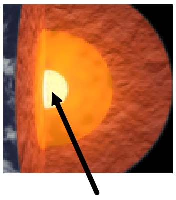
Chapter 13

VOLCANOES

I. Formation of Volcanoes

A. Volcanic activity is closely related to earthquakes. Wherever there are volcanoes, there will also be earthquakes. Both of these are in turn closely related to plate tectonics.

B. If you were to trace out the edges of the plates on a map, and then locate the major centers of volcanic activity, you would notice that most of the volcanoes on Earth are located on or near the edges of plates.



Magma for volcanoes does not come from Earth's core

C. Volcanic activity begins as molten rock, or magma, within the lower crust and upper mantle. When rock melts it expands, like all liquids, and becomes less dense than the surrounding rock. It begins to rise and burn it's way to the surface by either filling in previous cracks or simply melting away the rock as it moves. +1000 F - 2000 F

1. As the magma picks up new melted rock, the chemical composition of the magma begins to change and become more like the chemical composition of the rocks around it. For example, if magma burns through ocean basalt, the magma will change in composition towards a more basalt type magma.

2. This fact is the fundamental factor that leads to the type of eruption, type of lava, and resulting extrusive rock types. ← outside the earth

II. Volcanic Eruptions

A. The type of eruption and resulting volcanic form (volcano type) are the product of two factors. The first factor is the silica content. The silicon found in magma will determine the viscosity, or thickness, of the magma. Generally, the thicker the magma, the more explosive the eruption. Temperature / Composition

Thin / Runny
Hot Maple Syrup

1. Basaltic Magma- contains a low percentage of silica and is produced by the melting of rock in the upper mantle. The magma is at a very high temperature and flows very easily. Thus type of magma is associated with divergent plate boundaries and hot spots in the oceans. The magma is so thin that when it flows out of the ground, it spreads out in all directions like floodwater. **2000 F** Ocean Crust = Basalt

Thick / Pasty
Cold Maple Syrup

2. Silicic Magma- contains a high percentage of silica and forms from the melting of oceanic crust at collision (convergent) boundaries. Silicic magma is cooler than basaltic magma and does not flow as easy. It tends to thicker and pasty. **1000 F**
Continental Crust = Granite

Car Radiator
Pressure Cap

Temp exceed
230-240F

B. The second factor that determines the type of volcanic eruption is the water content of the magma. All magma contains superheated water. The water does not boil away because of the great pressure. This situation is similar to CO_2 being dissolved in soda. When the bottle is uncapped, the gas can escape quickly and easily. But if the bottle is shaken up and the pressure builds up, when the bottle is uncapped, there is a violent release of gas.

1. Superheated water escapes quietly from thin, runny magma producing mild eruptions. Hawaiian Volcanoes

2. Superheated water can cause powerful explosions as it forced out thicker, pasty magma. Mt St Helens

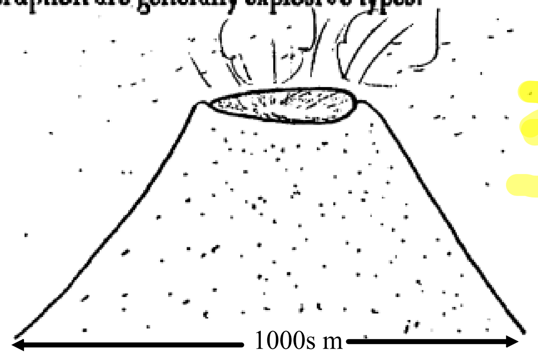
3. Refer to Figure 1 on page 228 for further illustrations on how silica content and water effect the eruption of a volcano.

III. Volcano Types

A. Cinder Cone- a cinder cone forms when eruptions throw out mostly ash and rock particles that buildup in a cone shape. These cones usually weather very quickly. Cinder cone eruption are generally explosive types.

High Silica
High Water
Explosive

Ash & Cinder
Small rock



Mt Capulin
pg 202-203

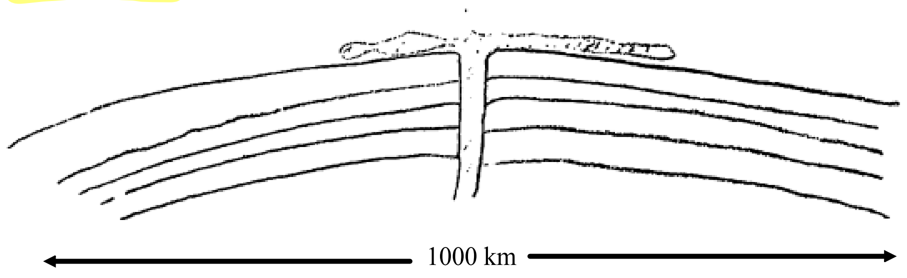
Eldfell, Iceland

B. Shield Volcano- non-explosive eruptions with easy-flowing basaltic lava. Shield volcano are broad gently sloping cones formed from the repeated flow of lava on top of them. The Hawaiian Islands are large shield volcanoes.

Low Silica
Low Water
Quiet Eruptions

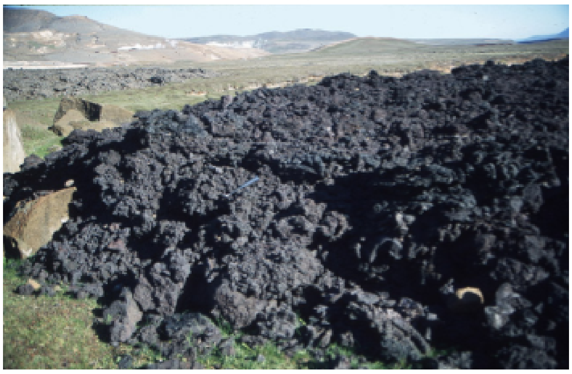
pg 202 Mauna Loa

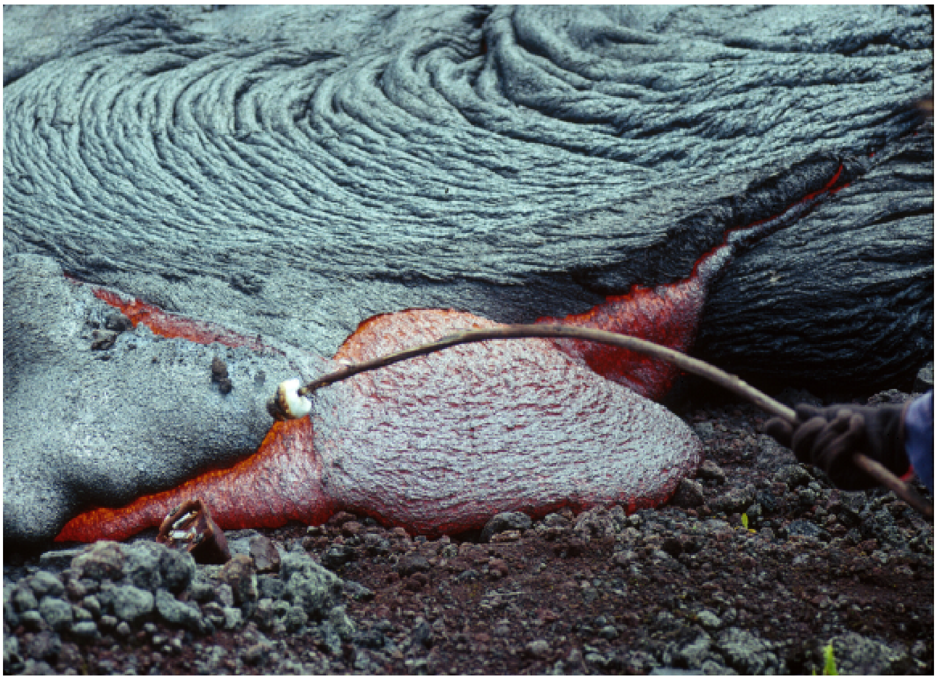
Pahoehoe - Hot Runny Silky - Rope like
Aa - Cooler Sharp Jagged Rocks



Pahoehoe
Hotter
Ropey - Silky

Aa
Cooler
Sharp Jagged





Strato-

C. Composite Volcano- alternating violent eruptions of ash and rocks followed by quiet lava flows form this type of volcano. Composite volcanoes are the most common large continental volcanoes. Mount St. Helens is a composite volcano.

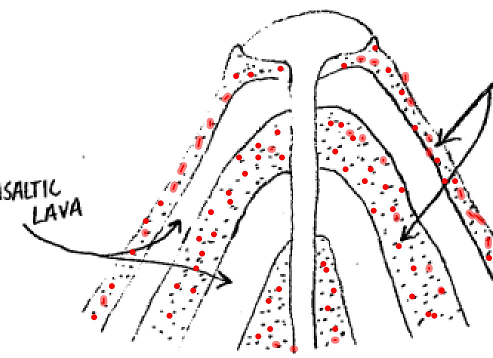
Continental / Ocean Plate Boundary
Ocean crust and Continental crust melting

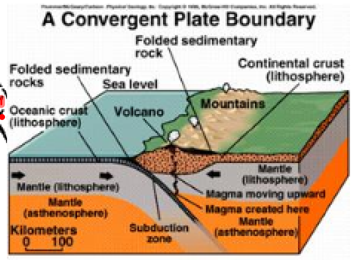
Mt St Helens pg 203

Cascade Mountains - Pacific Northwest
California, Oregon, Washington

Thick / Pasty Lava
Explosive Eruption

Quiet eruption
Thin Runny Lava



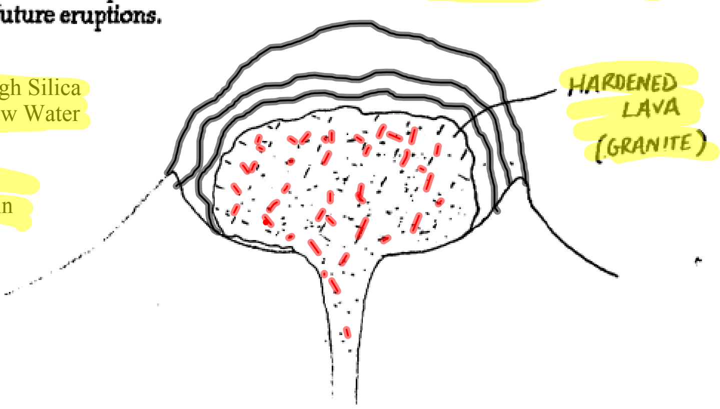


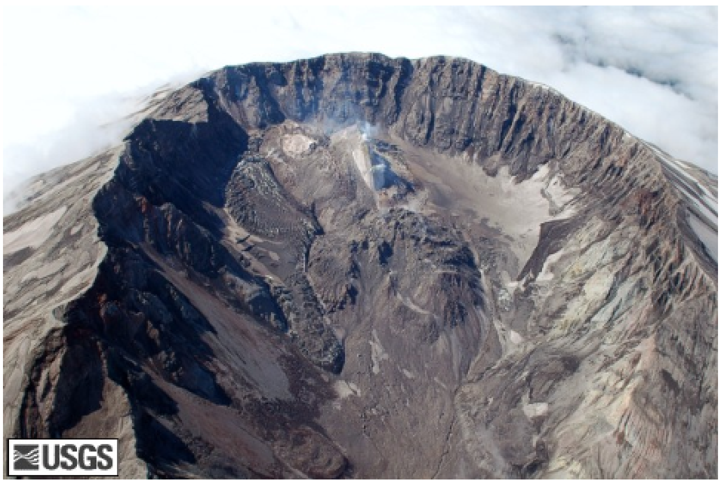
Interbedded lava flows

D. Dome Volcanoes- form from very silicic magma that barely flows. Domes often form in the craters of composite volcanoes. A dome plugs up the vent in a volcano causing pressure to build up. A dome has formed in the crater of Mount St. Helens which could lead to future eruptions.

High Silica
Low Water

Rebuilding
the mountain

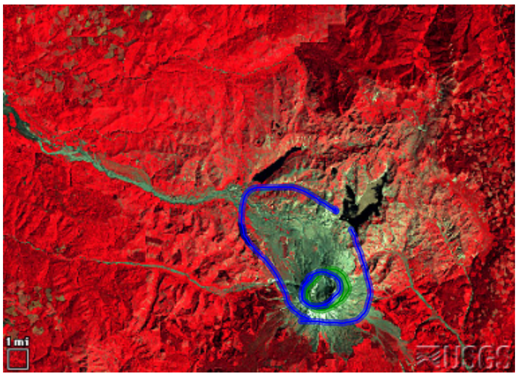


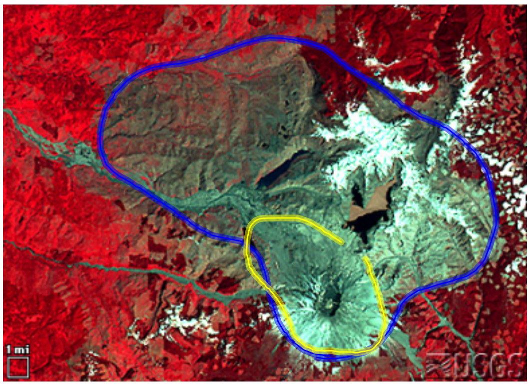


Silica = thickness of magma

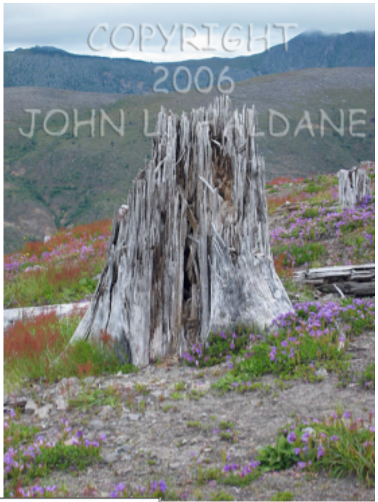
A lot of Silica = Thick pasty
Little bit of Silica = Thin runny

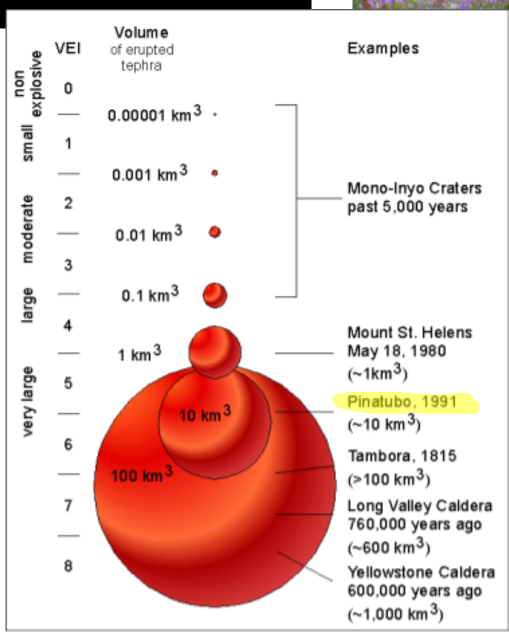
Water Content = Pressure control
A lot of water = High pressure
Little or no water = Low





1 km ^{3} ejected from Mt St Helens





Potentially Active Volcanoes of Western United States
Bellingham
Mount Baker
Glacier Peak
Seattle
WASHINGTON
Spokane
Mount Rainier
Mount St. Helens
Mount Adams
Portland
Mount Hood
Mount Jefferson
Three Sisters
Bend
Eugene
Newberry Crater
Crater Lake
OREGON
Great Falls
MONTANA
Billings
IDAHO
Yellowstone
Boise
Craters of the Moon
Casper
WYOMING
Pocatello
Mount Shasta
Medicine Lake
Cheyenne
Lassen Peak
Clear Lake
Reno
NEVADA
Salt Lake City
UTAH
Denver
COLORADO
Sacramento
San Francisco
Long Valley Caldera
CALIFORNIA
Coso
Las Vegas
San Francisco Field
Santa Fe
Albuquerque
Bandera Field
ARIZONA
NEW MEXICO
Los Angeles
San Diego
Phoenix
Tucson
Volcano active during past 2,000 years
Other potentially active volcanic areas
0 100 200 kilometers
0 100 miles
USGS
Topinka, USGS/CVO, 1998, Modified from: Brantley, 1994, Volcanoes of the United States: USGS General Interest Publication

INTRUSIVE IGNEOUS FORMATIONS

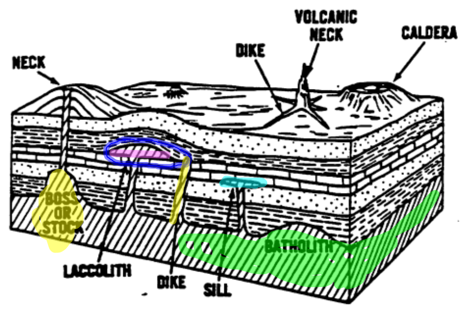
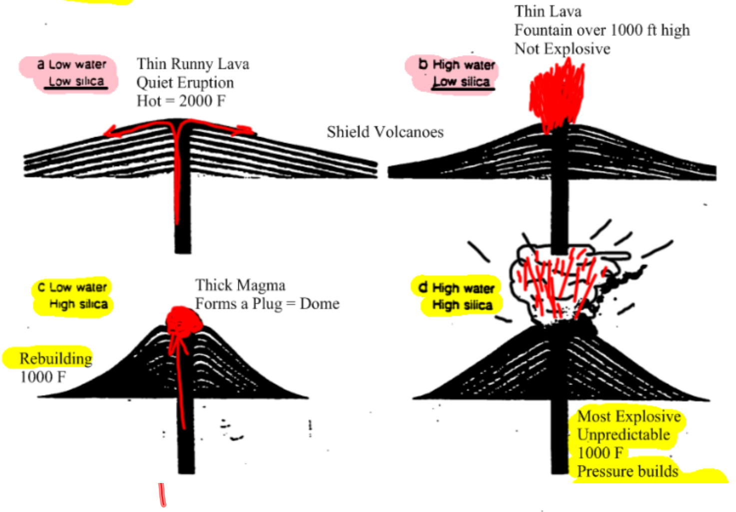
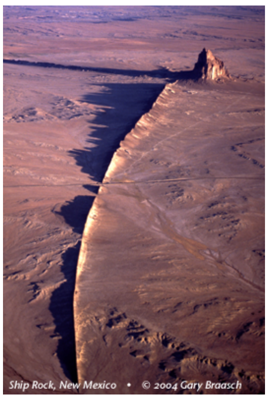


Figure 10-8 How does the water and silica content of magma affect eruptions?

How Water Content and Silica Affect Eruptions





From diagram on previous page

IV. Volcanic Features

Cold, Old Hard Rock Formations

A. Although there are some variations in the types of volcanoes and their eruptions, the features associated with volcanoes are mostly the same across all types. Below are the definitions of intrusive igneous rock features that are illustrated in the diagram on the top of the previous page.

Sill - magma that has cooled and hardened parallel to existing rock layers.
Dike - magma that has cooled and hardened perpendicular to existing rock layers.
Laccolith - similar to sill but formation has pushed above rock layers into a lens / dome shape
Batholith - large mass of rock that was the central magma chamber
Volcanic Neck - central pipe through which magma traveled to surface
Stock / Boss - similar to Batholith only smaller
Caldera - old volcanic crater (can fill with water to form a lake)

V. Volcanic Debris

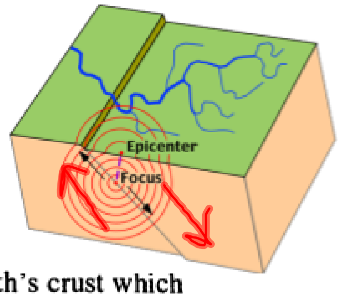
A. The material thrown from a volcano is classified generally as pyroclastic material or tephra. The particles are classified below

Material	Particle Size
Ash	< 2 millimeters
Lapilli	Up to 64 millimeters
Blocks/Bombs	> 64 millimeters

B. Blocks and bombs are similar except that blocks solid as they are thrown from the volcano, while bombs are liquids that cool and harden as they fall.

Football shaped

50 km^3 of material ejected



Chapter 12: Earthquakes

I. Earthquakes- A Definition

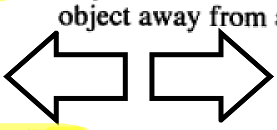
A. Earthquakes are sudden movements within the earth's crust which release energy in all directions in the form of waves.

B. Rocks of the earth's crust are elastic. This means that they have the ability to bend under great pressures without breaking. Bending will occur until rocks reach the elastic limit and then they break. When the rocks break, energy is released, sometimes in great amounts.

II. Forces Causing Earthquakes

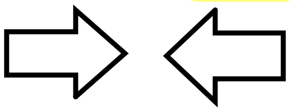
A. Forces applied to solid rock in the earth's crust can be of three types:

1. Tension- a system of forces that pulls or stretches an object away from a common point.



Divergent Boundaries

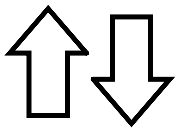
2. Compression- a system of forces which pushes towards a common point.



Convergent / Collision

3. Shearing- a system of forces which causes parts of an object to slide side by side to one another.

Inter- plate earthquake



B. These forces can be the result of three factors:

1. Plate Tectonics- The movement of crustal plates (Chp 8)

2. Buoyancy- An upward force that is equal to the force by which an object pushes back.

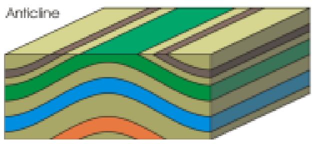
Example: 1) A boat floats because of buoyancy. The boat is displacing a mass of water that is equal to its own mass.
2) Glacial rebound (Chp 15)

3. Volcanic Activity- the movement of magma within the earth's crust can cause earthquakes as pressure builds and the magma shifts or is forced to the surface. All volcanoes have earthquakes associated with them.

III. Rock Structures

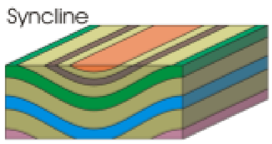
A. Rocks under pressure are elastic and will bend or fold. As long as the rocks do not reach their elastic limit, they will continue to fold. Folds are named by their shape. The shape of folds depends on the length of time the rocks were under pressure, the rock type, and the amount of pressure.

1. If rocks fold upward, the fold is classified as an Anticline.



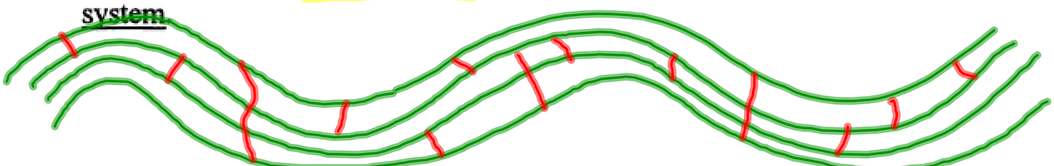
Arch
Capital A

2. If rocks fold downward, the fold is classified as a Syncline.



Sinking
Smile

B. When rocks are placed under enough pressure for a long enough period of time, they will fracture (break). A system of fractures is called a joint system.

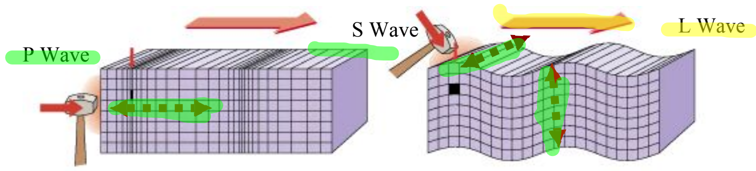


C. If pressure is still applied after fracturing occurs, faulting takes place. **Faulting is the movement of rock along a fracture.** Earthquakes occur when faulting occurs. Faults are classified by the direction of movement of forces. (More on this in Chp 16)

IV. Earthquake Waves

A. When rock layers fracture and fault, energy is released in the form of waves that move outward in **all** directions. The two main types of waves are as follows:

1. Body Waves- waves that travel through the earth's crust in all directions.



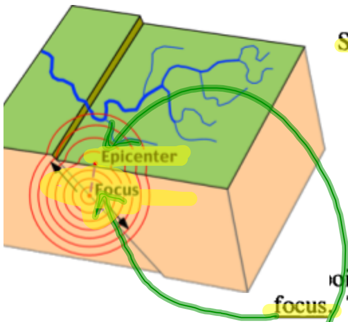
a. P Waves- these are the primary waves. They are the fastest moving, highest energy waves of all three types. They are least destructive because their wavelength is very short causing only a small vertical movement.

Primary
Push - Pull
Pulse

b. S Waves- These are the secondary waves. They are not as fast as P waves but faster than L waves. They are more destructive than P waves because their wavelength is longer causing more vertical movement.

Secondary
Side - Side

Only travel through solids



Surface or L Waves- these are the long waves. They are the slowest moving of all the wave types and carry the least energy. However, these are the most destructive of the three types because their wavelength is very long creating a great deal of vertical movement.

point within the earth's crust where faulting occurs is called the focus. The point on the surface directly above the focus is called the epicenter.

Each number increase wave height increases by 10

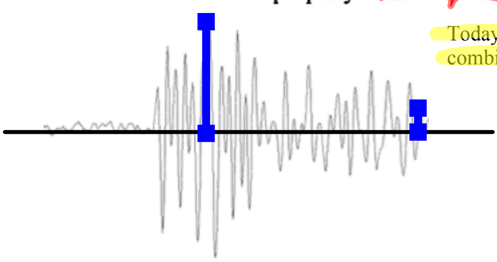
Energy released increases 30 times

C. Earthquake intensity is reported most commonly on the **Richter Scale** named after Dr. Charles Richter a geologist at CALTECH. The intensity of an earthquake is assigned a number. The higher the number, the more intense the quake. Anything less than a two is not recorded. The most intense quake ever recorded was in 1960 in Chile. This quake registered an 9.5 on the scale. The numbers on the scale increase or decrease by a factor of 10. In other words, a 5 quake is 10 times more destructive than a 4 quake, or a 6 quake is 10 times weaker than a 7 quake.

Rocks can only hold energy up to +9.0 Richter intensity

D. The **Modified Mercalli Scale** is a scale for the measurement of earthquake magnitude. The numbers on the scale range from I to XII and describe the affects of an earthquake on buildings and property. ~~This scale can be found in your textbook on page 210.~~

Today = Moment Magnitude
combines Richter measure and actual ground movement

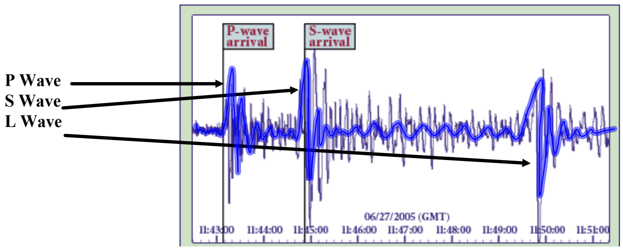


Comparison of the Richter and Mercalli Scales

Magnitude	Intensity	Effects
<3.4	I	Recorded only by seismographs
3.5-4.2	I I&III	Felt indoors by some
4.3-4.8	IV	Felt indoors by many
4.9-5.4	V	Felt indoors by all
5.5-6.1	VI and VII	Slight building damage
6.2-6.9	VIII and IX	Much building damage
7.0-7.3	X	Serious structural damage
7.4-7.9	XI	Great, widespread damage
>8.0	XII	You don't want to know

Richter - Quake Strength

Mercalli - Damage



Difference in arrival time P vs S waves = 1 min 40 sec
For every second that P and S differ
100 sec X 9.75 km = 975 km

E. Earthquake waves are measured on a device called a **seismograph**.

1. A seismograph is a machine that records the arrival time and the intensity of the 3 waves. From this information, the distance of an earthquake epicenter can be calculated. The direction of the quake can not be calculated.

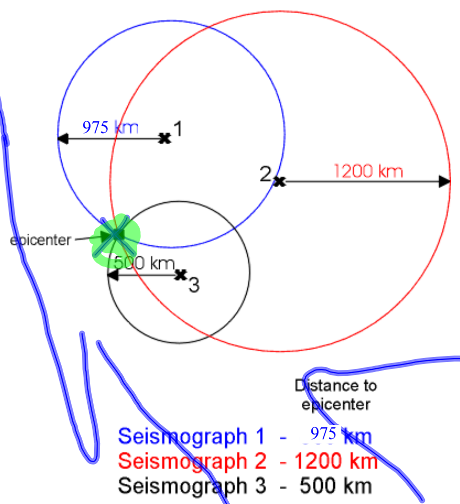
2. The arrival time and intensity of the waves are recorded on a **seismogram.**

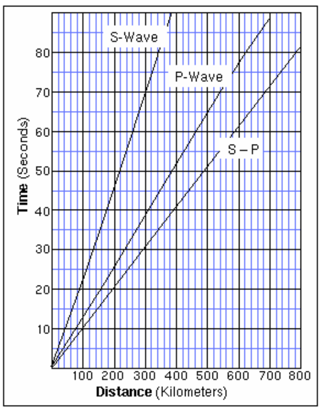
3. A **seismologist** is a scientist interested in the study of earthquakes.

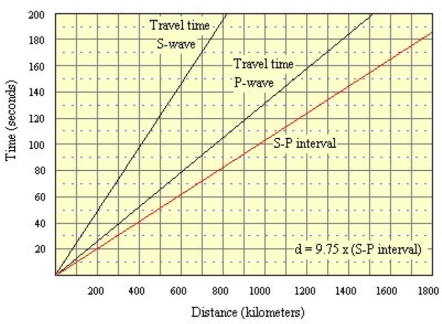
F. Locating earthquakes is done by the process called triangulation. Since seismographs can only report distance (arrival times) and intensity, it takes three seismographs to locate an earthquake epicenter.

1. Scientists triangulate by knowing the difference in arrival time of the P and S waves. From this, they can calculate the distance. Since they only know the distance from any one station, the seismologists draw a circle with a radius equal to the distance of the quake around the station.

2. When at least three stations have calculated the distance to a quake, they compare their circle distances. Wherever all three circle cross, that is the earthquake epicenter.







V. Earthquakes and the Earth's Interior

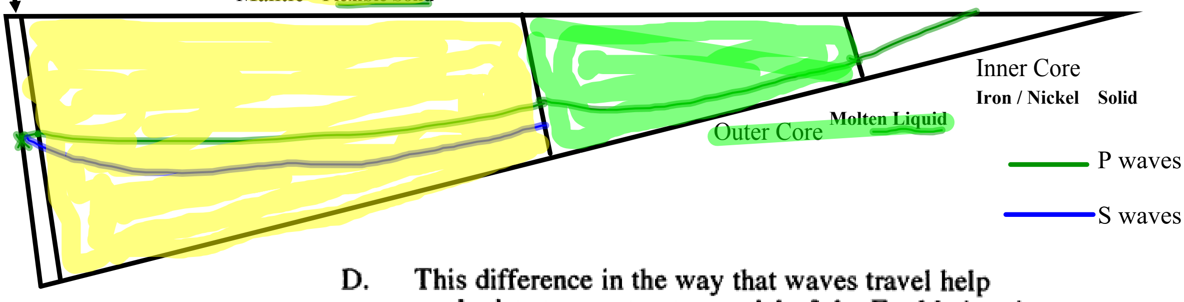
A. Most information about the Earth's interior has come from an analysis of seismogram tracings.

B. By the nature of the different earthquake waves, they will only travel through certain type of materials.

1. P waves can travel through solids and liquids equally.

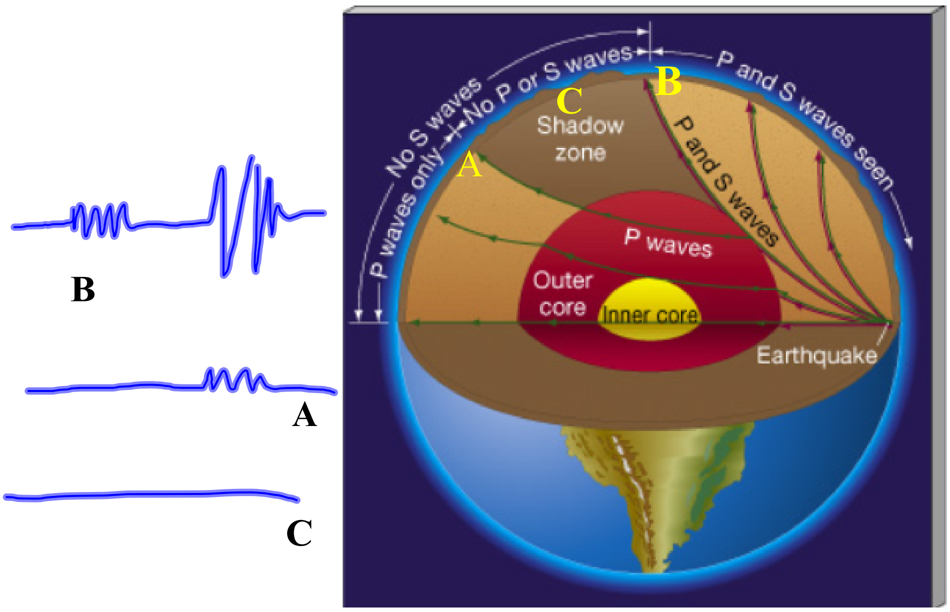
2. S waves will travel only through solids.

C. Within the Earth, there is a zone where P waves traveling through it will slow down and S waves simply stop. Due to this occurrence, there must be a layer within the Earth that is liquid. The boundary where S waves stop is called the Mohorovicic discontinuity or Moho for short. Because the crust varies in thickness, the depth that the Moho occurs also varies.

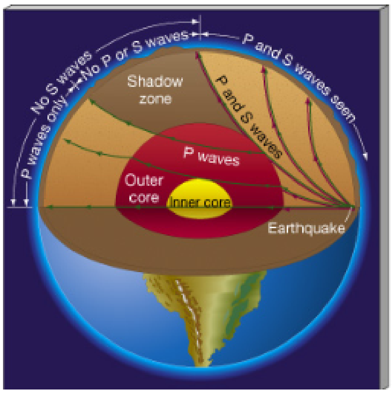


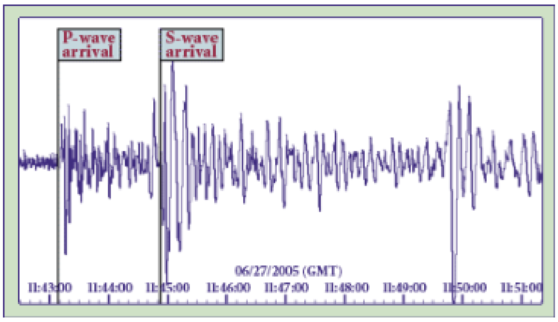
D. This difference in the way that waves travel help geologists to construct a model of the Earth's interior.

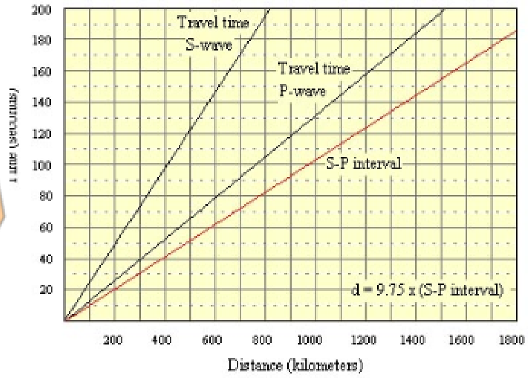
Shadow Zone= where no seismic waves are detected

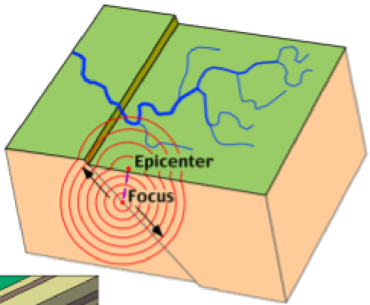


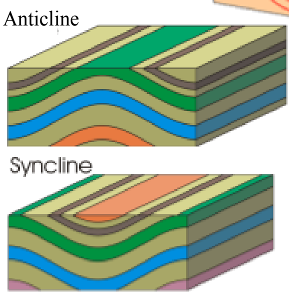
Seismic Gap = location that has not had an earthquake in a long time

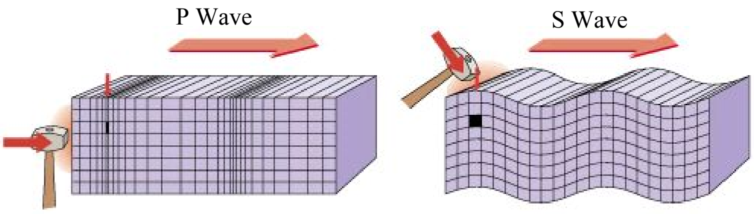


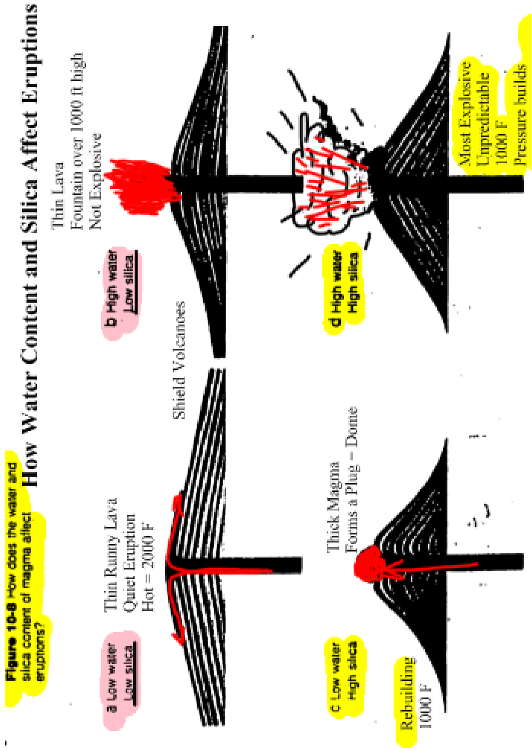




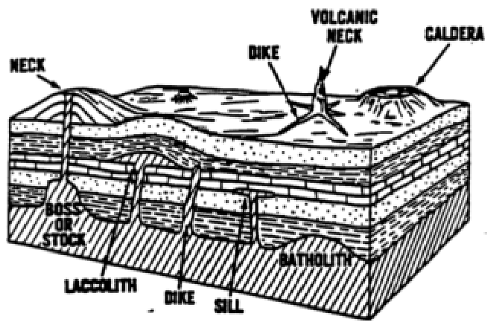








INTRUSIVE IGNEOUS FORMATIONS



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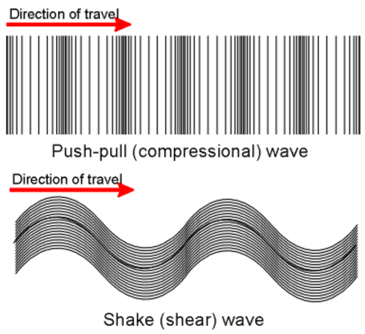
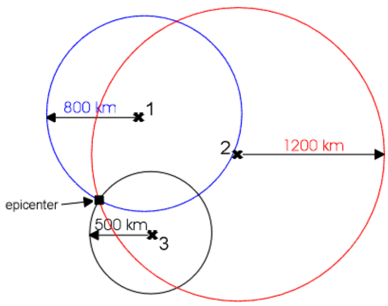
7.0-7.3	X	Serious structural damage
7.4-7.9	XI	Great, widespread damage
>8.0	XII	You don't want to know



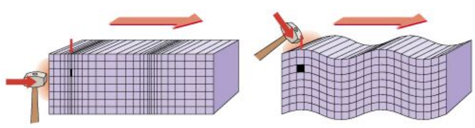
Comparison of the Richter and Mercalli Scales

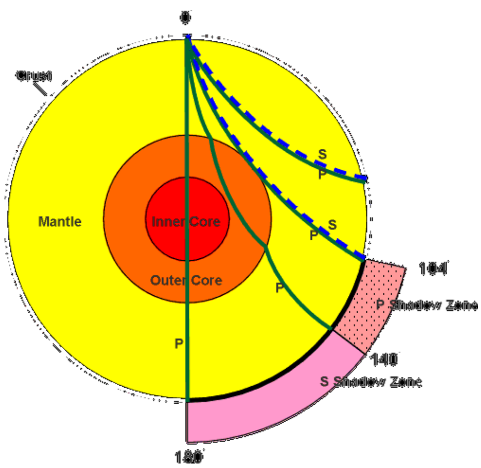
Magnitude	Intensity	Effects
<3.4	I	Recorded only by seismographs
3.5-4.2	I I&III	Felt indoors by some
4.3-4.8	IV	Felt indoors by many
4.9-5.4	V	Felt indoors by all
5.5-6.1	VI and VII	Slight building damage
6.2-6.9	VIII and IX	Much building damage
7.0-7.3	X	Serious structural damage
7.4-7.9	XI	Great, widespread damage
>8.0	XII	You don't want to know

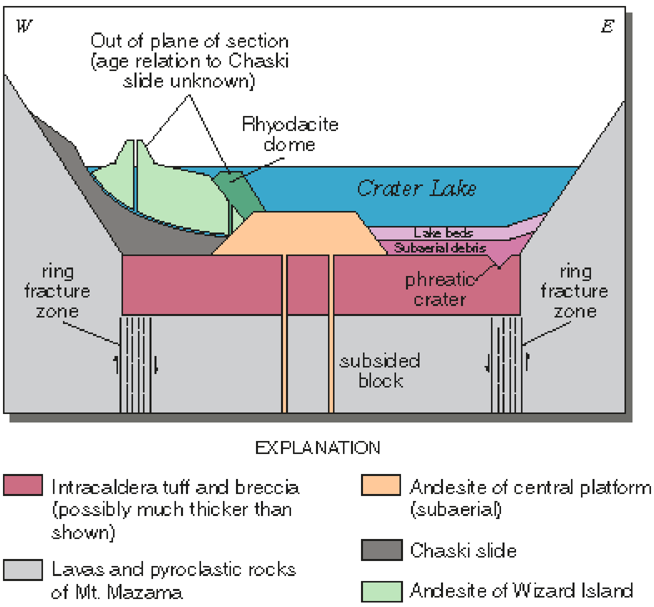


Distance to epicenter

Seismograph 1 - 800 km
Seismograph 2 - 1200 km
Seismograph 3 - 500 km






W
E
Out of plane of section
(age relation to Chaski
slide unknown)
Rhyodacite
dome
Crater Lake
Lake beds
Subaerial debris
ring
fracture
zone
phreatic
crater
ring
fracture
zone
subsided
block
EXPLANATION
Intracaldera tuff and breccia
(possibly much thicker than
shown)
Lavas and pyroclastic rocks
of Mt. Mazama
Andesite of central platform
(subaerial)
Chaski slide
Andesite of Wizard Island