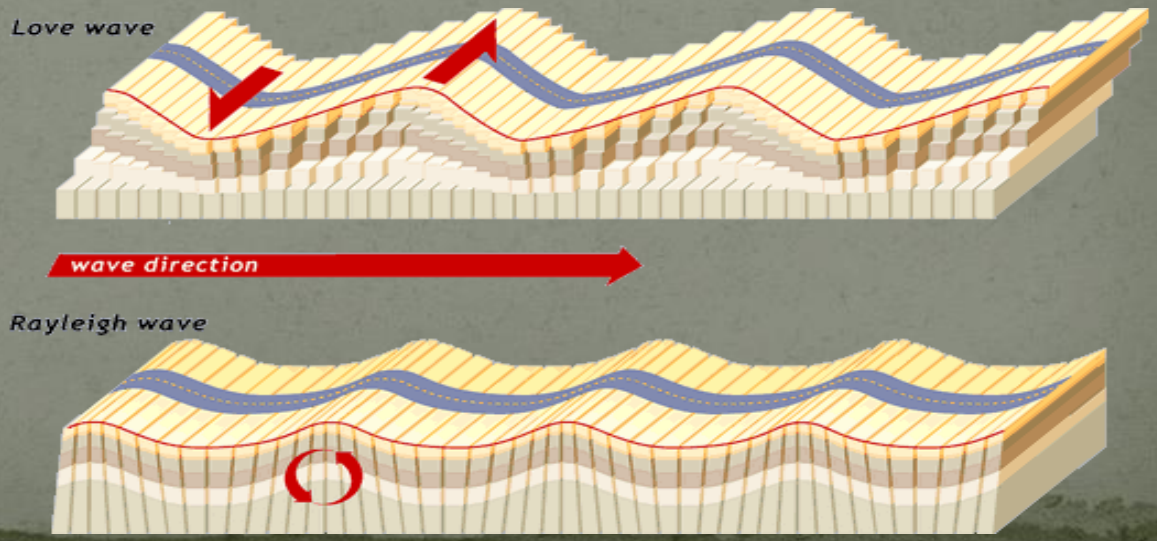
S wave

- S wave
- Secondary wave (2nd)
- Slower
- Side to side (shearing)
- Shaking, structural damage
- Solids only (travels through)

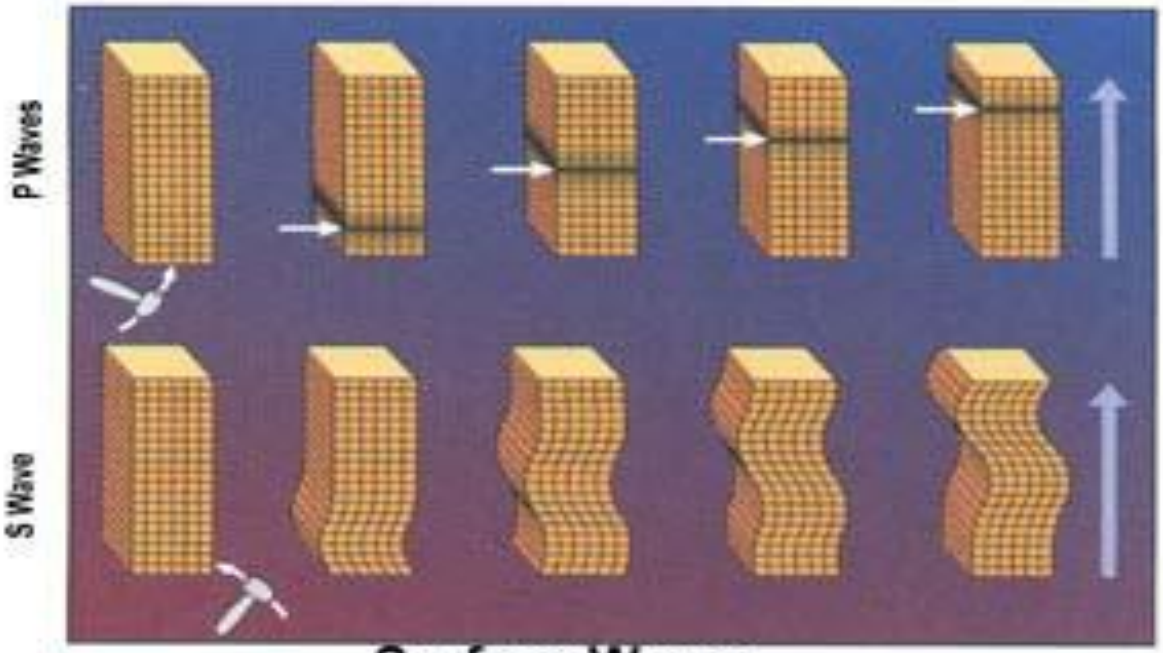


Surface waves

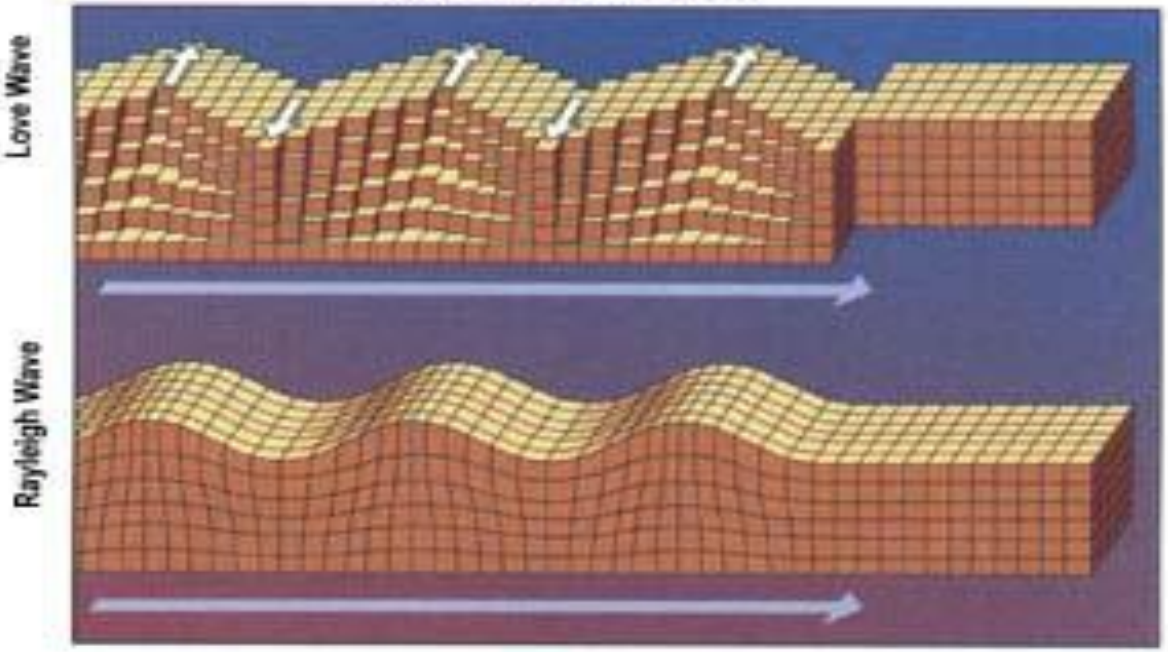
- Surface waves?
- Surface waves: Travel over the surface.
- L & R waves (lateral & rolling)
- Land rolling waves (lifts and rolls land)
- Last waves
- lots of damage
- Land (travels over)



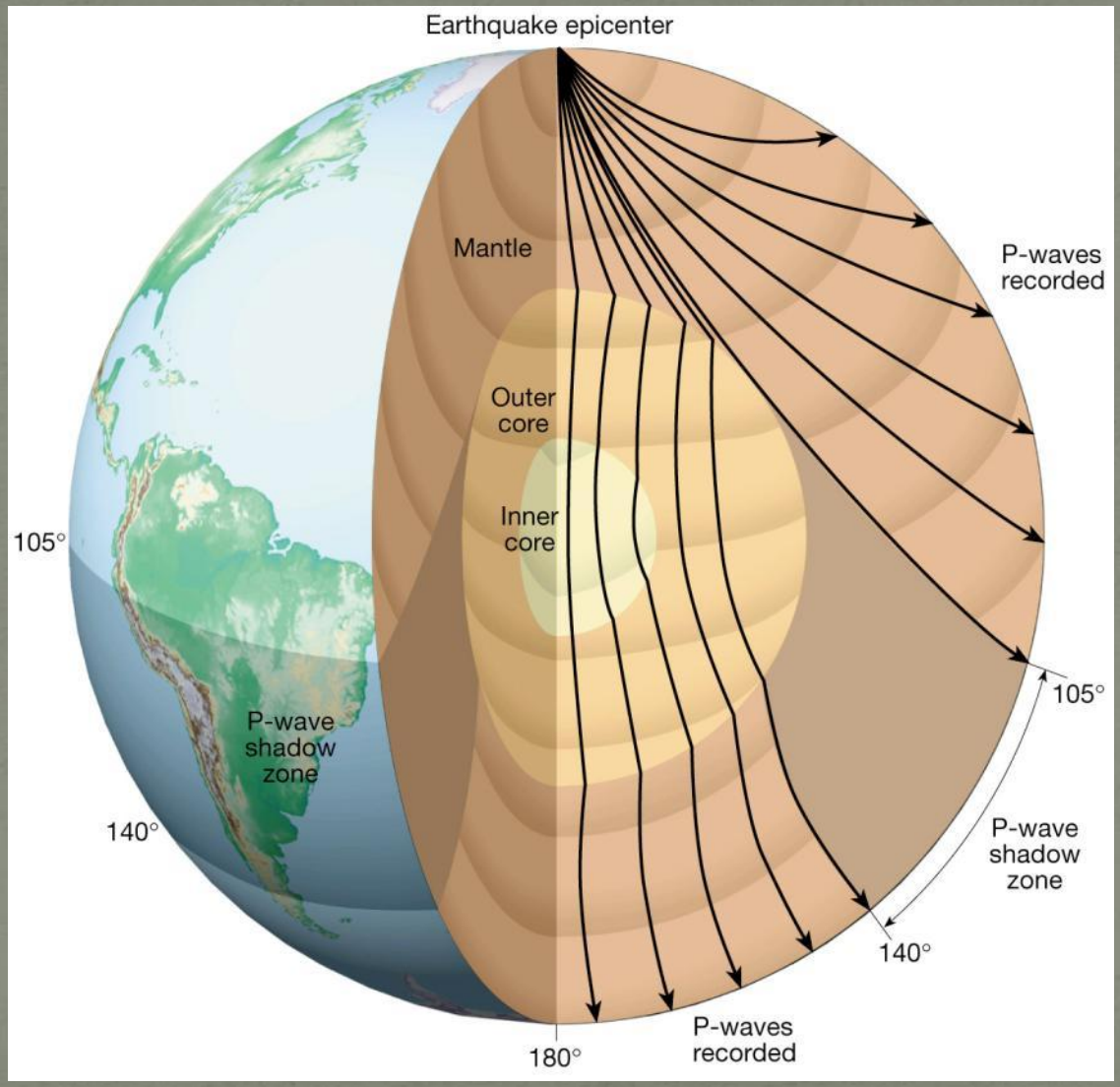
Body Waves



Surface Waves



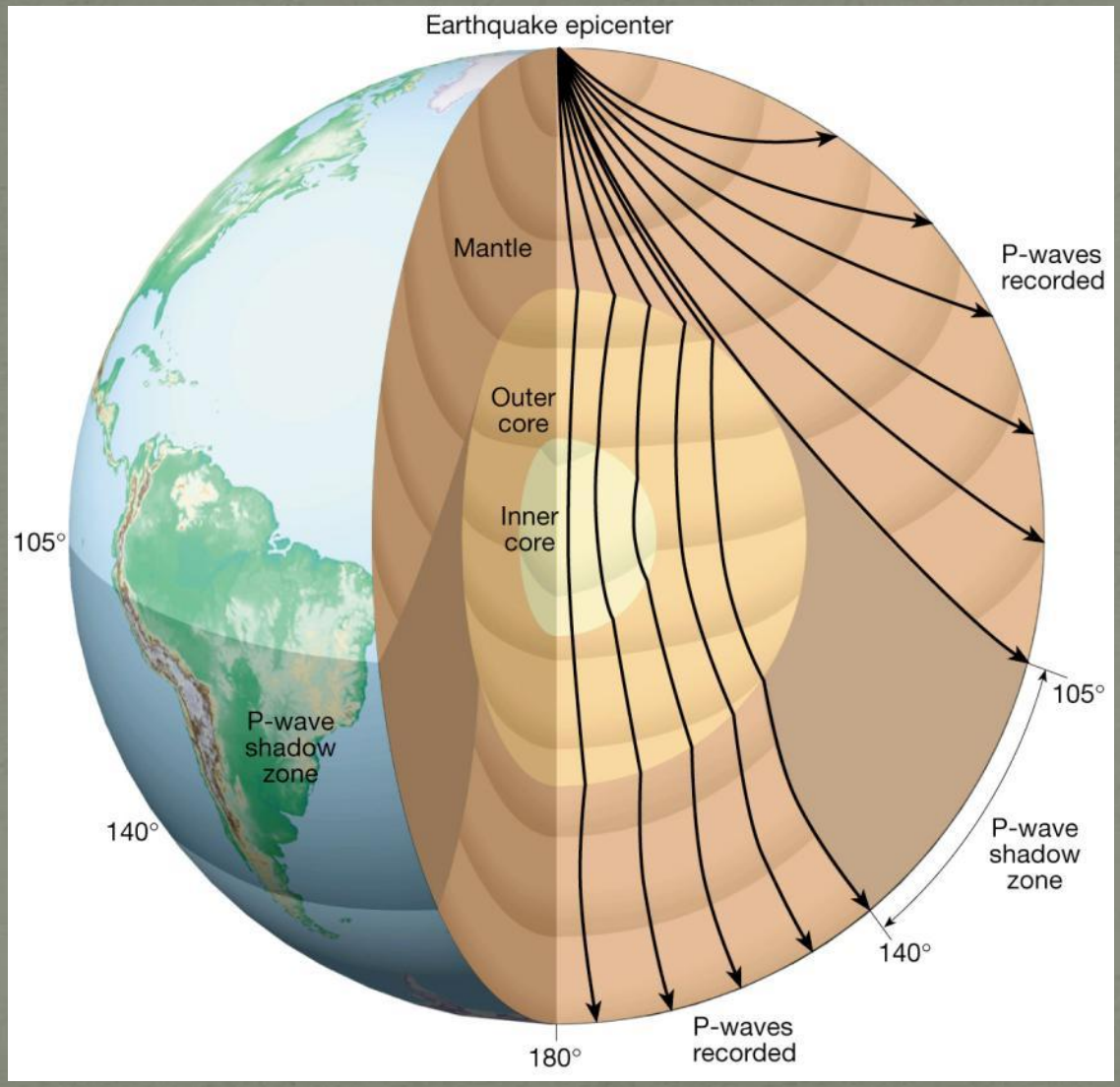
- Pg
- 256


Earthquake epicenter
Mantle
Outer core
Inner core
P-waves recorded
105°
105°
P-wave shadow zone
140°
140°
P-wave shadow zone
180°
P-waves recorded

Shadow Zone (R)

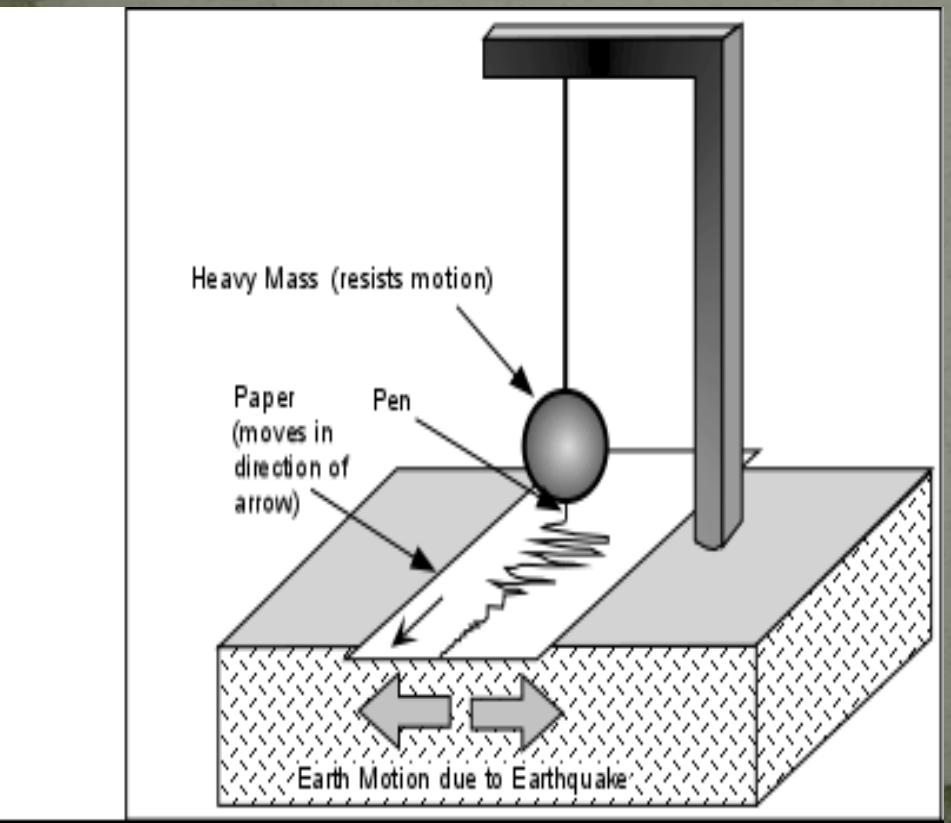
- Shadow Zone
- S waves get stopped by the liquid core

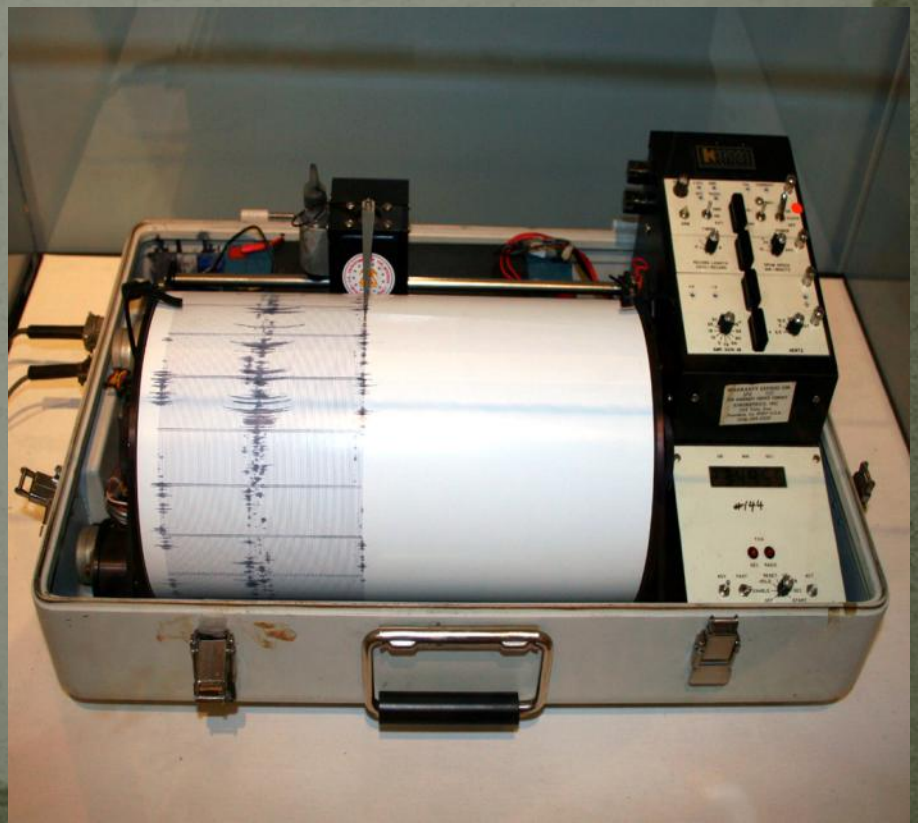
- P waves can go through the entire Earth, however, the liquid core does refract (bend) them. This creates a shadow zone where no waves are felt.


Earthquake epicenter
Mantle
Outer core
Inner core
P-waves recorded
105°
105°
P-wave shadow zone
140°
140°
P-wave shadow zone
180°
P-waves recorded

Detection

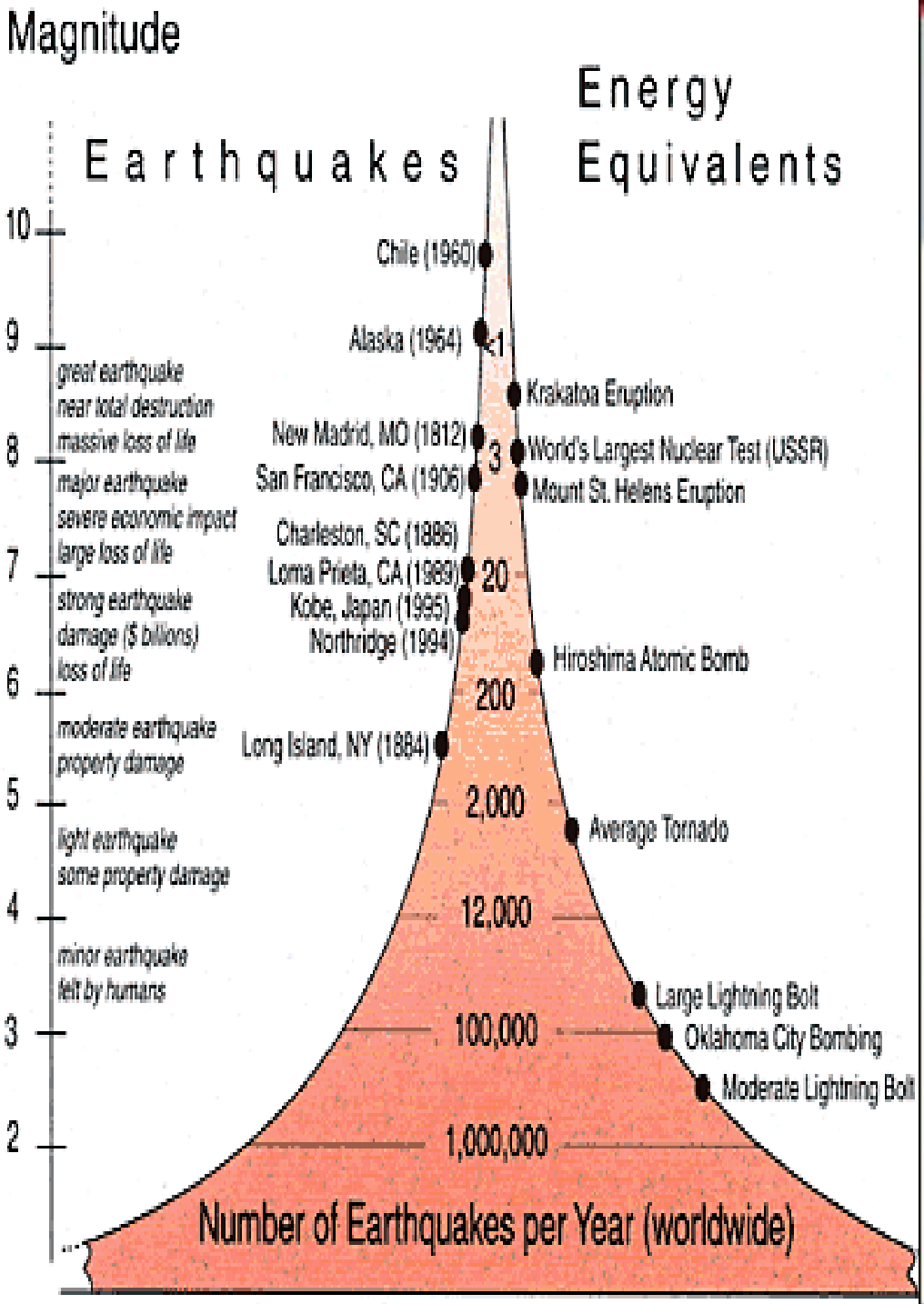
- How do we detect Earthquakes?
- Seismometers: measure Earthquake waves.
- Seismologist: Studies Earthquake waves.

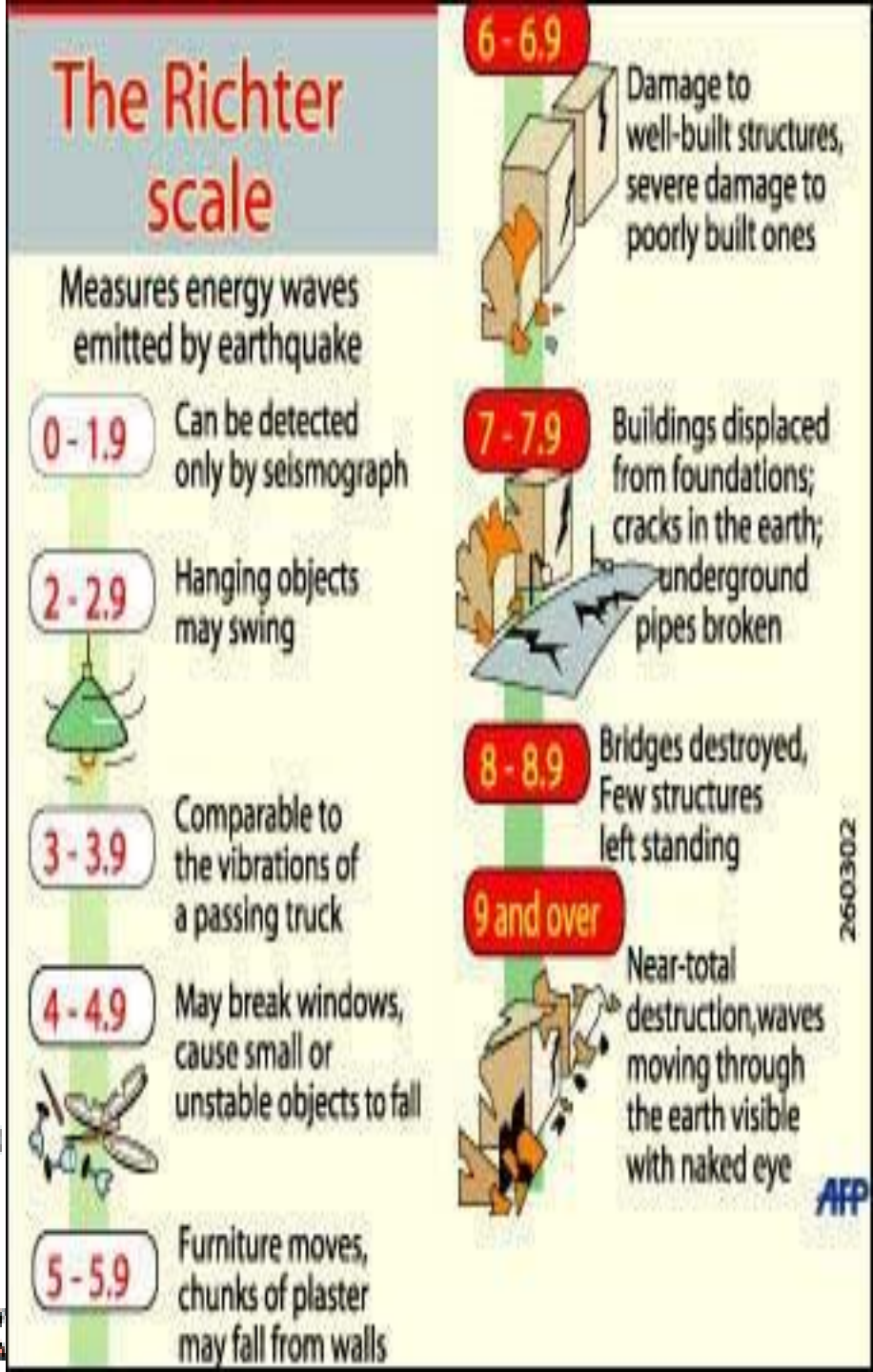




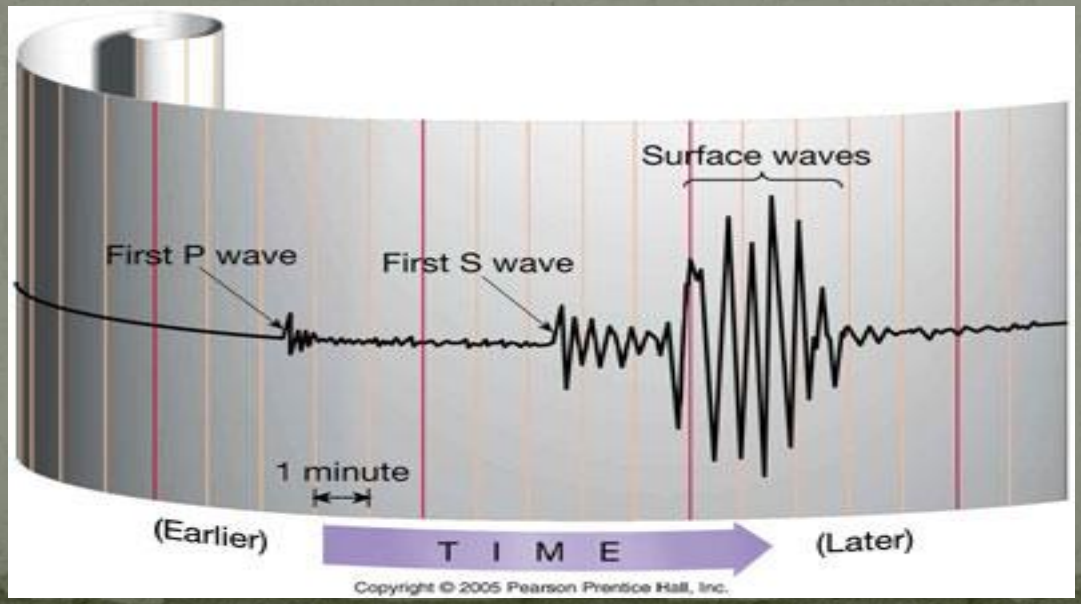
- What scale measures Earthquakes?
- Richter scale: Measure Earthquake strength.
- How much more powerful is each #?
- Each number is ~30 x's more powerful than the last.
- Shakes the ground 10 x's harder.

  What is the highest # on the scale?
- Basically a 1-10 scale
- No official top #, but no Earthquake has hit a 10 yet.

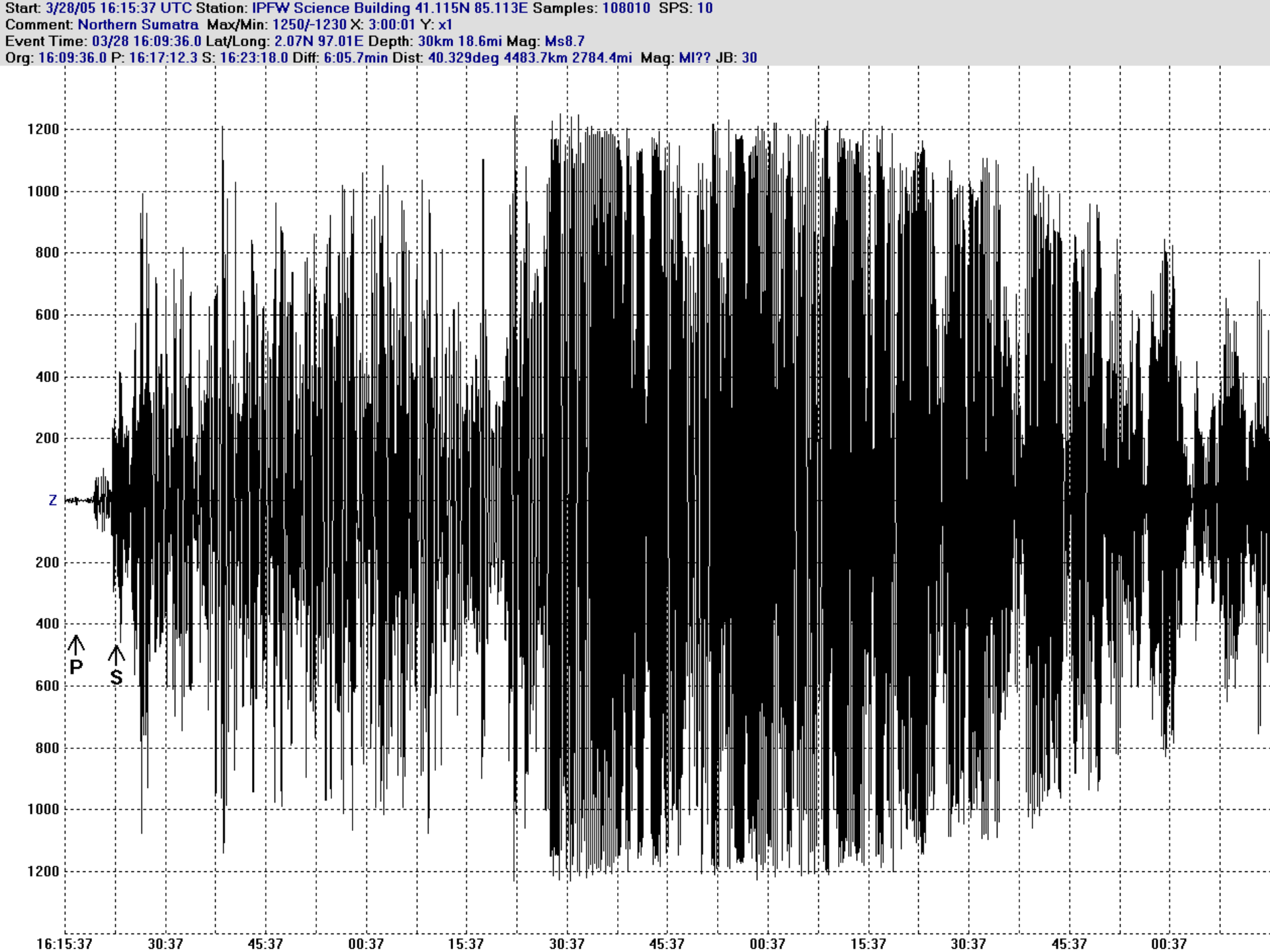

Magnitude
Earthquakes
Energy Equivalents
10
9
8
7
6
5
4
3
2
great earthquake
near total destruction
massive loss of life
major earthquake
severe economic impact
large loss of life
strong earthquake
damage ($ billions)
loss of life
moderate earthquake
property damage
light earthquake
some property damage
minor earthquake
felt by humans
Chile (1960)
Alaska (1964)
<1
Krakatoa Eruption
New Madrid, MO (1812)
3
World's Largest Nuclear Test (USSR)
San Francisco, CA (1906)
Mount St. Helens Eruption
Charleston, SC (1886)
Loma Prieta, CA (1989)
20
Kobe, Japan (1995)
Northridge (1994)
Hiroshima Atomic Bomb
200
Long Island, NY (1884)
2,000
Average Tornado
12,000
Large Lightning Bolt
100,000
Oklahoma City Bombing
Moderate Lightning Bolt
1,000,000
Number of Earthquakes per Year (worldwide)

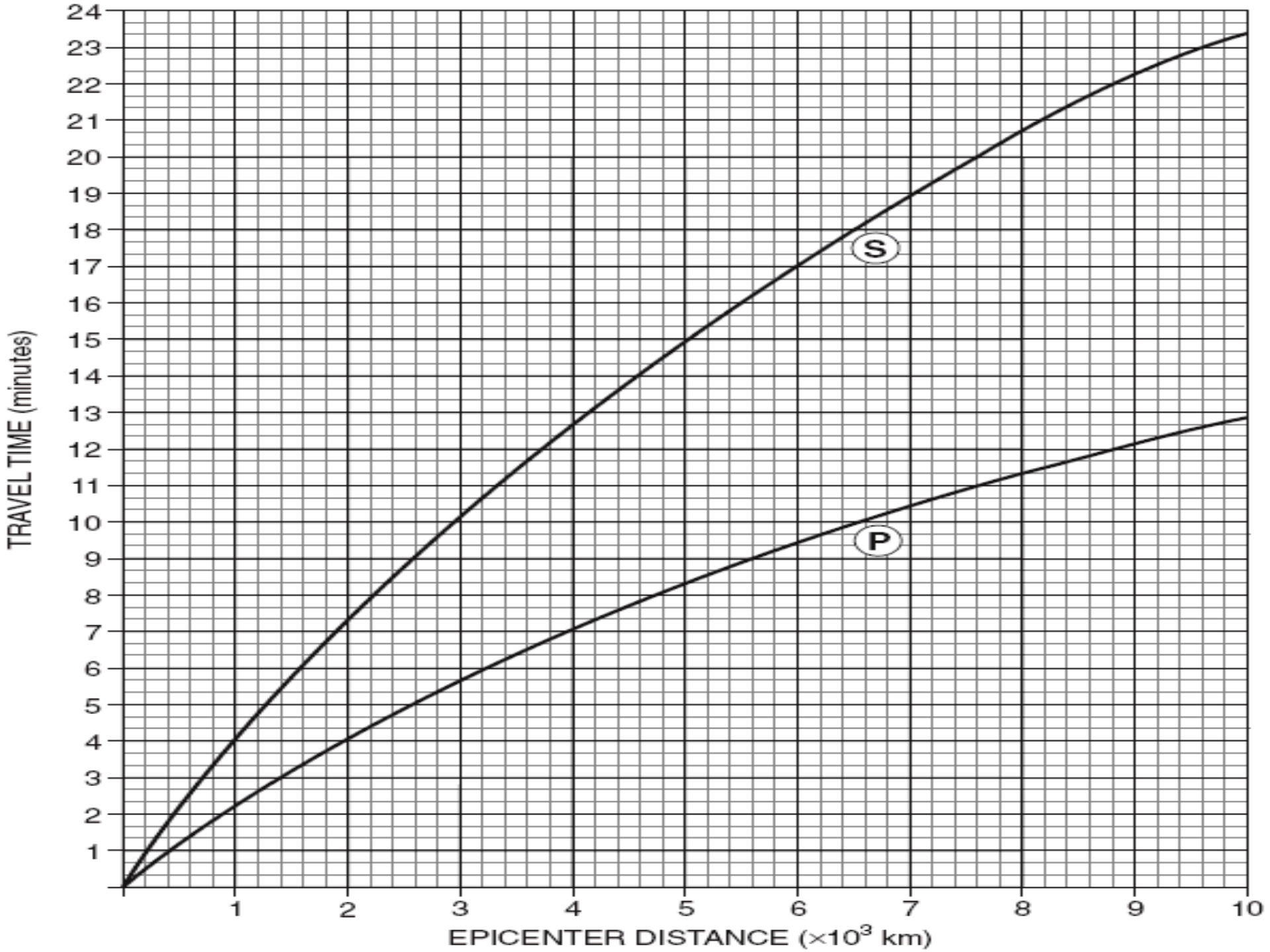

The Richter scale
Measures energy waves emitted by earthquake
0 - 1.9
Can be detected only by seismograph
2 - 2.9
Hanging objects may swing
3 - 3.9
Comparable to the vibrations of a passing truck
4 - 4.9
May break windows, cause small or unstable objects to fall
5 - 5.9
Furniture moves, chunks of plaster may fall from walls
6 - 6.9
Damage to well-built structures, severe damage to poorly built ones
7 - 7.9
Buildings displaced from foundations; cracks in the earth; underground pipes broken
8 - 8.9
Bridges destroyed, Few structures left standing
9 and over
Near-total destruction,waves moving through the earth visible with naked eye
260302
AFP

- What do we learn from Seismometers
- Seismograph: Record of Seismic activity.
- Measures arrival time of each. (First P then S then L)
- Shows difference of arrival time between waves.
- Shows strength and duration of the Earthquake.

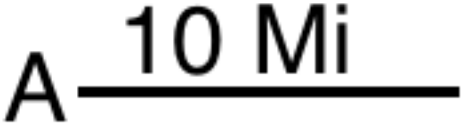


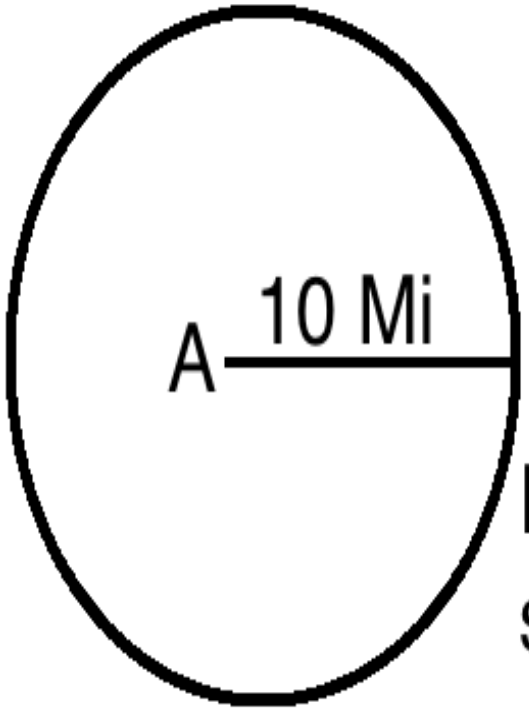
- What does the time difference between P & S wave tells us?
- Epicenter location: Finding arrival time differences between the P & S waves we can figure out how far away an Earthquake started.
- (like counting seconds between thunder & lightning)


Start: 3/28/05 16:15:37 UTC Station: IPFW Science Building 41.115N 85.113E Samples: 108010 SPS: 10
Comment: Northern Sumatra Max/Min: 1250/-1230 X: 3:00:01 Y: x1
Event Time: 03/28 16:09:36.0 Lat/Long: 2.07N 97.01E Depth: 30km 18.6mi Mag: Ms8.7
Org: 16:09:36.0 P: 16:17:12.3 S: 16:23:18.0 Diff: 6:05.7min Dist: 40.329deg 4483.7km 2784.4mi Mag: Ml?? JB: 30
1200
1000
800
600
400
200
Z
200
400
600
800
1000
1200
P
S
16:15:37
30:37
45:37
00:37
15:37
30:37
45:37
00:37
15:37
30:37
45:37
00:37

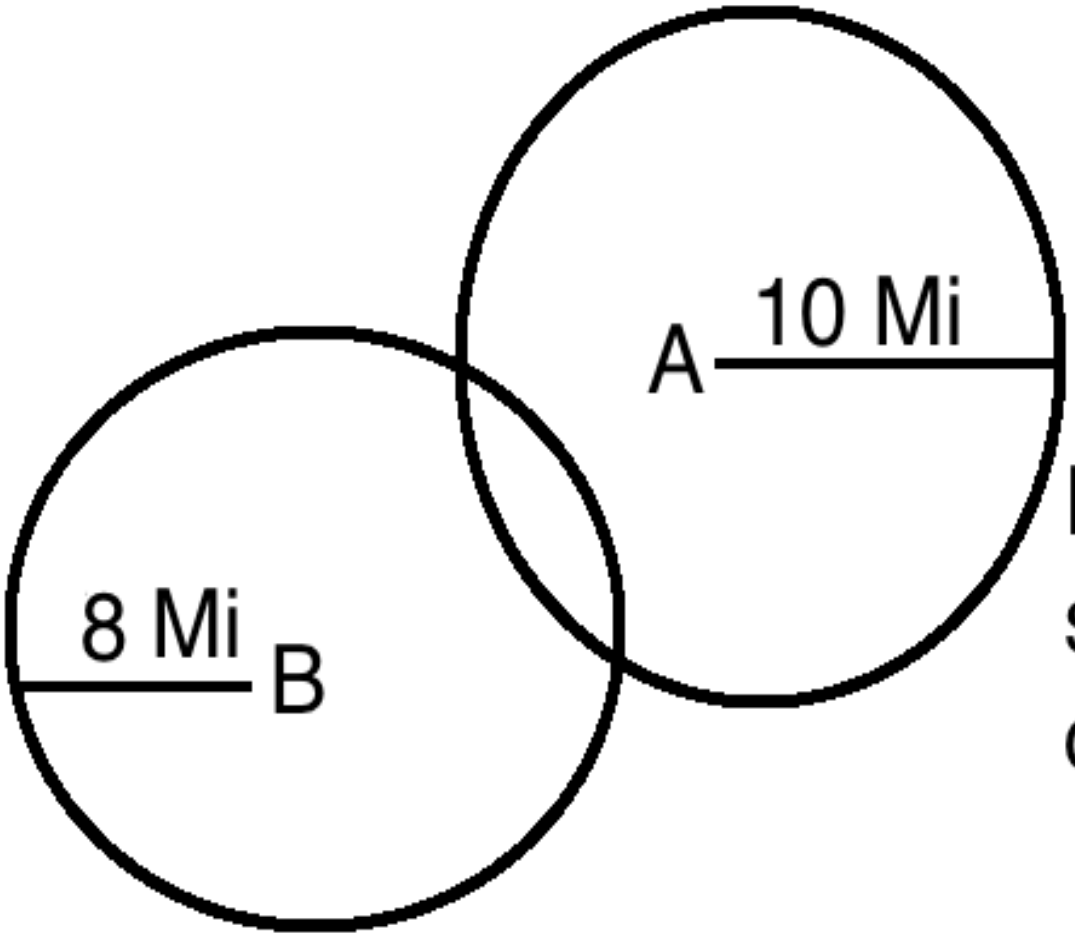

TRAVEL TIME (minutes)
EPICENTER DISTANCE (×10³ km)
S
P
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24

- Does knowing the distance of an epicenter tell us where the Earthquake was?
- Arrival time difference at 1 seismometer does not tell us where an Earthquake started, only how far it was from that 1 station.

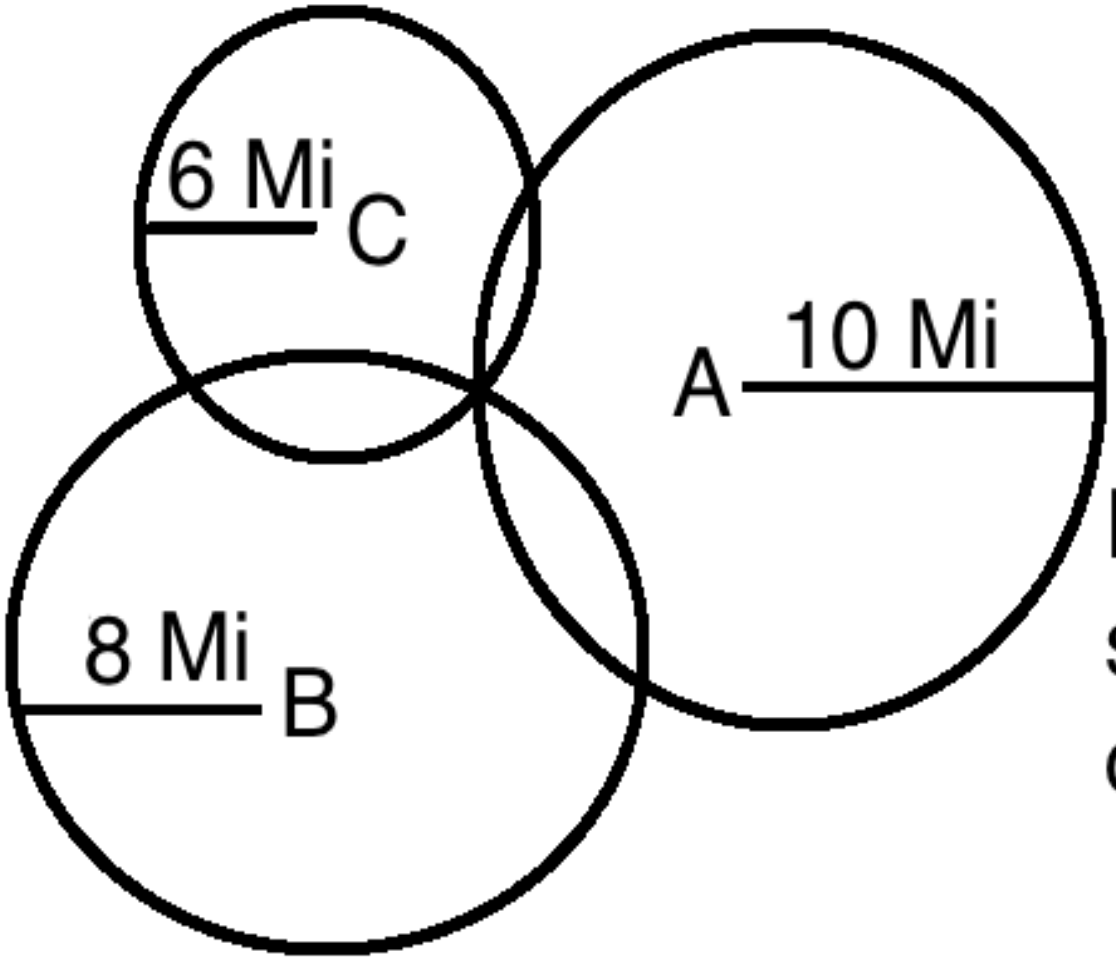

A
10 Mi



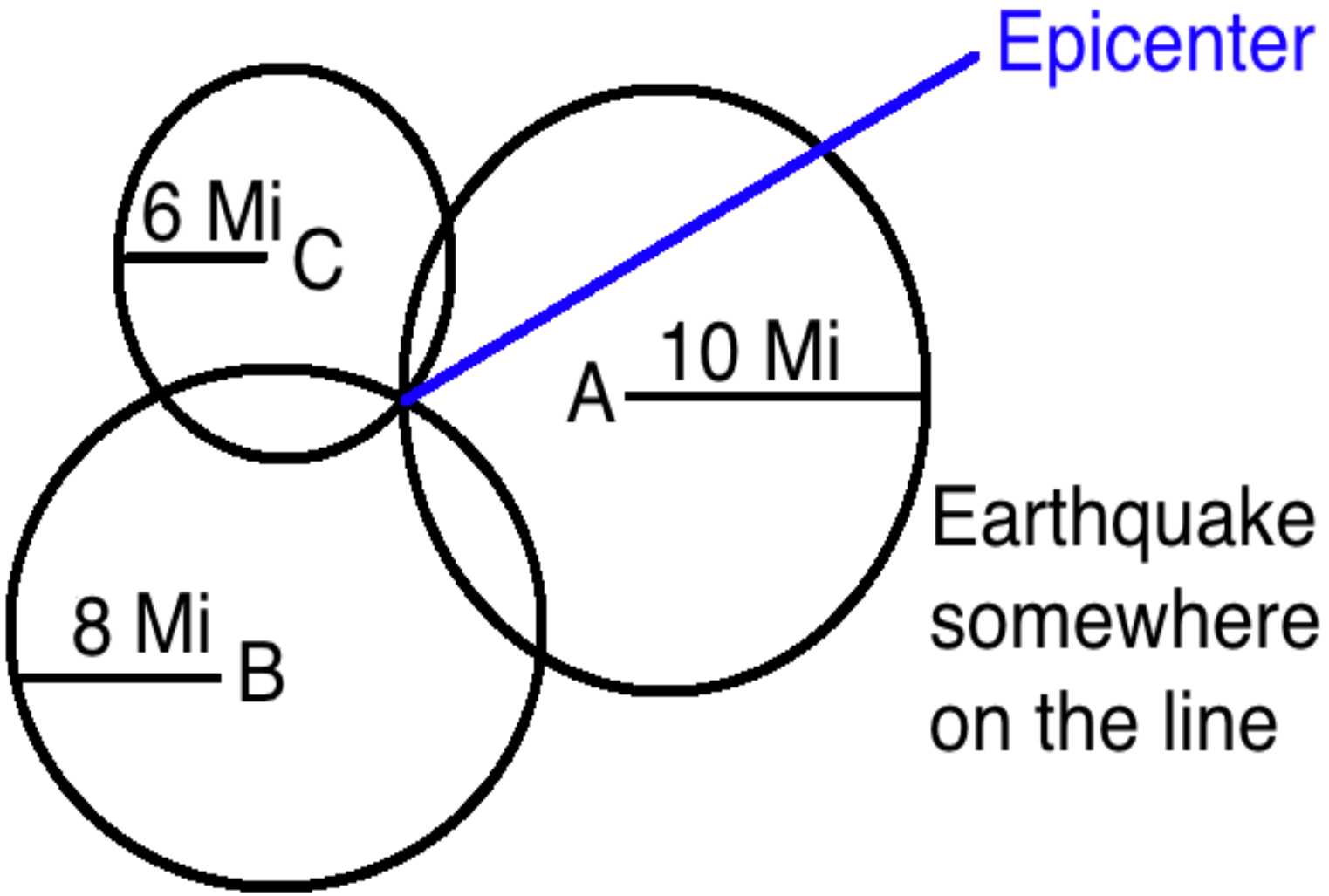
Earthquake somewhere on the line



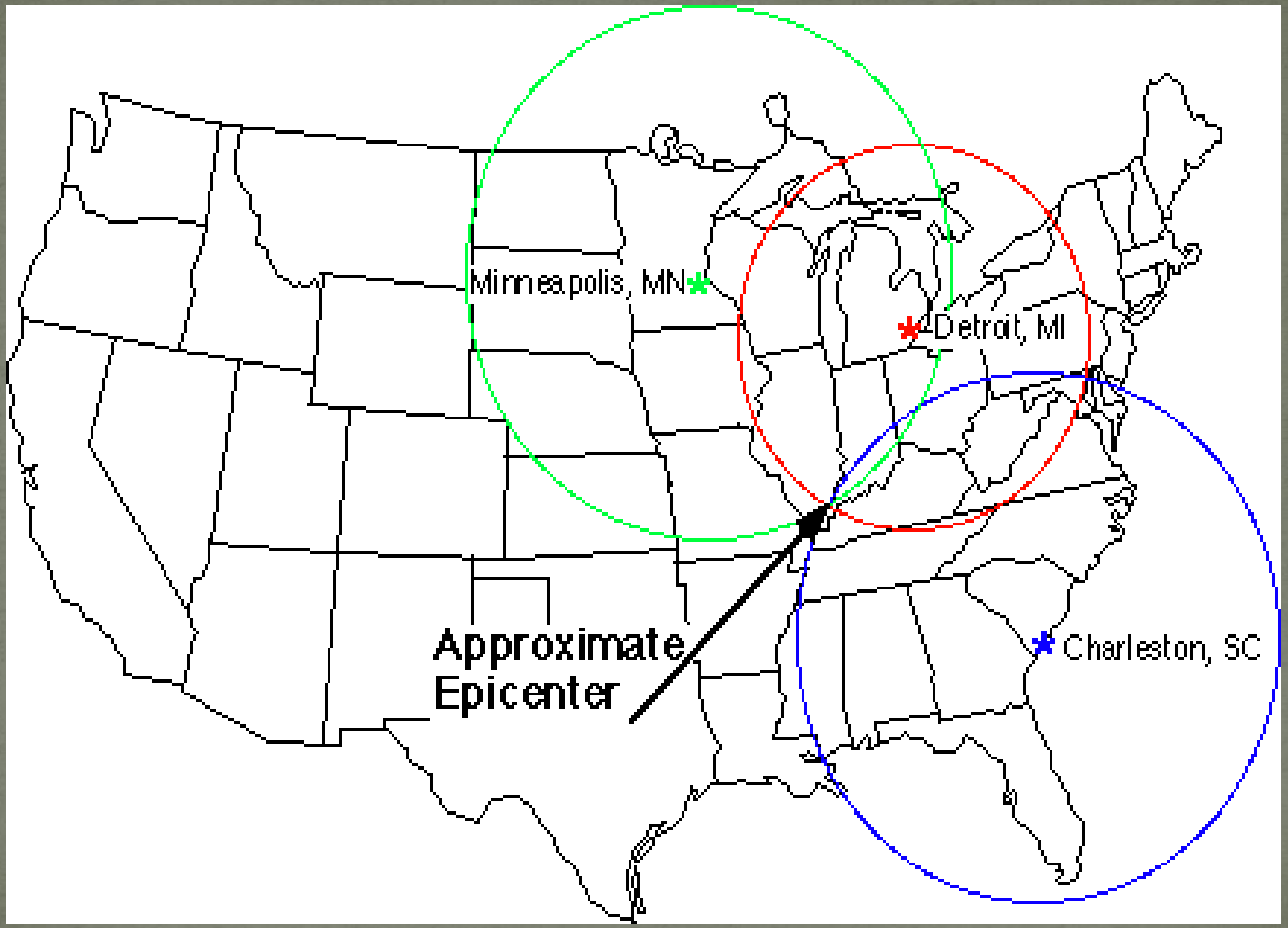
Earthquake somewhere on the line



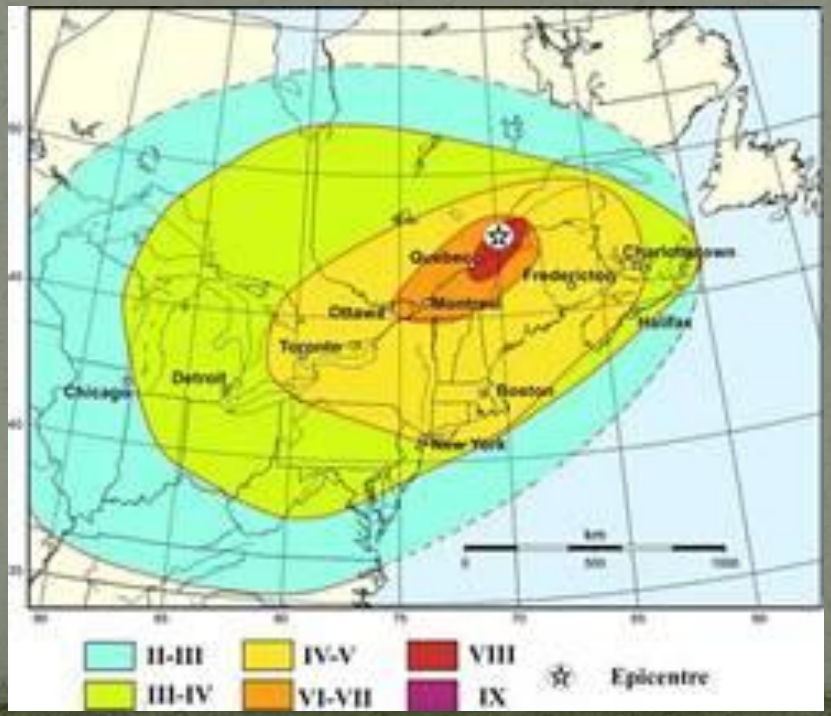
Earthquake somewhere on the line


Epicenter
6 Mi
C
10 Mi
A
8 Mi
B
Earthquake somewhere on the line

- How many Seismometers are needed to find an Epicenter?
- Triangulation: Using 3 Seismometers to locate 1 common point which is your Epicenter.


Minneapolis, MN
Detroit, MI
Charleston, SC
Approximate
Epicenter

- Where do Earthquakes strike the hardest?
- Like water waves, Earthquake waves strike hardest at the Epicenter. Using isoseismic maps we can also determine the epicenter (not as specific). They look like contour lines with the hardest hit #'s in the center.



- Preparation:
- If you live in an Earthquake prone location:
- Earthquake preparation is done Ahead of time!!!
- Have properly built house.
- Secure hazards in your house.
- Emergency kit.
- Meet up plan.
- Get outside if possible.
- Cover up / get in a door way.

- Earthquake Explanation Video
- http://www.youtube.com/watch?v=VSgB1IWr6O4
- Earthquakes video long
- https://www.youtube.com/watch?v=hReS4Fm94L4

Regents Triangulation Lab (R)

- Purpose – Learning how to find an epicenter.
- Data – Location distances sheet
  - Triangulated map
  - Question sheet

Conclusion:

Define Earthquakes? Where do they happen?

Parts: Focus, Epicenter

Waves: P-waves, S-waves, L-waves

Seismometers

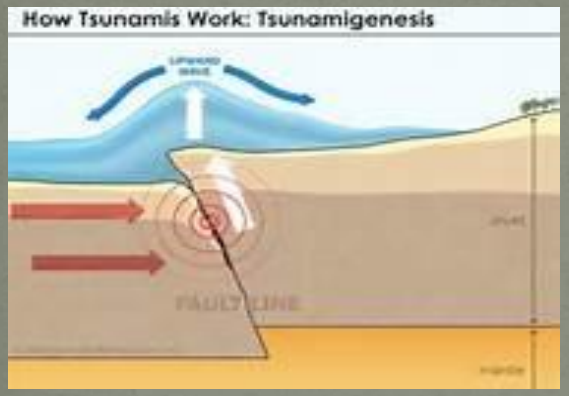
Finding distance to an Earthquake

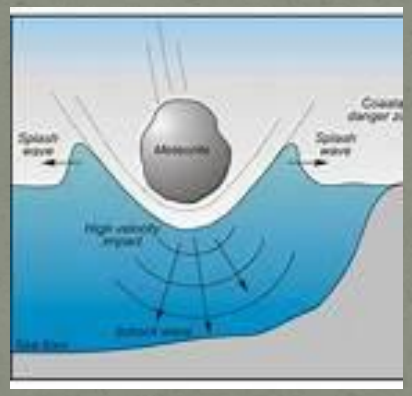
Triangulation

- What else can an Earthquake do besides shake the ground???
- http://www.youtube.com/watch?v=foxww-tMoNg

Tsunami

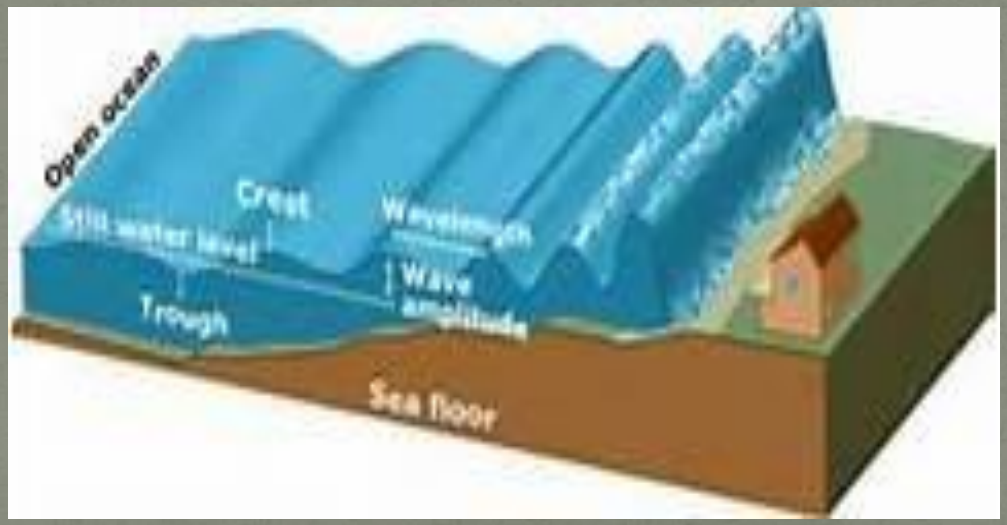
- What is a Tsunami?
- Tsunami: Series of large ocean waves caused by a large displacement of water.
- What can cause them?
- Caused by: underwater Earthquake, Volcanoes, Landslides and Meteors.





- Speed?
- They can travel at hundreds of mph and go several miles inland.

- How do they look in the open water?
- In the open water they would only be a few inches/feet high. It is the land that pushes them up and creates the wave.



- What do they look like?
- Typically resembling a large rising wall of water, not a crest wave like the beach. (multiple waves)

This is Not what a Tsunami looks like!
See next slide for actual Tsunamis

- REAL TSUNAMIS

- Full run though on Tsunamis
- http://www.youtube.com/watch?v=chbbiSCczB8

- Waves From Japan Tsunami – Helicopter shot
- http://www.youtube.com/watch?v=w3AdFjklR50
- Japan Earthquake and Tsunami
- http://www.youtube.com/watch?v=8Pa3LJ9Cvb0&feature=related

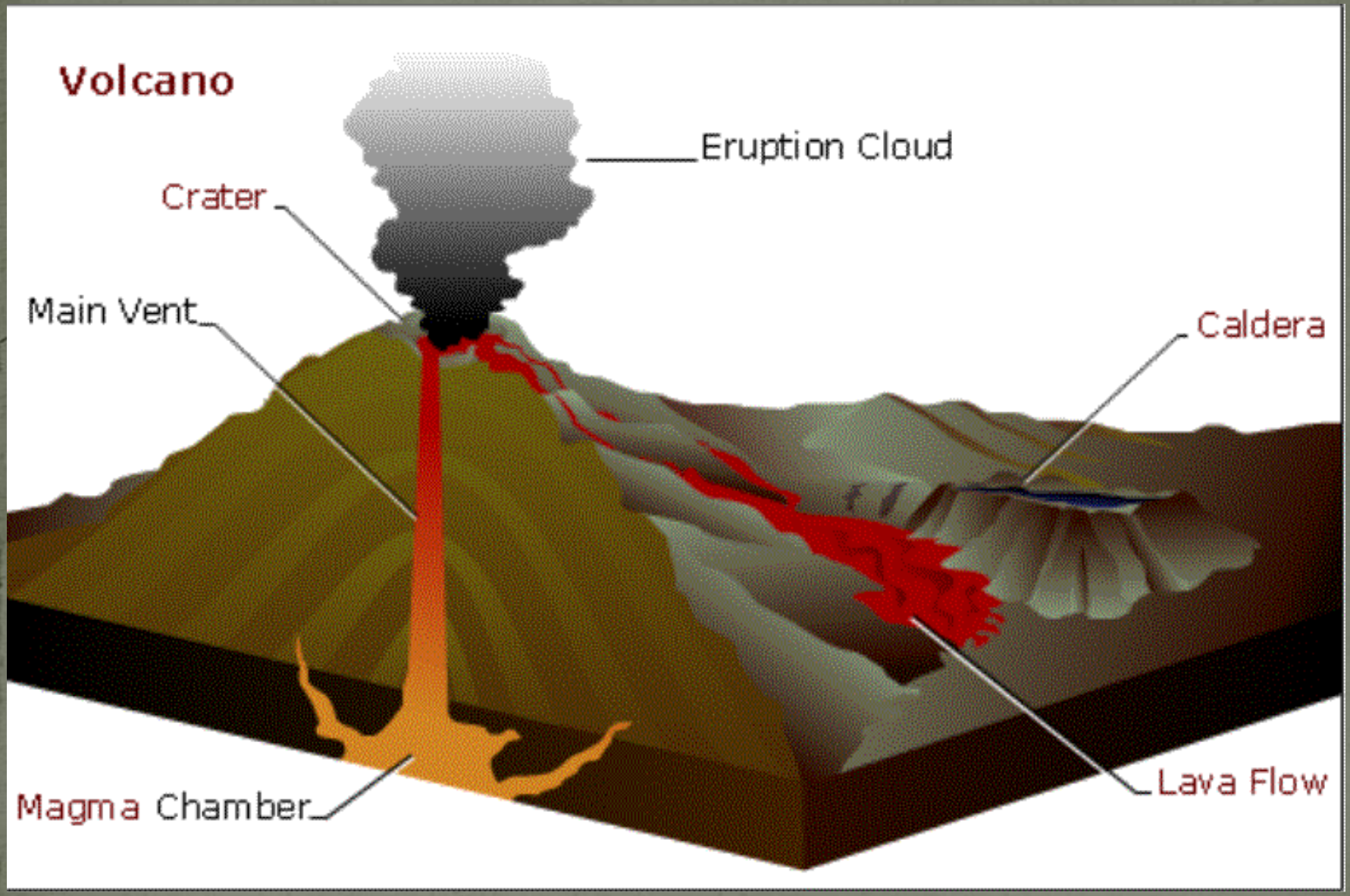
Tsunami Preparation

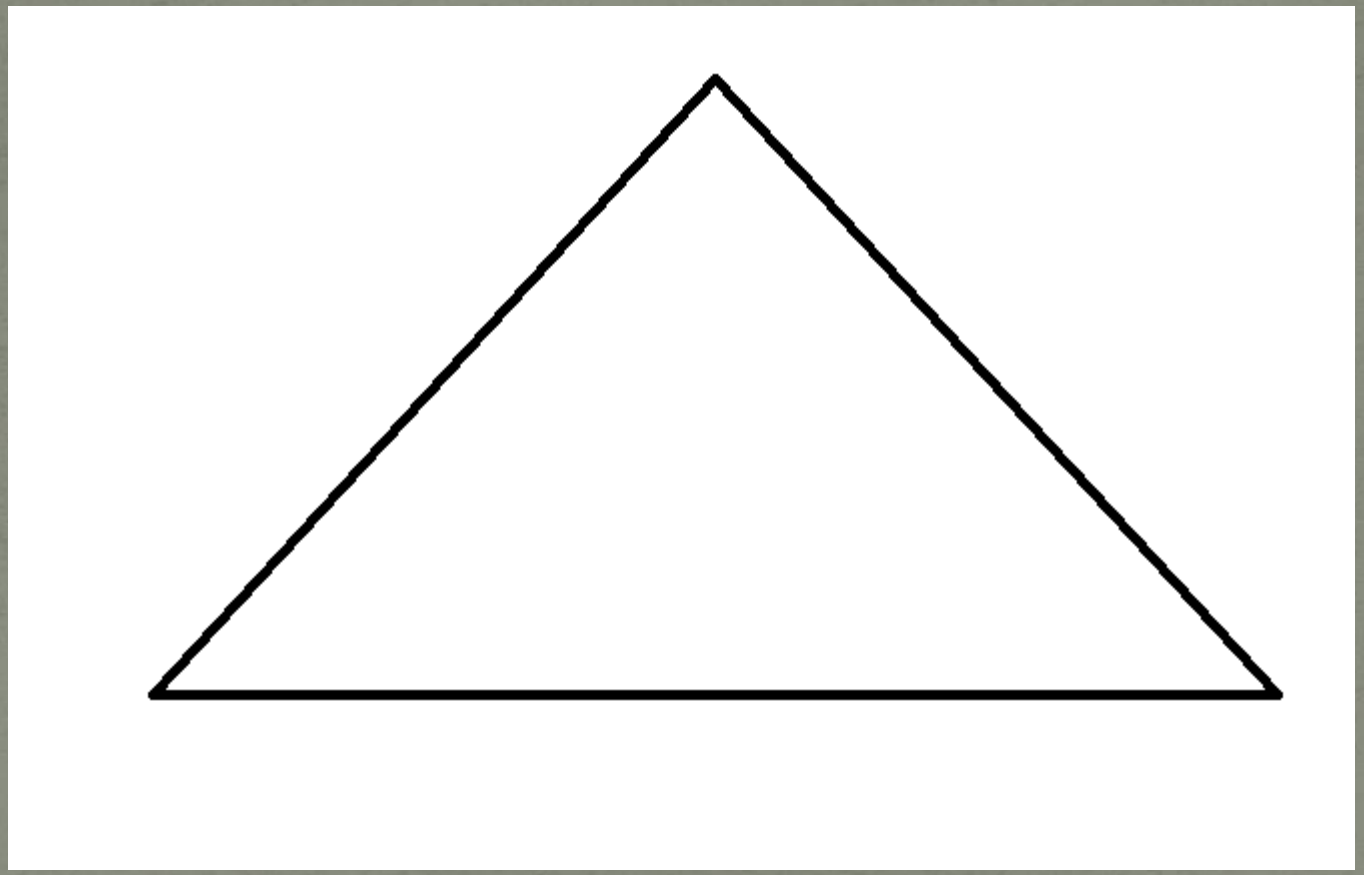
- Tsunami Preparation:
- Listen for Sirens
- Watch for water receding extremely far out to sea
- Follow evacuation routes
- Get to High Grounds
- Get far enough in land.

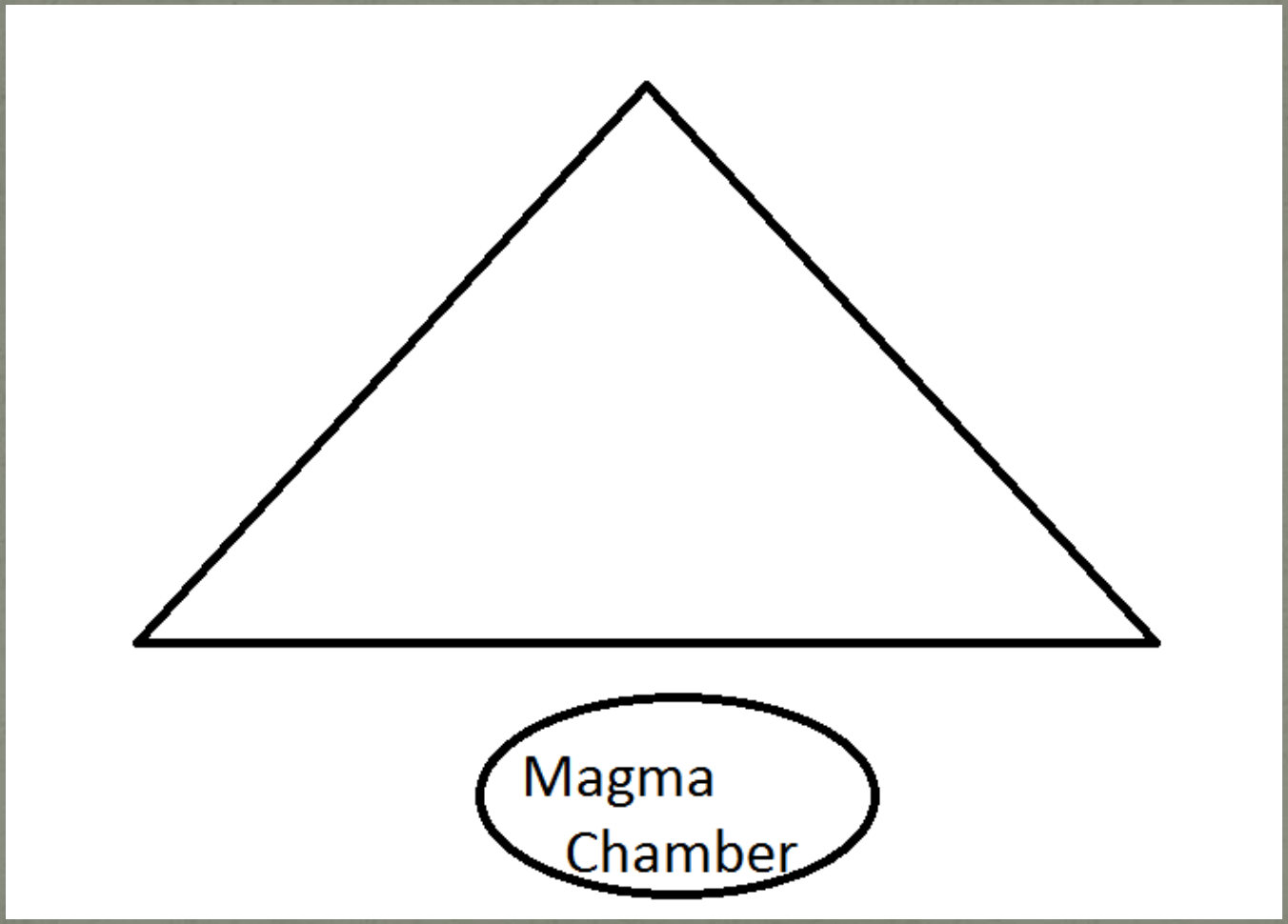
- Japan Before and After Pictures.
- http://www.guardian.co.uk/world/interactive/2012/mar/08/japan-tsunami-recovery-interactive

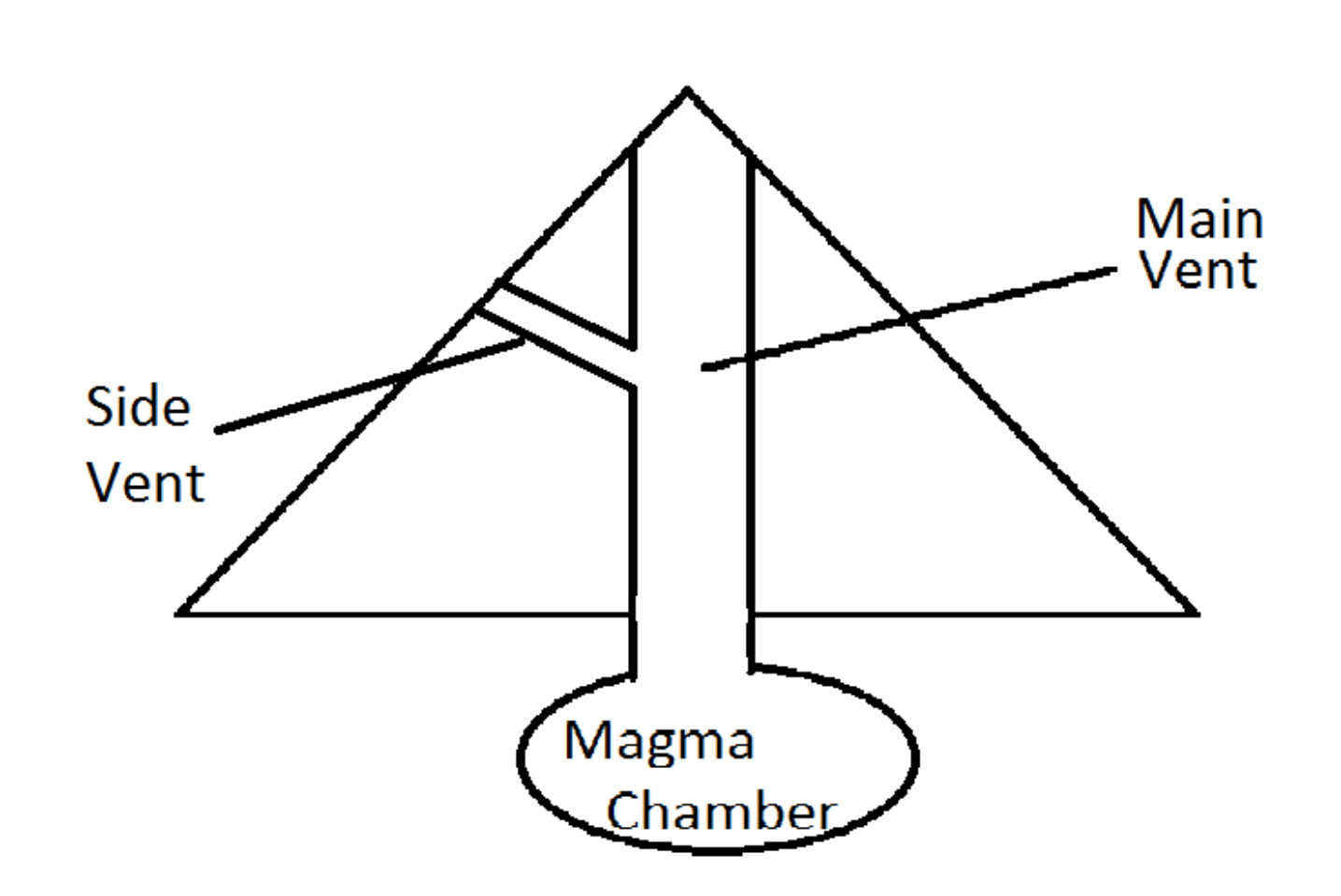
Volcanoes

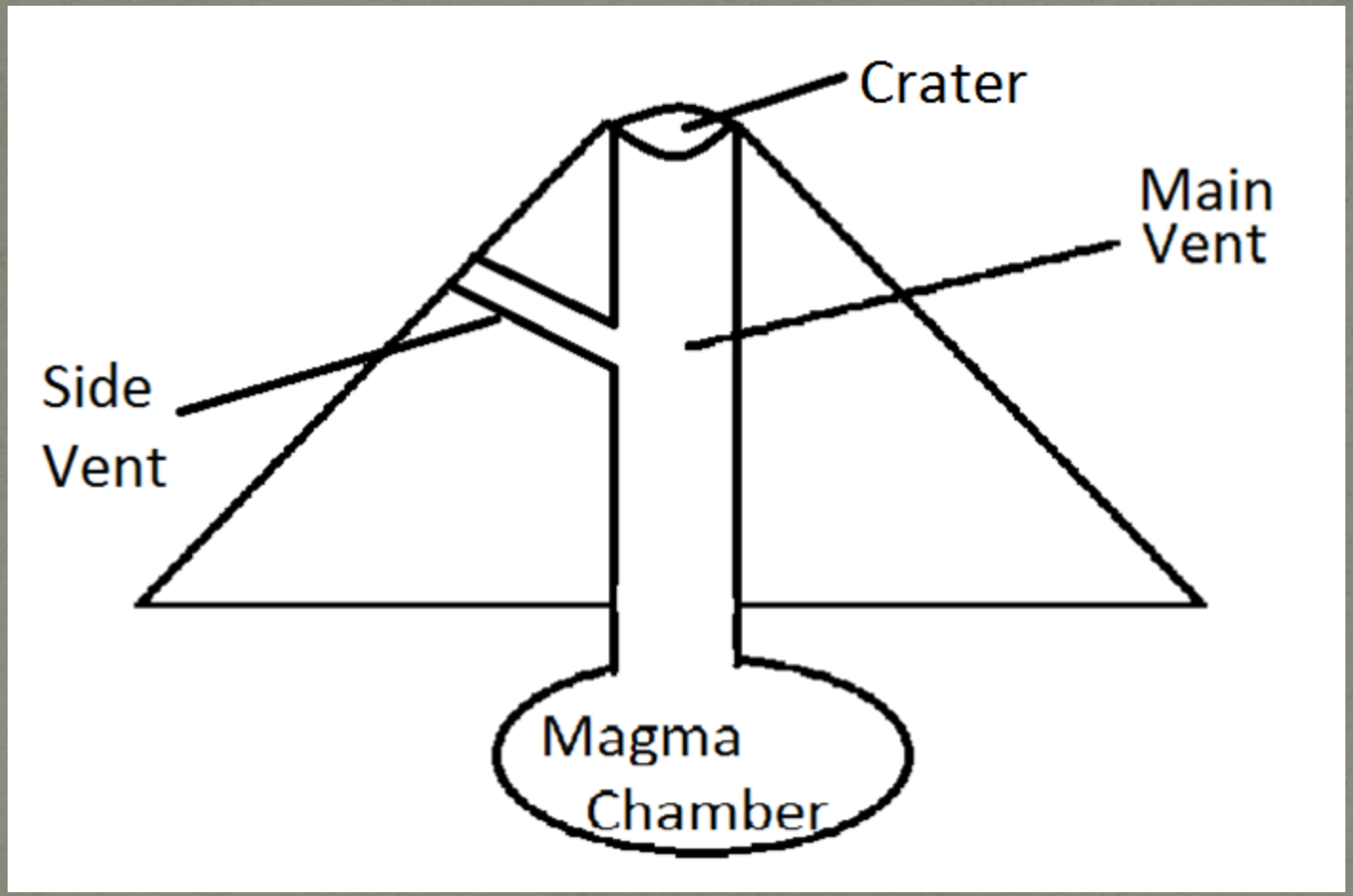
- Volcano?
- Volcano: Opening in the Earth that allows:
- Lava, ash and gas to escape.

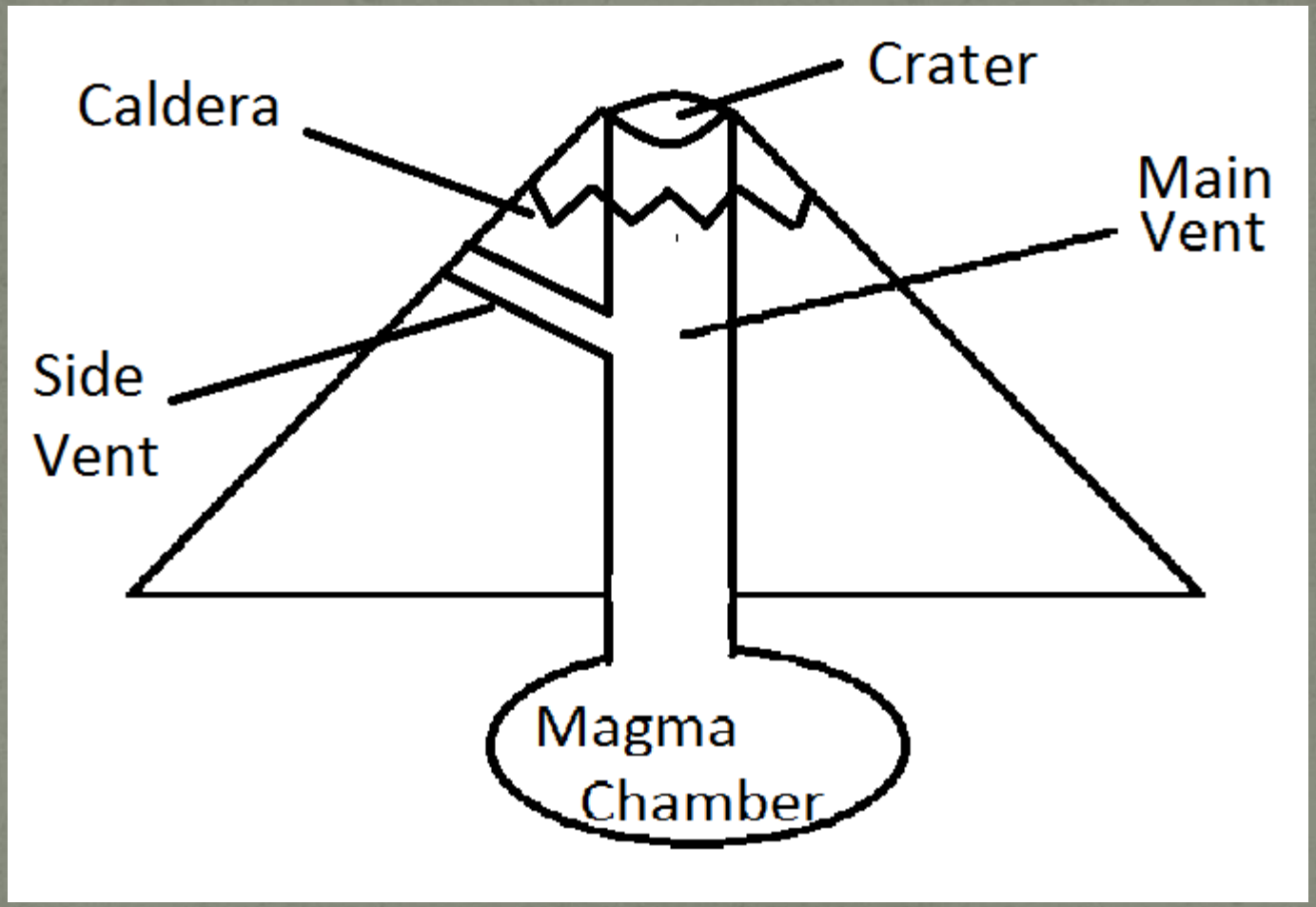

Volcano
Eruption Cloud
Crater
Main Vent
Caldera
Lava Flow
Magma Chamber




Magma
Chamber


Main
Vent
Side
Vent
Magma
Chamber


Crater
Main
Vent
Side
Vent
Magma
Chamber

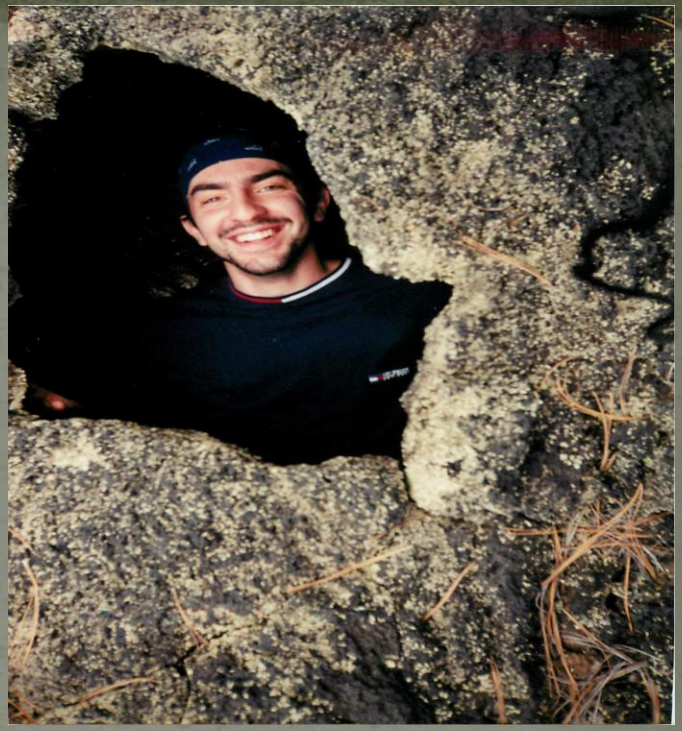

Crater
Caldera
Main
Vent
Side
Vent
Magma
Chamber

Crater

- Caldera

Parts of a Volcano

- Magma Chamber?
- Magma Chamber: Stores Magma underground.
- Vent?
- Vent: Brings Magma to the surface
- Crater?
- Crater: Depression left behind where Lava erupts.
- Caldera?
- Caldera: Large collapse of a crater.



- What else can Volcanoes erupt besides lava?
- Other materials ejected from Volcanoes:
- Pyroclastic material: debris, rock and ash
- Types:
- Dust: Smallest particles ejected
- Ash: Rice size particles
- Cinder: Golf ball sized particles
- Bombs: Large volcanic debris

- Poisonous gas is also ejected.

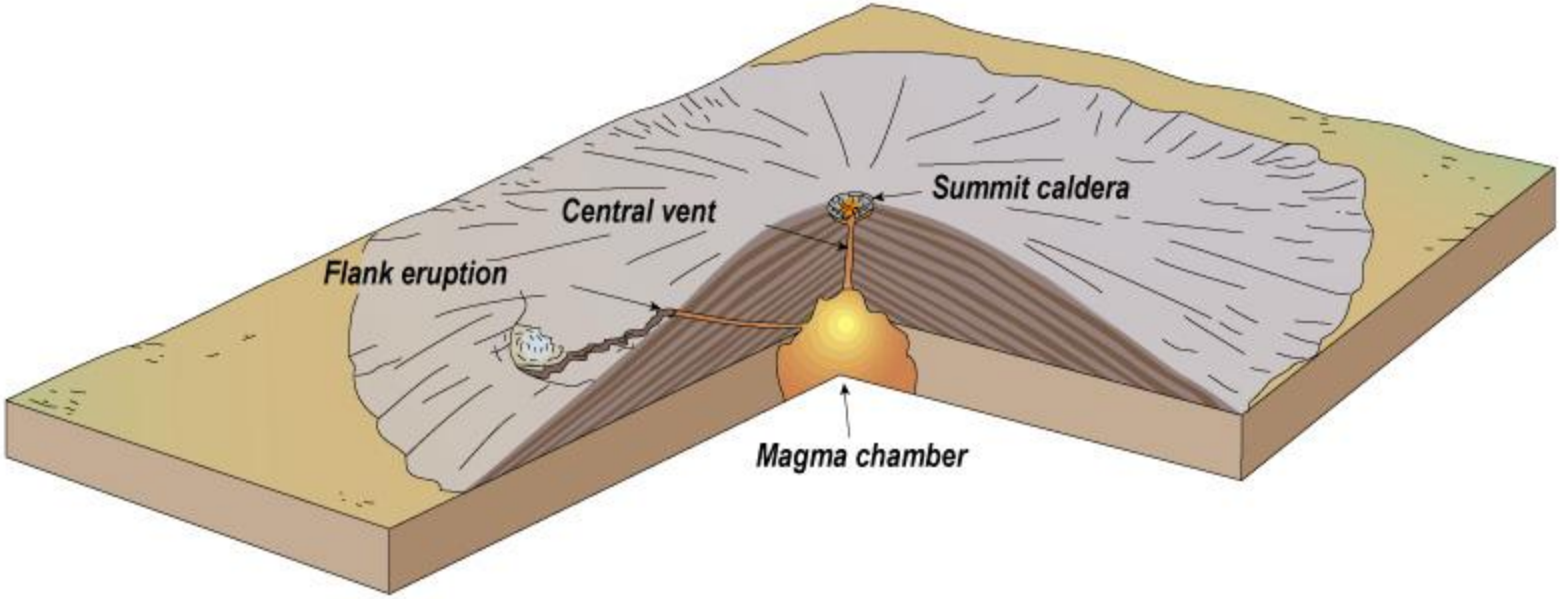
Volcanic Dust

Volcanic Ash

Volcanic Cinder

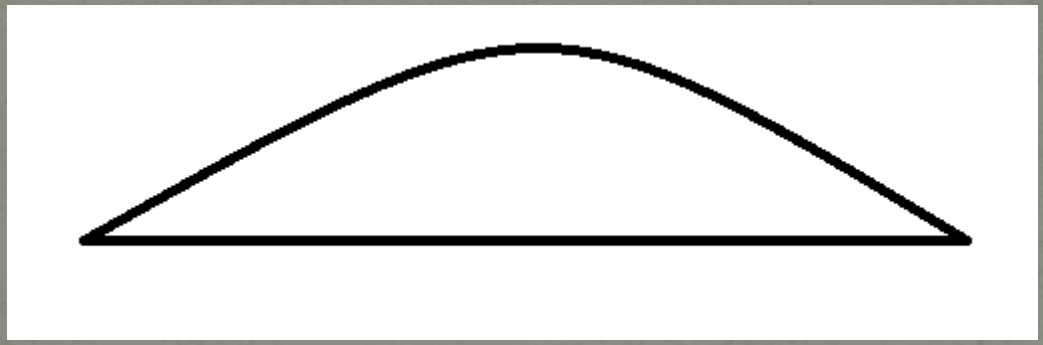
Volcanic Bombs

- How many types of Volcanoes are there?
- There are 3 common types of Volcanoes:
- 1) Shield
- 2) Cinder Cone
- 3) Composite

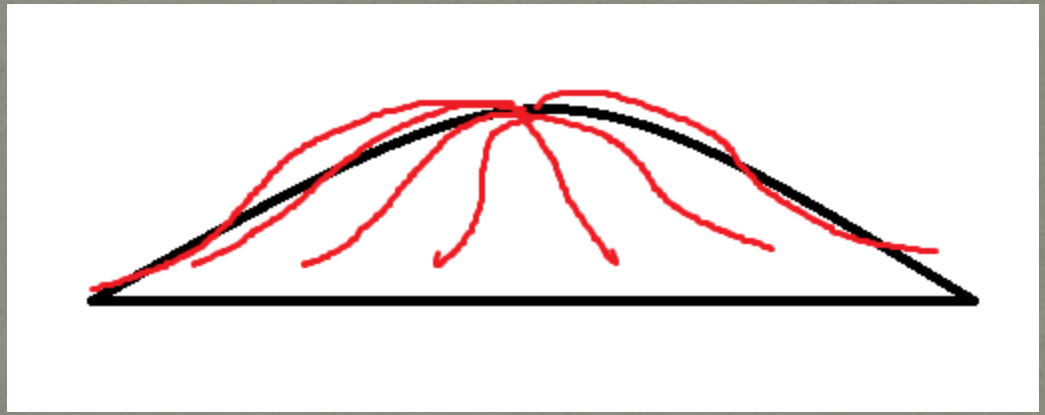


(b) Shield volcano

es



Shield Volcano



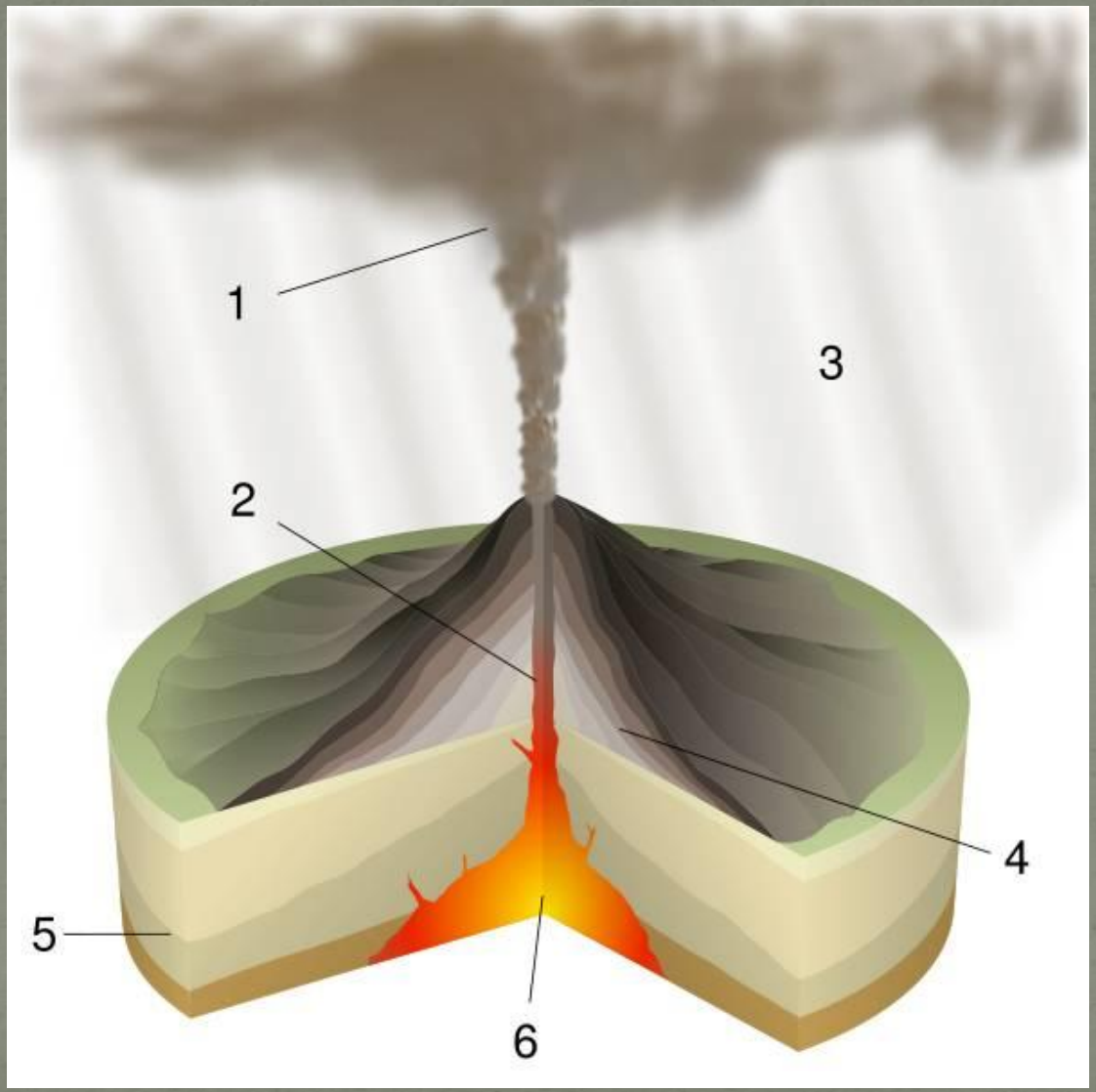
Layers of building lava flows

Types of Volcanoes

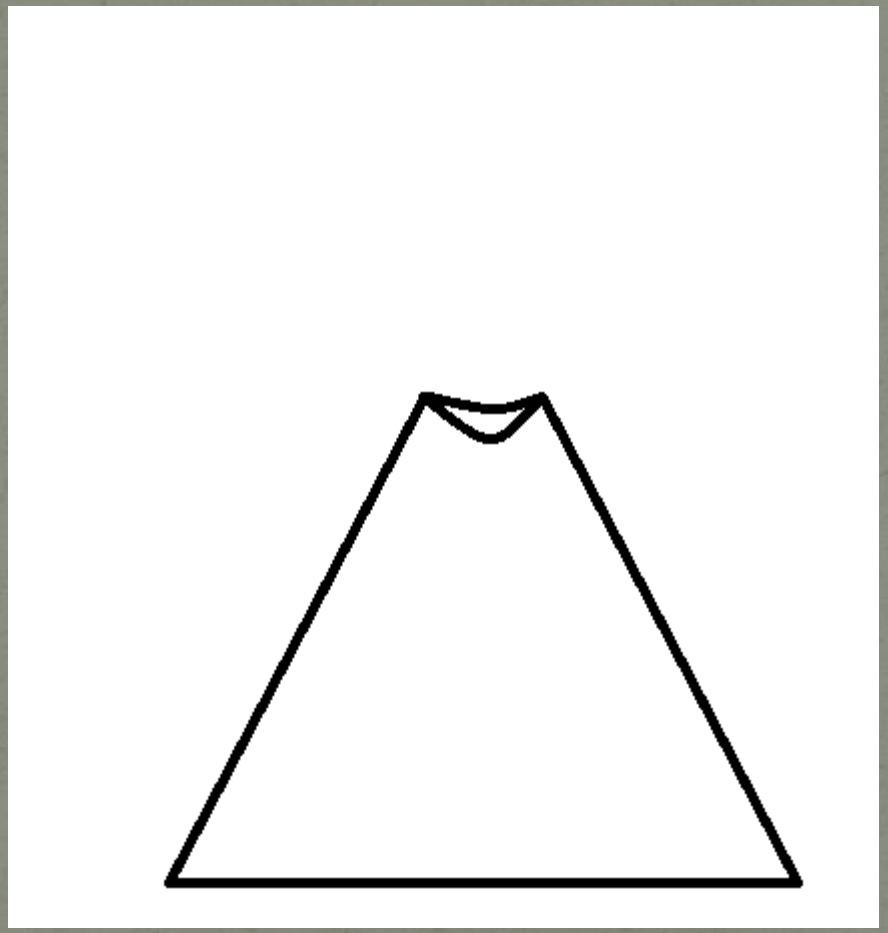
- Shield Volcano
- Shield Volcano:
- Quiet eruptions
- Lava flows build on top of each other (can continually erupt for years)
- Gentle sloped sides
- Dome shaped (Shield on its side)

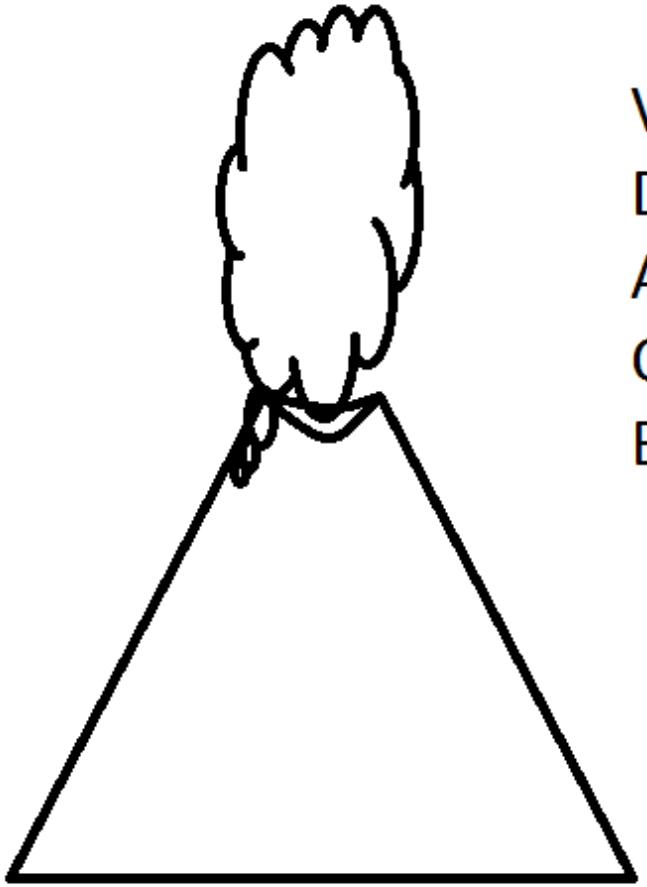
- Hawaiian Islands

Pahoehoe

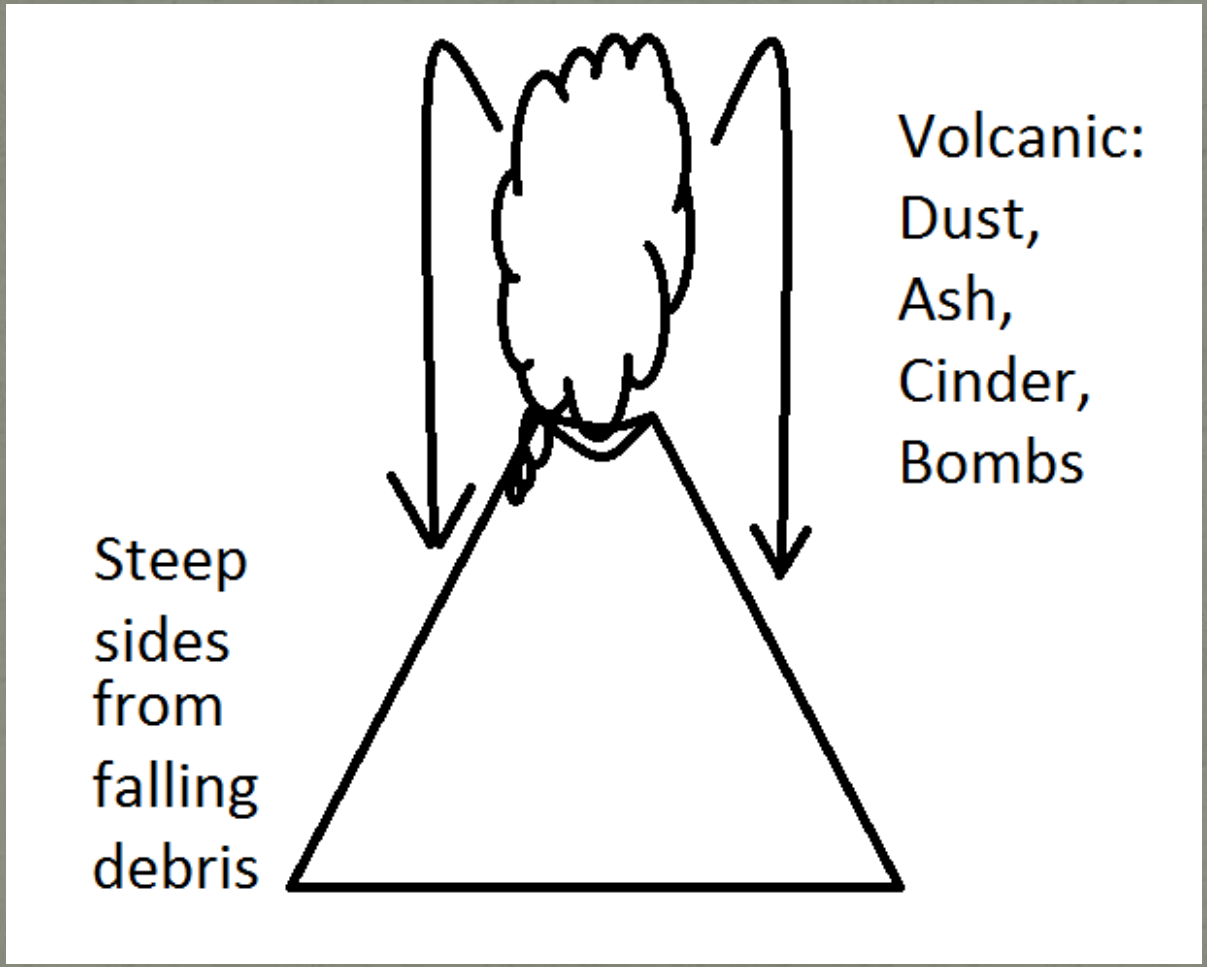

1
2
3
4
5
6

Cinder Cone Volcano





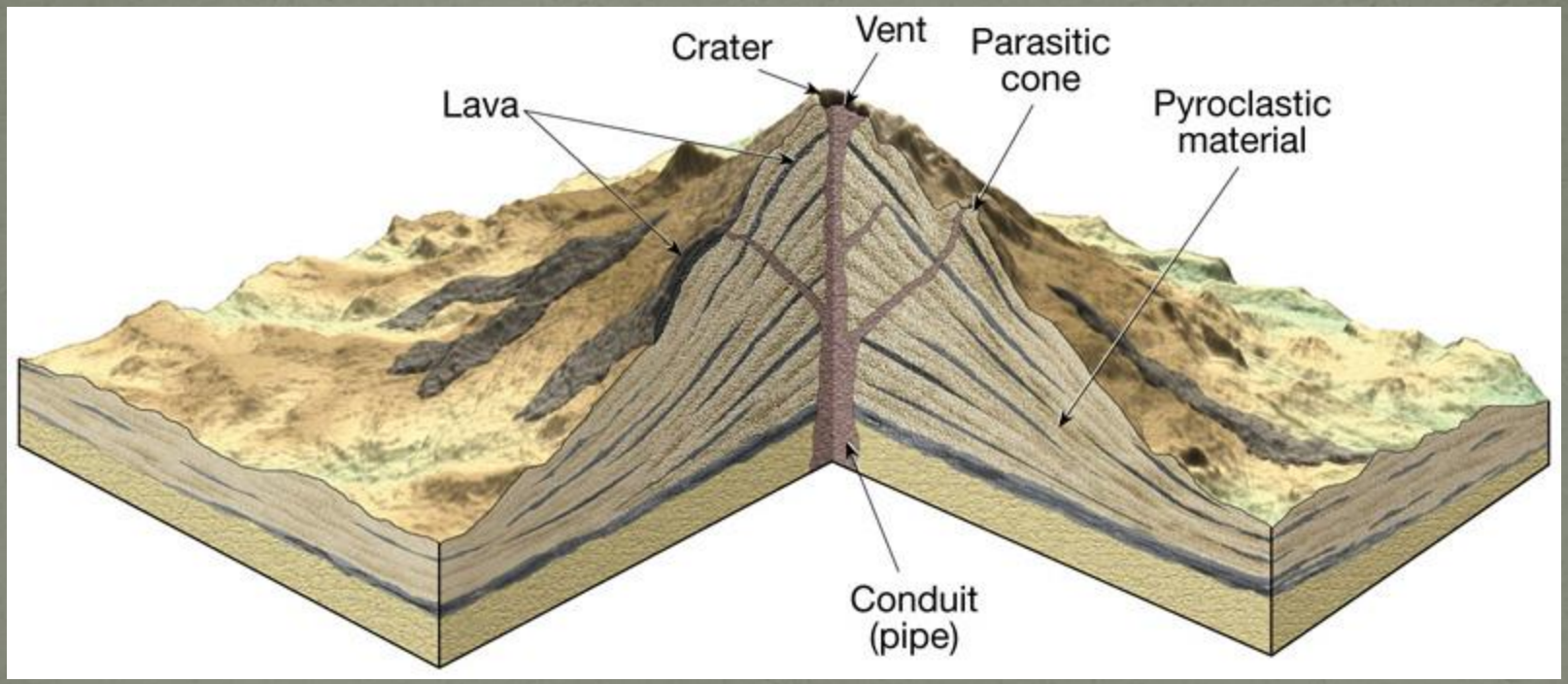
Volcanic:
Dust,
Ash,
Cinder,
Bombs


Volcanic:
Dust,
Ash,
Cinder,
Bombs
Steep
sides
from
falling
debris

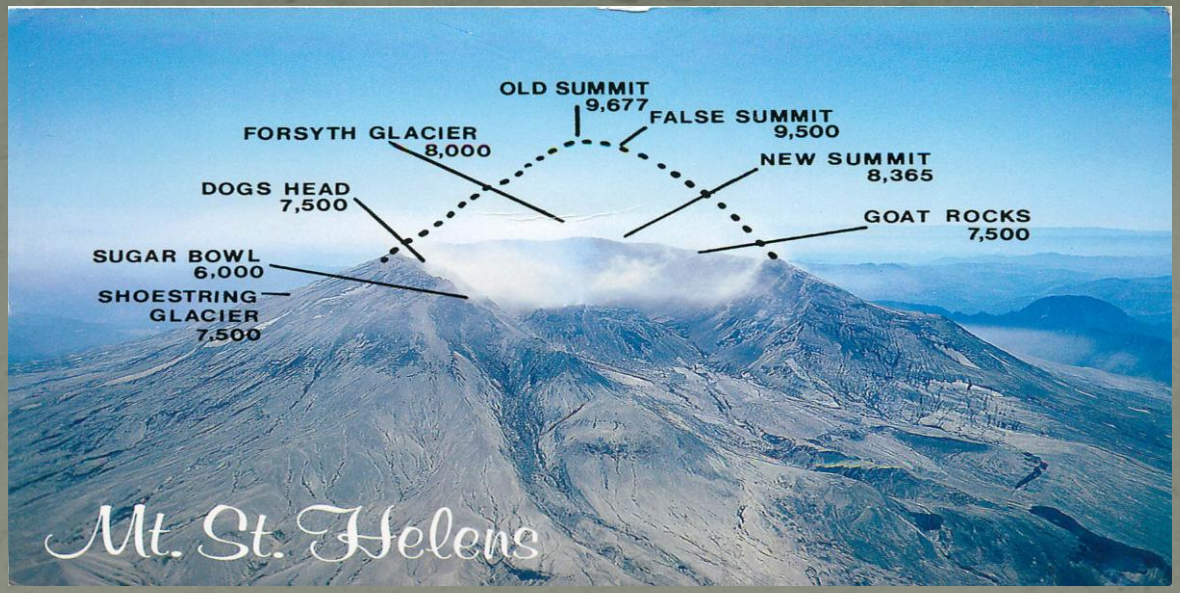
Types of Volcanoes

- Cinder cone:
- Cinder cone
- Loud eruptions
- Falling debris piles up
- Steep sides
- Cone shaped

A'a


Crater
Vent
Parasitic cone
Lava
Pyroclastic material
Conduit (pipe)

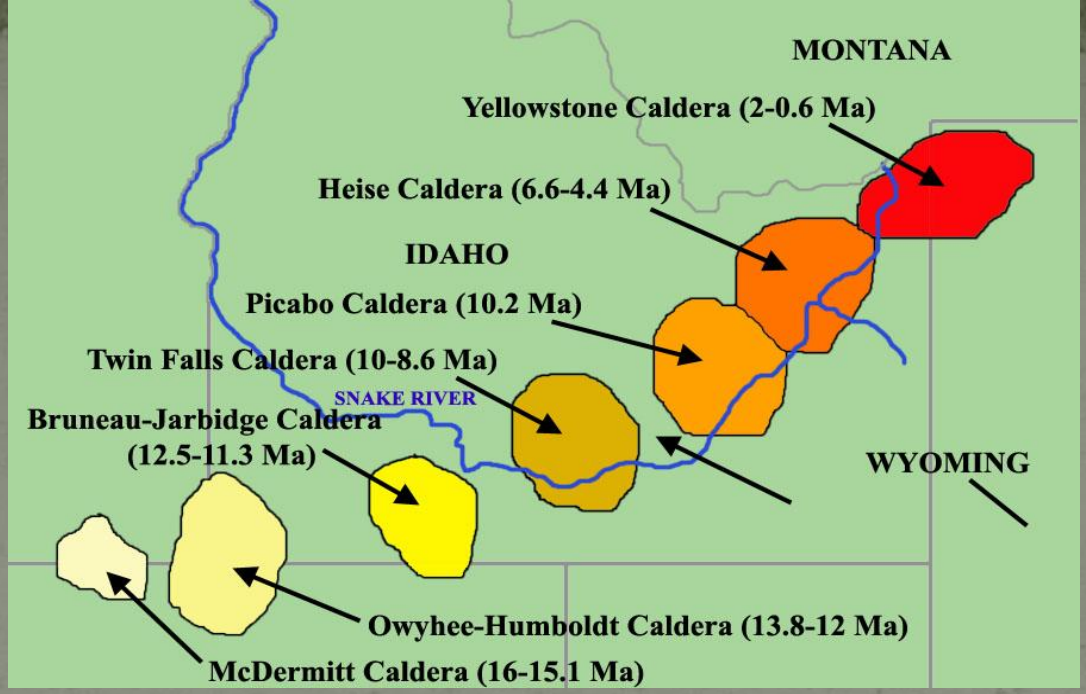

USGS

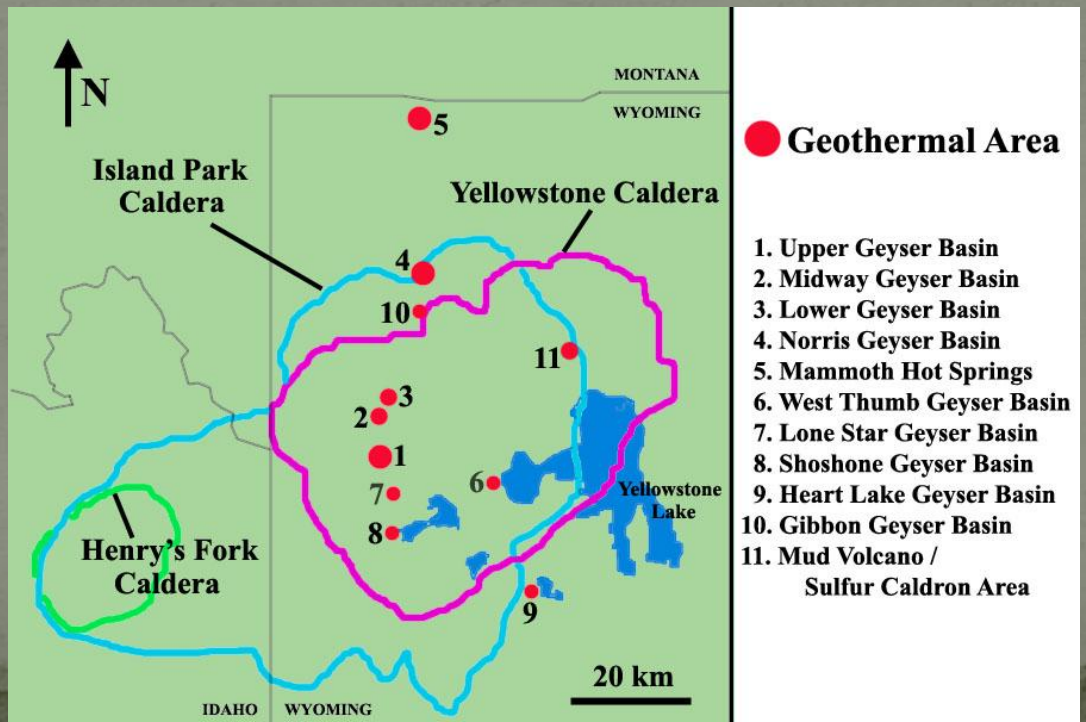


At 8:32 a.m. on May 18, 1980, a magnitude 5.1 earthquake triggered the largest landslide in recorded history. Reaching velocities up to 150 mph in only 10 minutes, the avalanche raced 15 miles and covered 25 square miles of the North Fork Toutle River Valley in debris that measured an average depth of 150 feet. Within minutes a lateral blast, equal to an explosion of 10 million tons of TNT, ripped through this sliding avalanche of debris. The blast accelerated to 670 mph and to temperatures of 570 degrees F. impacting 230 square miles. Ash clouds rose to 70,000 feet and on the first day of the explosion 50% of Washington State was covered in ash. Mount St. Helens' summit was left 1314 feet lower and today reaches 8363 feet above sea level. The damage to Washington State included $970 million in economic losses, a great loss of wildlife and 36 known human deaths. Twenty-one people remain missing.

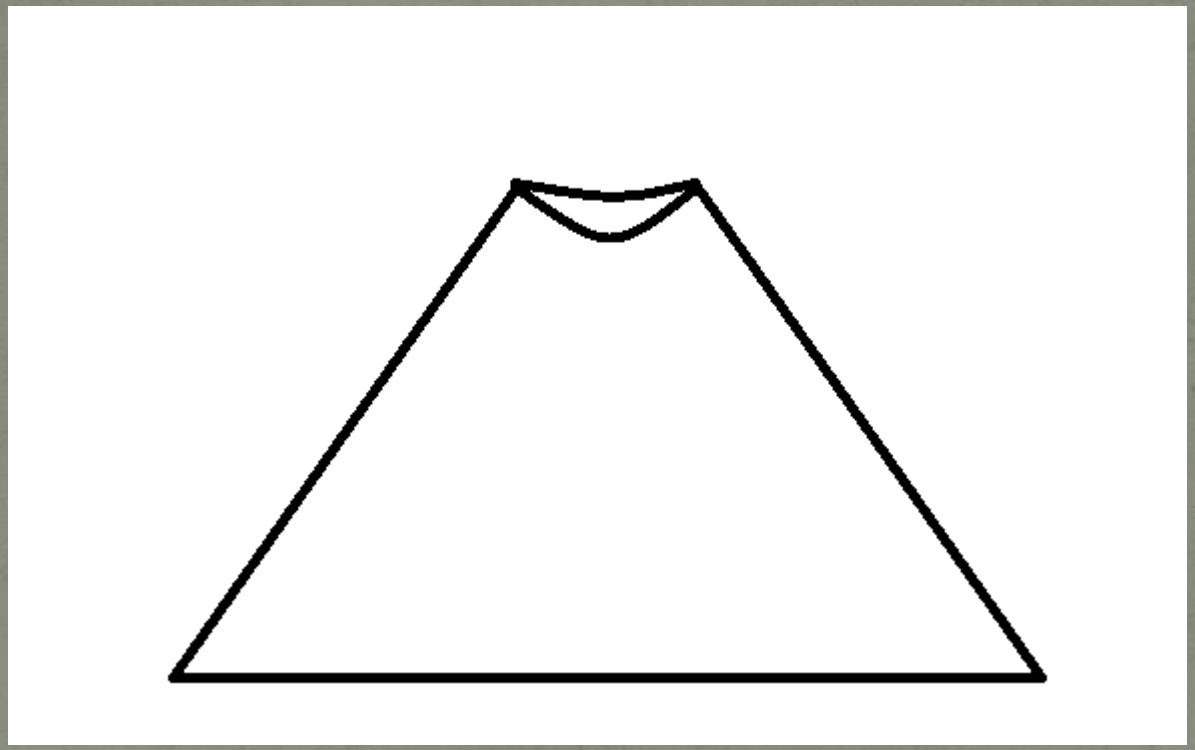
Despite the dramatic effect this historic event had on this region, life is a cycle of death and renewal, and this process is being enacted today on Mount St. Helens. Legislation passed in 1982, authorized the Mount St. Helens National Volcanic Monument and provided guidelines for its management, setting aside 110,000 acres for research, education and recreation. Within the monument's boundaries recovery has begun, both natural and human assisted. Timber has been cleared and trees and other vegetation have been planted and are propagating, beginning a new cycle of life. The animals are returning to the area and the rivers and streams are hosting fish once again.

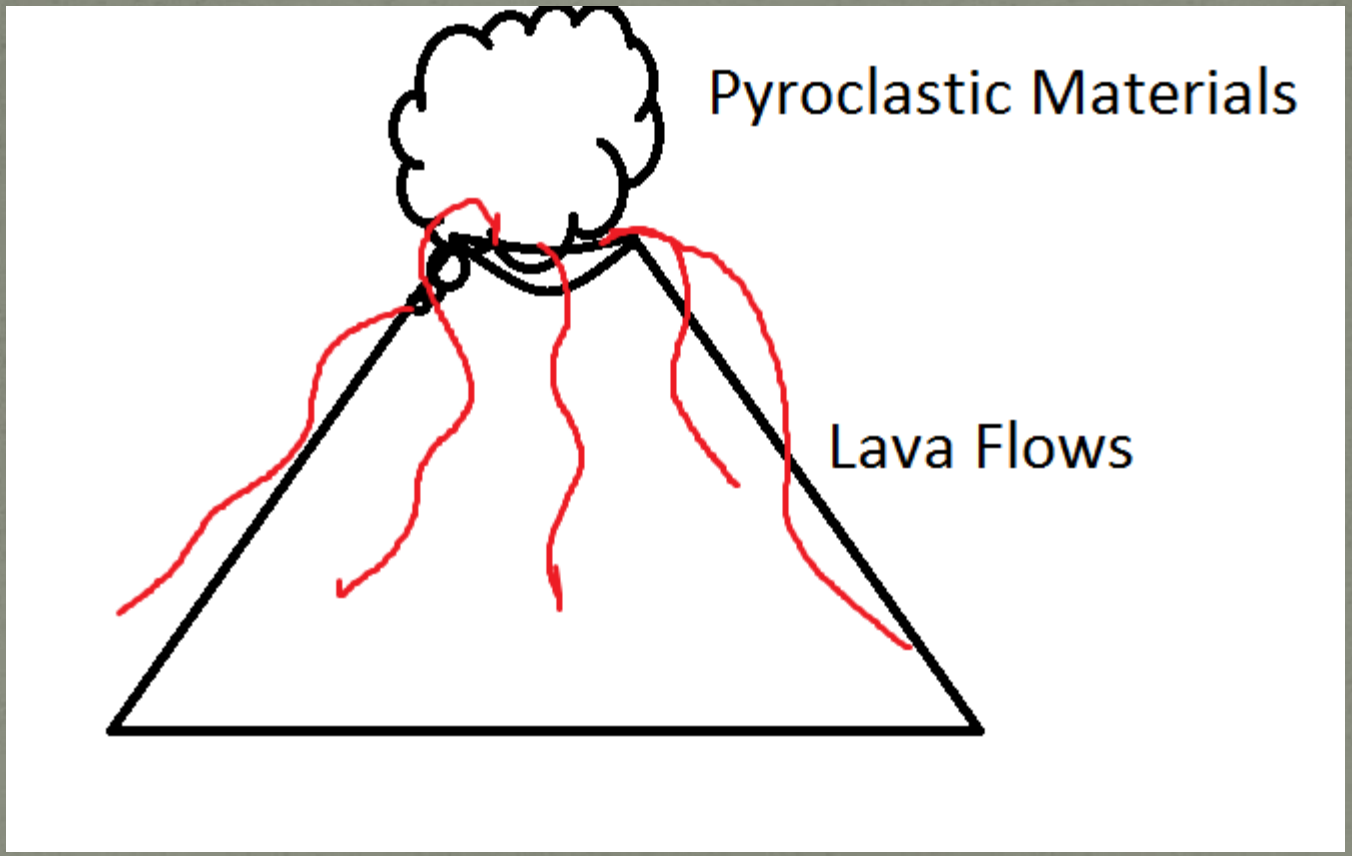
Figure 412.—Removal of ash from the May 18 eruption, Interstate 90, eastern Washington. Photograph by Washington State Highway Department.


MONTANA
Yellowstone Caldera (2-0.6 Ma)
Heise Caldera (6.6-4.4 Ma)
IDAHO
Picabo Caldera (10.2 Ma)
Twin Falls Caldera (10-8.6 Ma)
SNAKE RIVER
Bruneau-Jarbidge Caldera
(12.5-11.3 Ma)
WYOMING
Owyhee-Humboldt Caldera (13.8-12 Ma)
McDermitt Caldera (16-15.1 Ma)


N
MONTANA
WYOMING
Island Park
Caldera
Yellowstone Caldera
Henry's Fork
Caldera
Yellowstone
Lake
20 km
IDAHO
WYOMING
Geothermal Area
1. Upper Geyser Basin
2. Midway Geyser Basin
3. Lower Geyser Basin
4. Norris Geyser Basin
5. Mammoth Hot Springs
6. West Thumb Geyser Basin
7. Lone Star Geyser Basin
8. Shoshone Geyser Basin
9. Heart Lake Geyser Basin
10. Gibbon Geyser Basin
11. Mud Volcano /
Sulfur Caldron Area

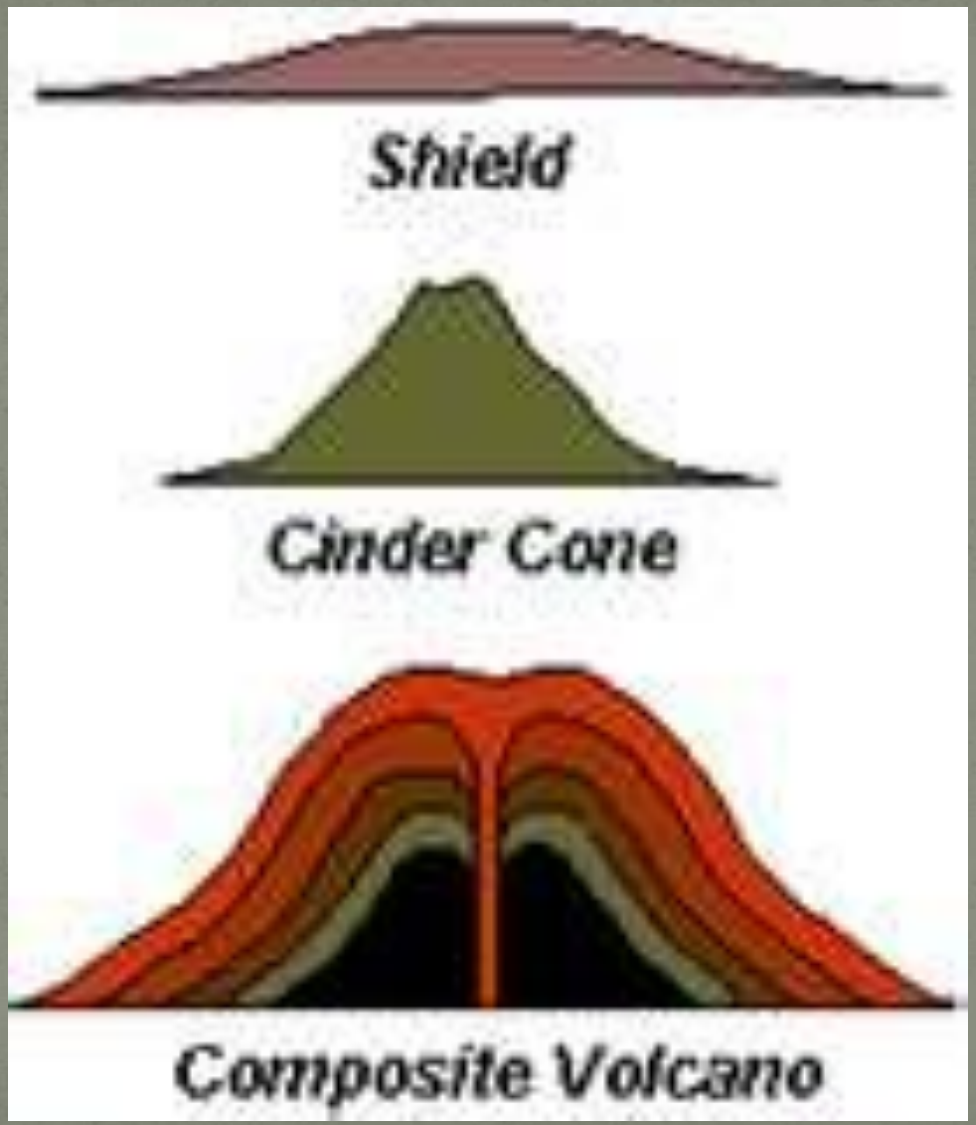
Composite Volcano




Pyroclastic Materials
Lava Flows

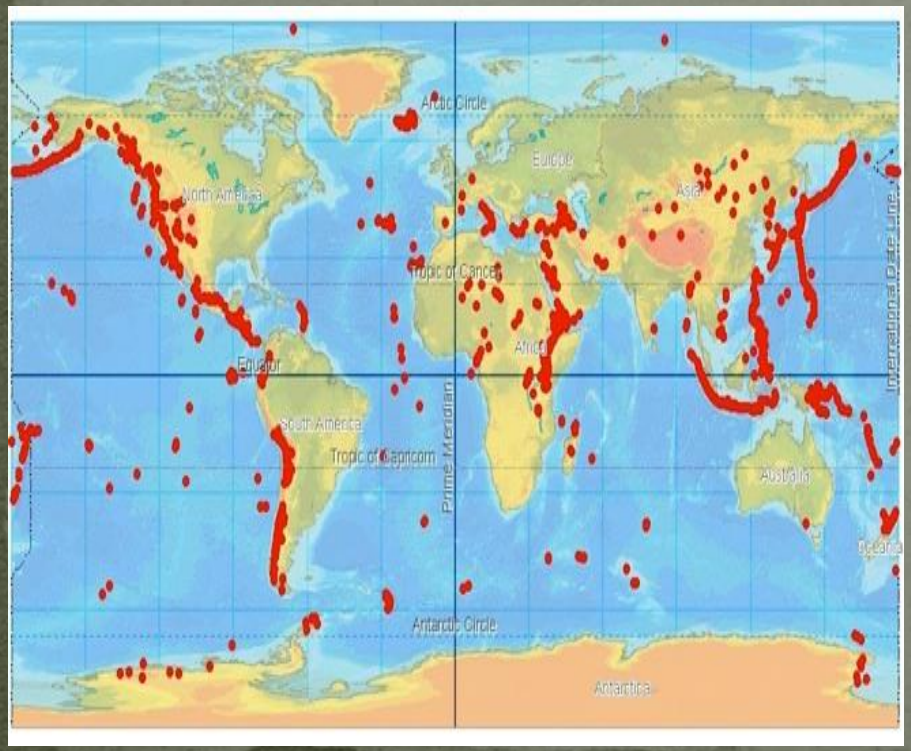
- Composite Volcanoes?
- Composite volcano
- Combination Lava & Pyroclastic
- Typically explosive eruption because lava creates a plug over the opening until enough pressure builds to explode outwards.
- Can become very large

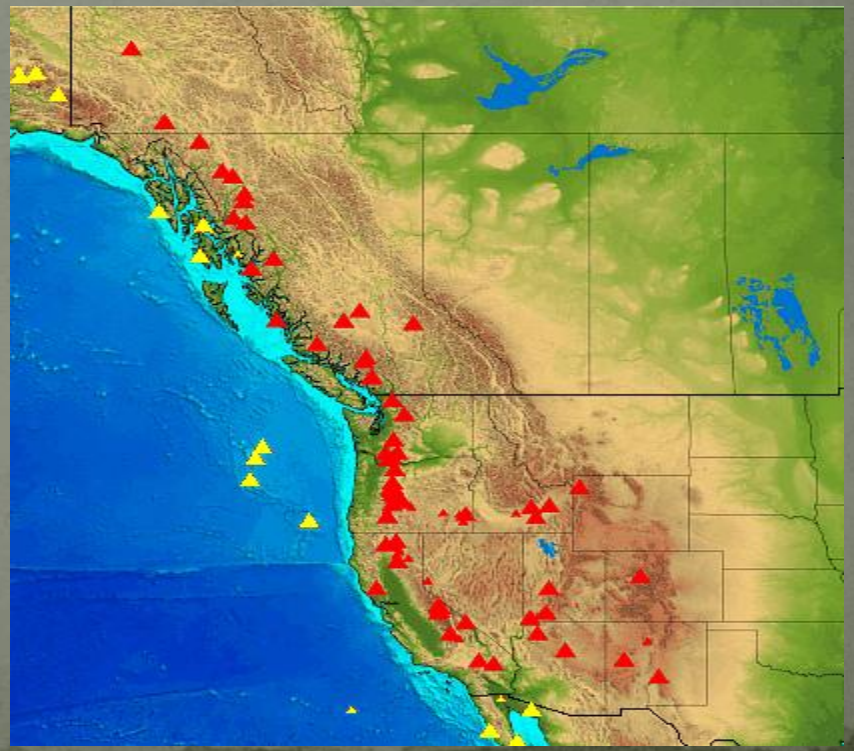
- Ex. Mt. St. Helens, Mt. Fuji


Shield
Cinder Cone
Composite Volcano

Where do Volcanoes exist

- Where do most volcanoes form?
- Most Volcanoes form at plate boundaries.
- Most are located in the ring of fire.



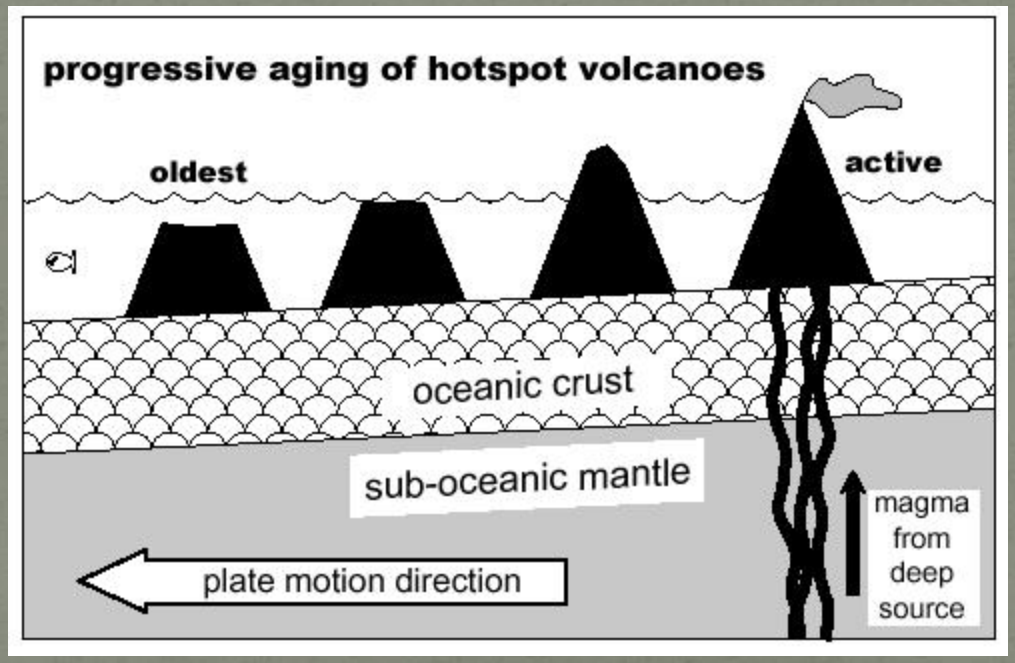


Hot spots

- How did Hawaii form in the center of the Pacific Plate?
- Hotspots: Area of super hot mantle burns through the overlying plate.
- Example: Hawaii

- What happens when the plate moves?
- As the plate moves a new volcano is formed over the hotspot and the old volcano moves and becomes extinct.
- This creates island chains (Hawaiian islands)

Pillow Lava

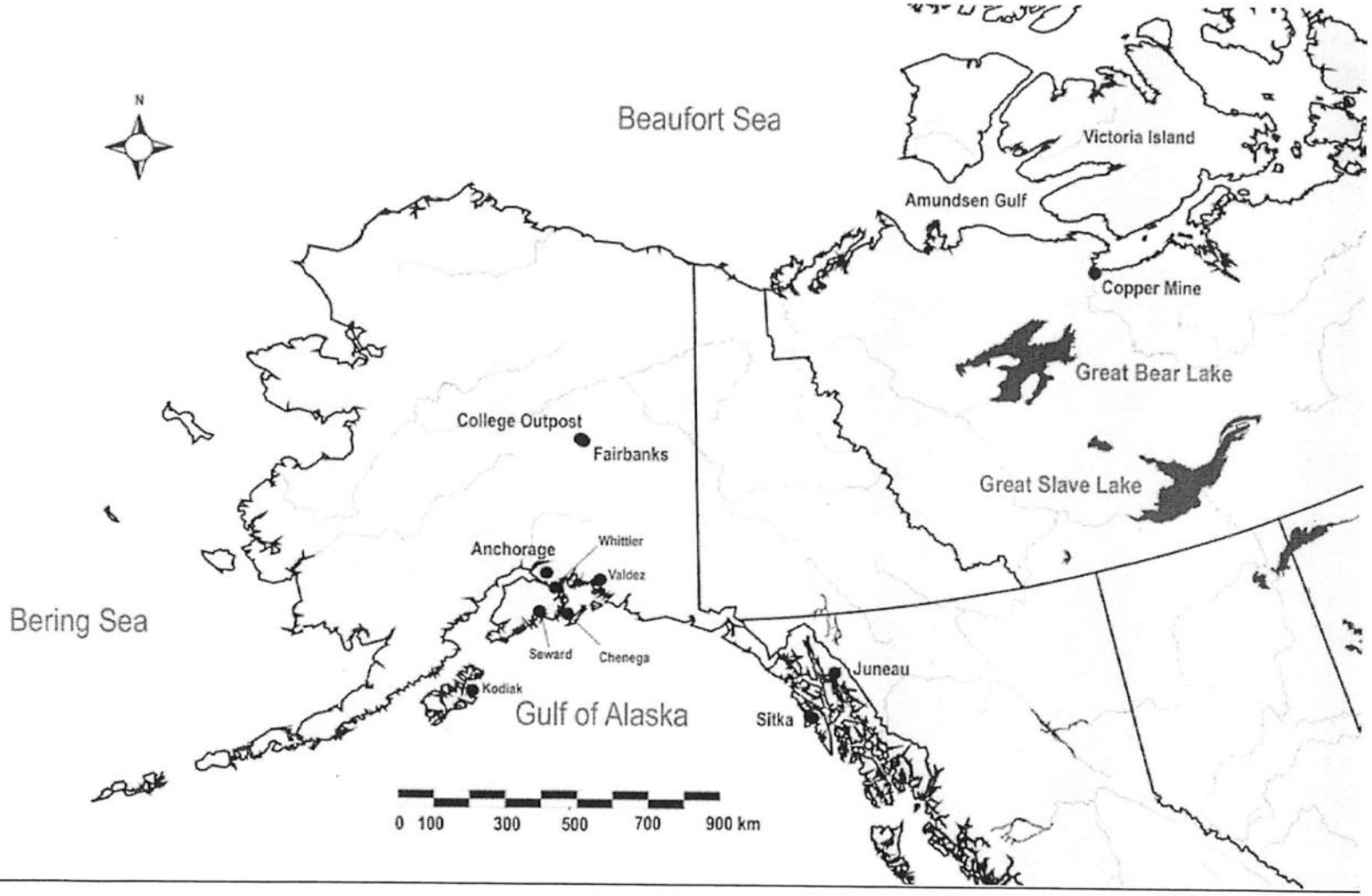

progressive aging of hotspot volcanoes
oldest
active
oceanic crust
sub-oceanic mantle
magma from deep source
plate motion direction

Stages of a Volcano

- What are stages of a Volcano?
- Volcano Stages:
- 1) Active: Currently erupting or has erupted in recent time and may erupt again soon.
- 2) Dormant: Sleeping. Has not erupted anytime recently but it may erupt at some point.
- 3) Extinct: Not currently erupting and thought to pose no future threat of eruption

- Are volcanoes all bad?
- Volcanoes do bring great fertilizers up to the surface and in time life will return.

- Volcanoes
- http://www.youtube.com/watch?v=DnBggrCdkNo
- Mt St Helens
- http://www.youtube.com/watch?v=pGImksoOwtU



Seismometer Station	P-wave Time	S-wave Time	Time Difference	Distance to Epicenter
Sitka, Alaska	5:38:00PM	5:39:20PM	_____ min	_____ km
College Outpost, Alaska	5:36:40PM	5:37:20PM	_____ min	_____ km
Copper Mine, Canada	5:39:40PM	5:42:30PM	_____ min	_____ km

What was the approximate time of the 3/27/1964 Good Friday Earthquake? _____ PM