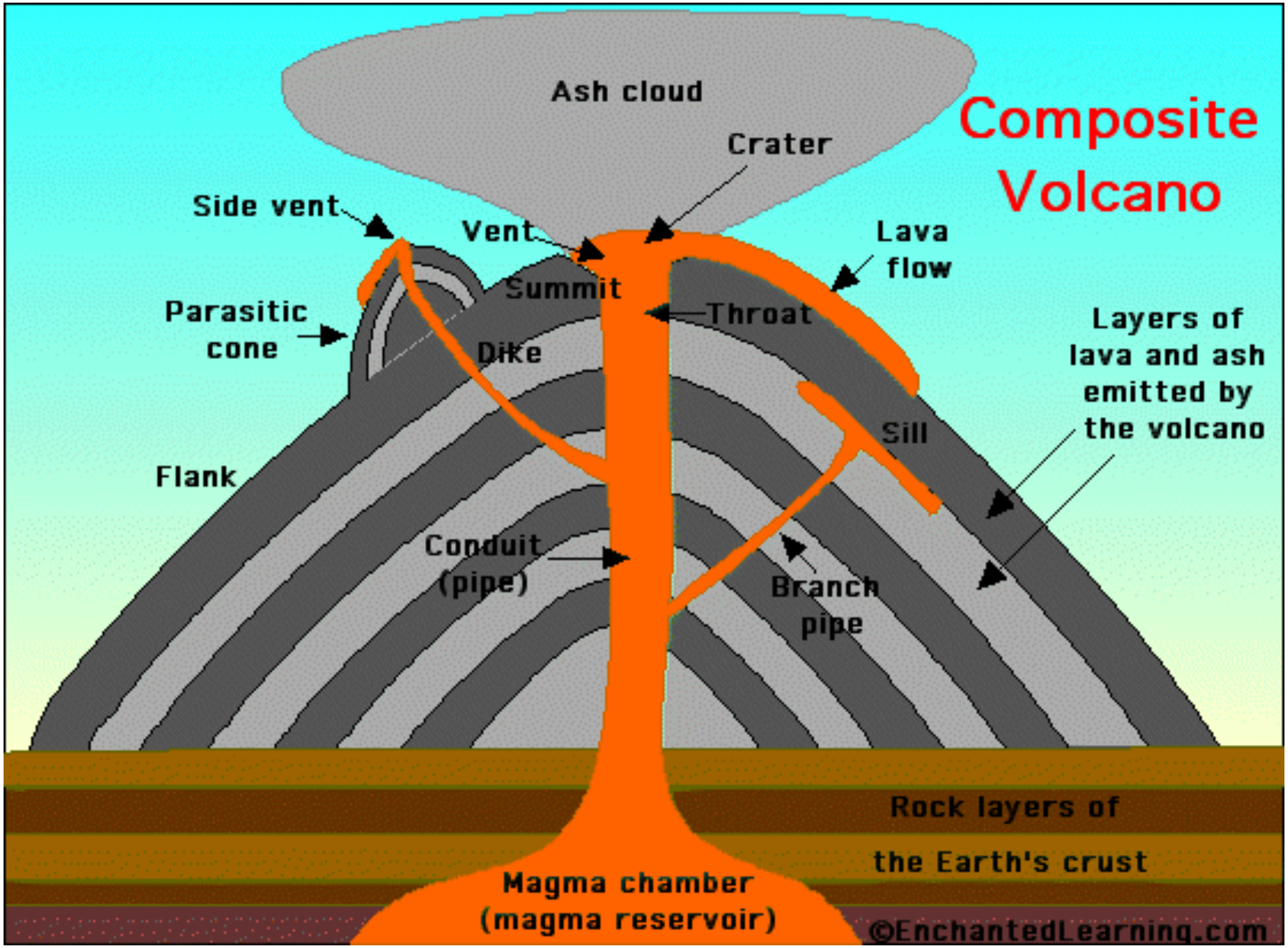
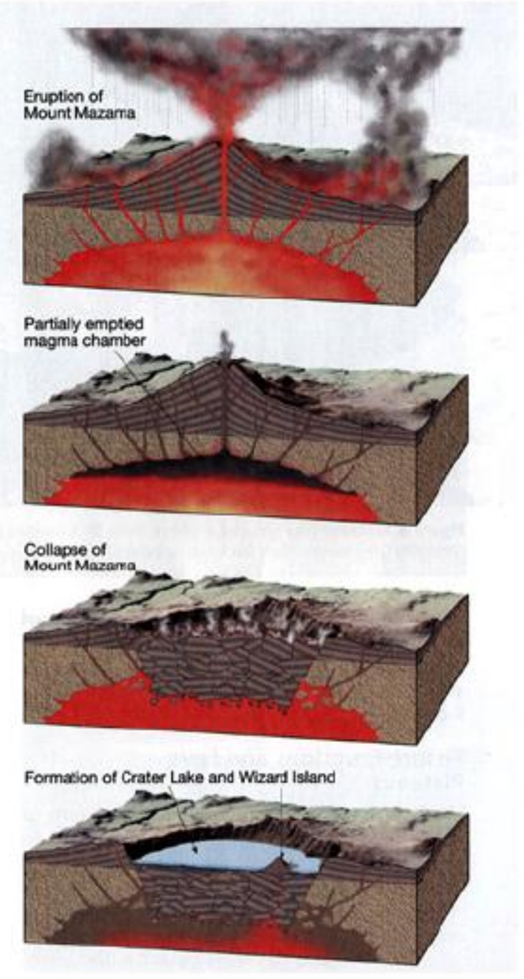
Volcanoes

Liquid Rocks

Basic Volcano Diagram



Caldera Formation



Figs. 4.16

Types of volcanoes

- Shield Volcano
- Cinder Cone
- Fissure Eruption
- Composite Cone

Shield Volcanoes

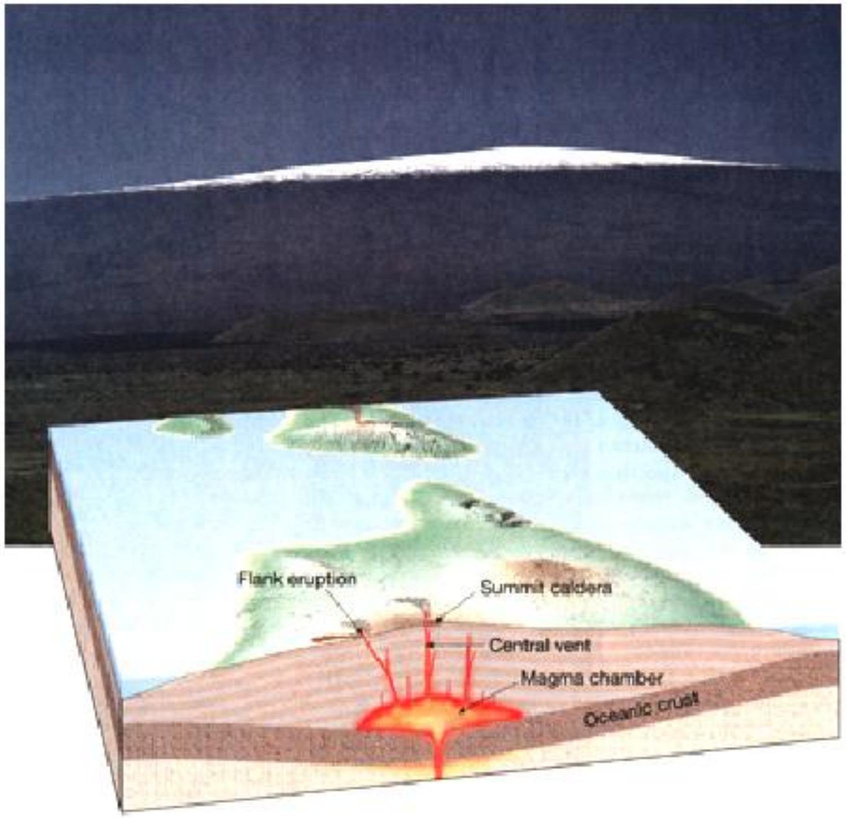
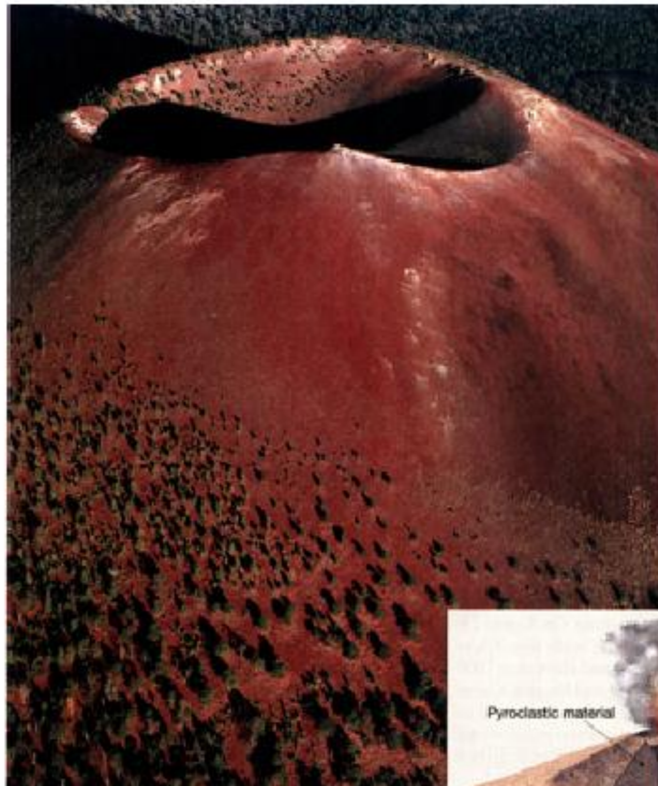


Fig. 4.9

Shield Volcano

A shield volcano is generally flatter - shaped like a shield. This is because of the type of magma that the shield volcano emits. The magma of a shield volcano (that becomes lava at the surface) is more fluid, it “runs” more, so it spreads out forming a mound or hump more than a peak.

Cinder Cones



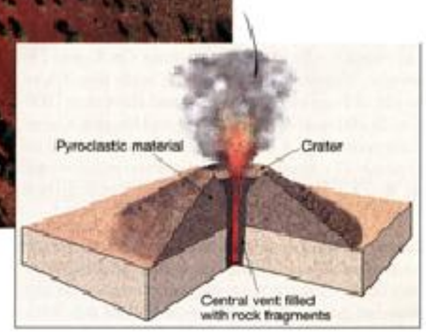


Figure 4.11 Sunset Crater, near Flagstaff, Arizona. This somewhat larger-than-average cinder cone formed over 900 years ago and rises about 300 meters (1000 feet) above its surroundings. Note the Ponderosa pine forest for scale. (Photo by Adriel Heisey)

Figs. 4.11

Cinder Cone

A cinder cone volcano is made of mostly cinders. A cinder is a volcanic rock about the size of a finger tip. Because a cinder cone is made of already solidified rock it forms a pile like a pile of dry sand from a sand box.

Fissure Eruption

Fissure Eruption in Iceland

Minnesota Fissure Eruption

Mid Continent Rift

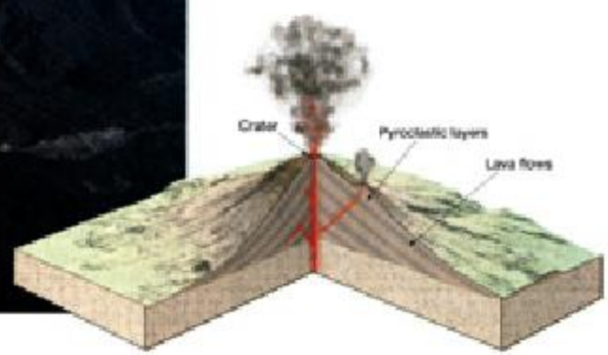
A significant part of the geology of eastern Minnesota is due to an ancient fissure eruption called the Mid Continent Rift. Here the spreading of two continental plates formed an a basaltic lava flow that is still visible near Lake Superior and at Interstate State Park near Taylor's Falls.

Composite Cone

Composite cones are the most "famous" kind of volcanoes because they form the mountains and produce spectacular explosions.

Composite Volcanoes

Figure 4.13 Mount Shasta, California, one of the largest composite cones in the Cascade Range. (Photo by John S. Shelton)

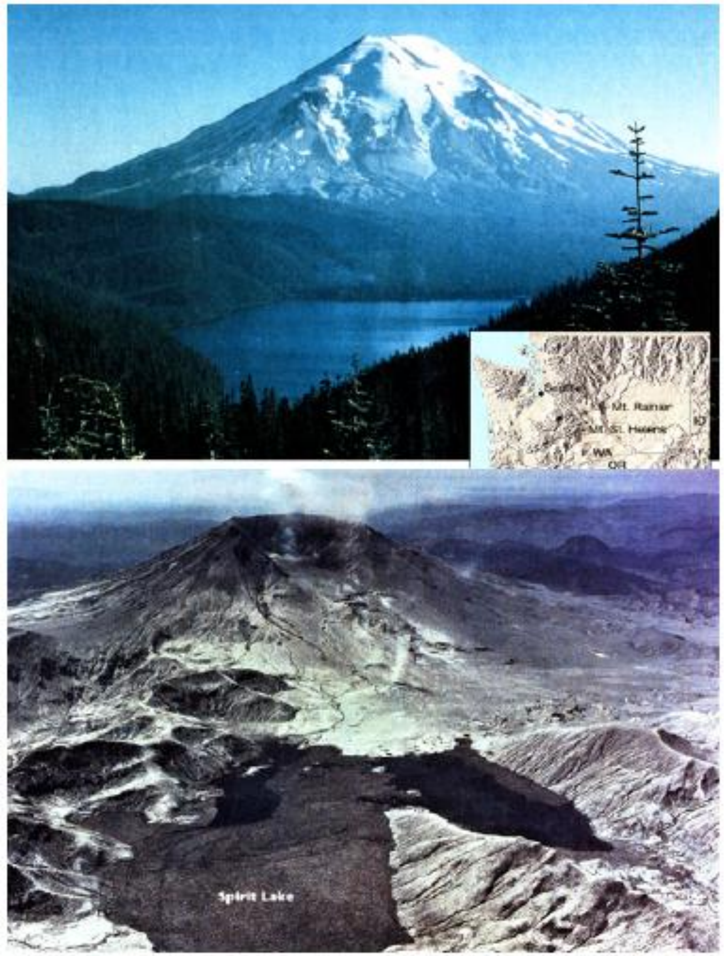


Figs. 4.13

Composite Cone

A composite cone is a mixture of a shield volcano and a cinder cone volcano. Because it is a mixture it often grows larger than a shield volcano and lasts longer than a cinder cone volcano. The kinds of magma that a composite cone volcano produces are very viscous which means that the magma doesn't flow well. This provides great opportunities for explosions.

Mount St. Helens, Washington



Figs. 4.A

Mt. St. Helens

Mount Saint Helens is a rather modern example of a composite volcano eruption with explosive results. In geologic terms a volcano may be very active while no one alive has witnessed an eruption. This sometimes presents difficult social and political problems.

http://www.olywa.net/radu/valerie/mshbefore.html

http://www.fs.fed.us/gpnf/mshnvm/

Structural Lava Types

Lava that flows is usually basaltic in composition like that found in Hawaii

- pahoehoe - looks like braided ropes
- aa - jagged, sharp edges often with needle like projections
- pillow - curved and “fluffy looking”, cause by very rapid cooling in contact with water

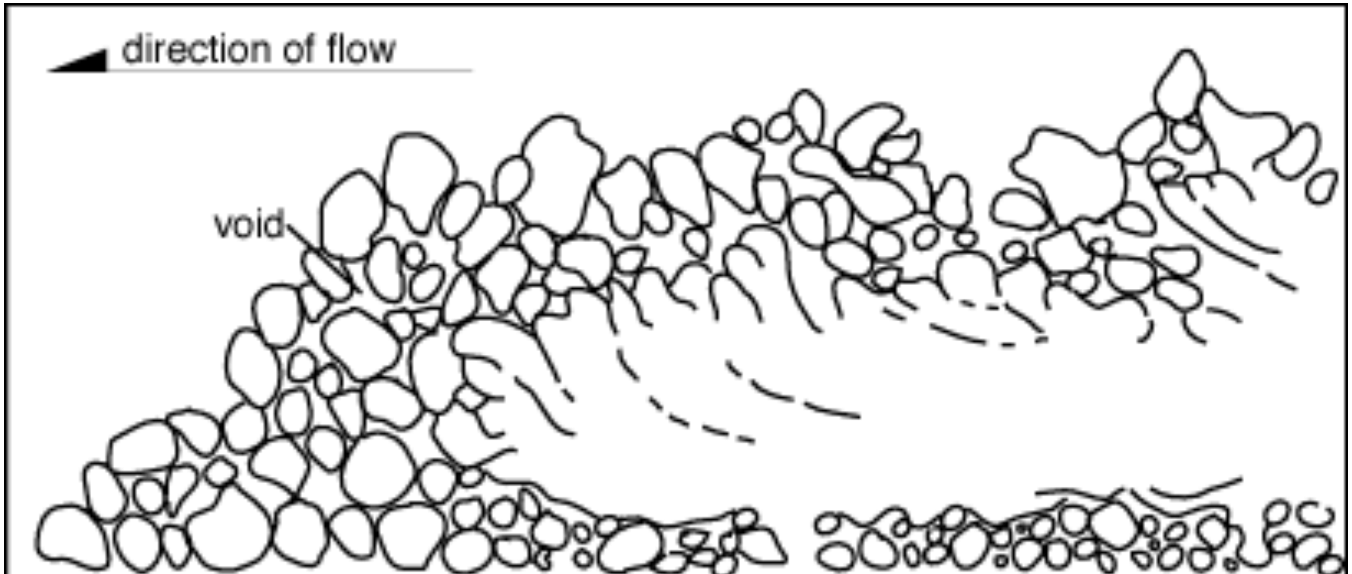
pahoehoe lava

pahoehoe lava

aa lava

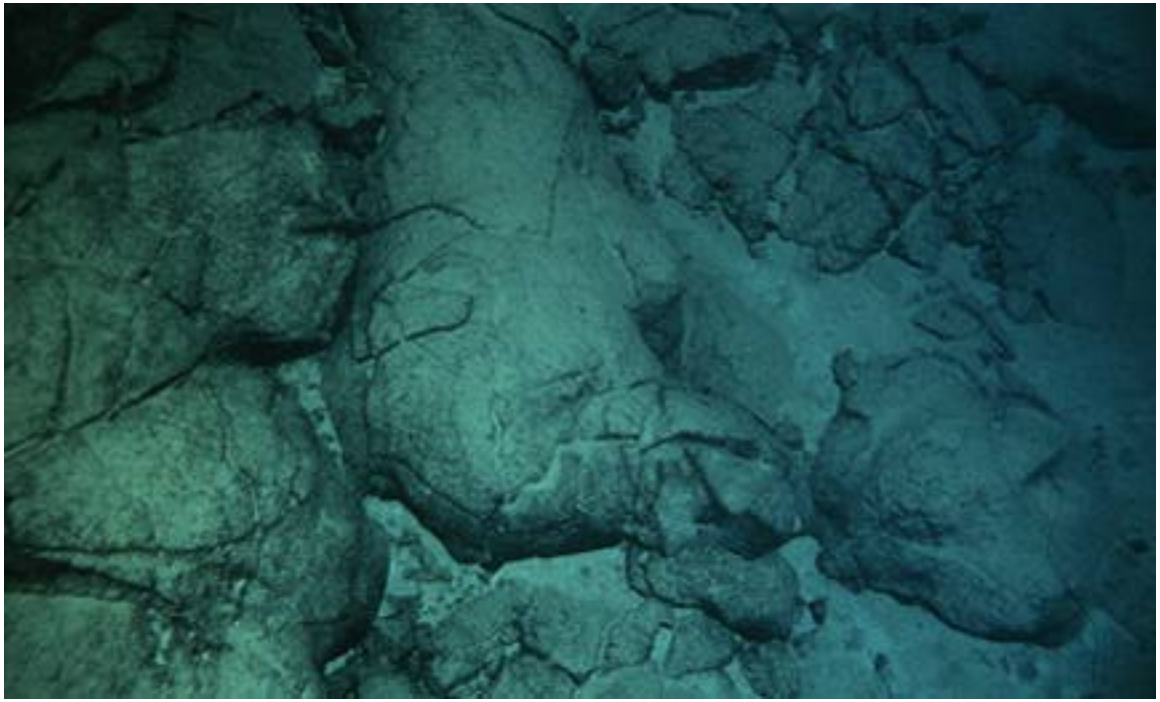
aa lava

aa lava



Compared to pahoehoe, aa flows are thicker and have rough, clinkery surfaces. This cross-section shows one aa flow.

pillow lava



pillow lava in Minnesota

Minnesota pillow lava

This is a cross section of a pillow lava tube near Gilbert High School.

Gases

- Gases from volcanoes represent from 1% to 5% of the mass of all emitted material
- The most abundant gas is water vapor (70%)
- Other major gases are carbon dioxide, sulfur dioxide, sulfur trioxide and nitrogen
- Because gases can be compressed they often help form the explosions as they are released near the surface.

Pyroclastic Materials

Pyro - fire, hot. Clastic - pieces, parts.

- Ash and dust -very small pieces
- Tuff - pieces of ash that are welded together
- Pumice - larger pieces of material with so many holes it will float in water. The holes are the result of the escaping gases.
- Nuee' ardente - fiery cloud or glowing avalanches - can move over 150 miles per hour

More Pyroclastic Materials

- Lapilli - “little stones” about the size of quarters
- Cinders - pea sized to finger tip sized usually with many voids (air holes) from escaping gases
- Blocks -larger than lapilli and solid when ejected, sometimes as large as a car
- Bombs - larger than lapilli and liquid (often glowing) when ejected

Kinds of magma (lava)

- Basaltic
- Andesitic
- Granitic
- Granitic and basaltic rocks are found in Minnesota and are evidence of old volcanic mountains.

Basaltic (mafic) Magma

- Highest melting point
- Lowest viscosity
- Lowest tendency to explode or form pyroclastic materials
- Mineral components of olivine, pyroxene and calcium feldspar
- Dark in color, low is silica (quartz) content

Granitic (felsic) Magma

- Lowest melting point
- Highest viscosity
- Greatest tendency to explode or form pyroclastic materials
- Mineral components of quartz, mica, potassium feldspar
- Usually lighter in color, high silica content

Andesitic Magma

- Andesitic magma is the intermediate form, in the middle of basaltic and granitic.

The Ring of Fire

- Where are volcanoes?
- How do they form?
- Where does the heat come from?
- How hot do rocks have to get in order to melt?


RING OF FIRE
Aleutian trench
Kurile trench
Japan trench
Izu Bonin trench
Ryukyu trench
Philippine trench
Marianas trench
Challenger Deep
Equator
Bougainville trench
Java (Sunda) trench
Tonga trench
Kermadec trench
Middle America trench
Peru-Chile trench
Puerto Rico trench
South Sandwich trench

Volcano Locations

- The vast majority of the earth's volcanoes are located in three general areas:

1) "The Pacific Rim". This is an area that can generally be described as at the edges of the Pacific Ocean.
2) Pacific Hot Spots. These are areas like the Hawaiian Islands and other Pacific volcanic islands
3) The Mid Atlantic Rift. The most visible of these are in Greenland and Iceland.

Hot Spots

- The Hawaiian Islands are examples of hot spots. These are thin parts of the lithosphere (crust) where hot liquid rock (magma) comes up and becomes solid at the surface.
- Pacific Islands
- USGS - United States Geological Survey

Earth's Dynamics

- To understand the causes of the volcanoes we must consider the THEORY of plate tectonics.
- In simple form, the theory of plate tectonics describes the surface of the earth much like ice floating on a frozen lake.
- All of the land masses are slabs of solid rock floating on a liquid mantle.

Earth Diagram

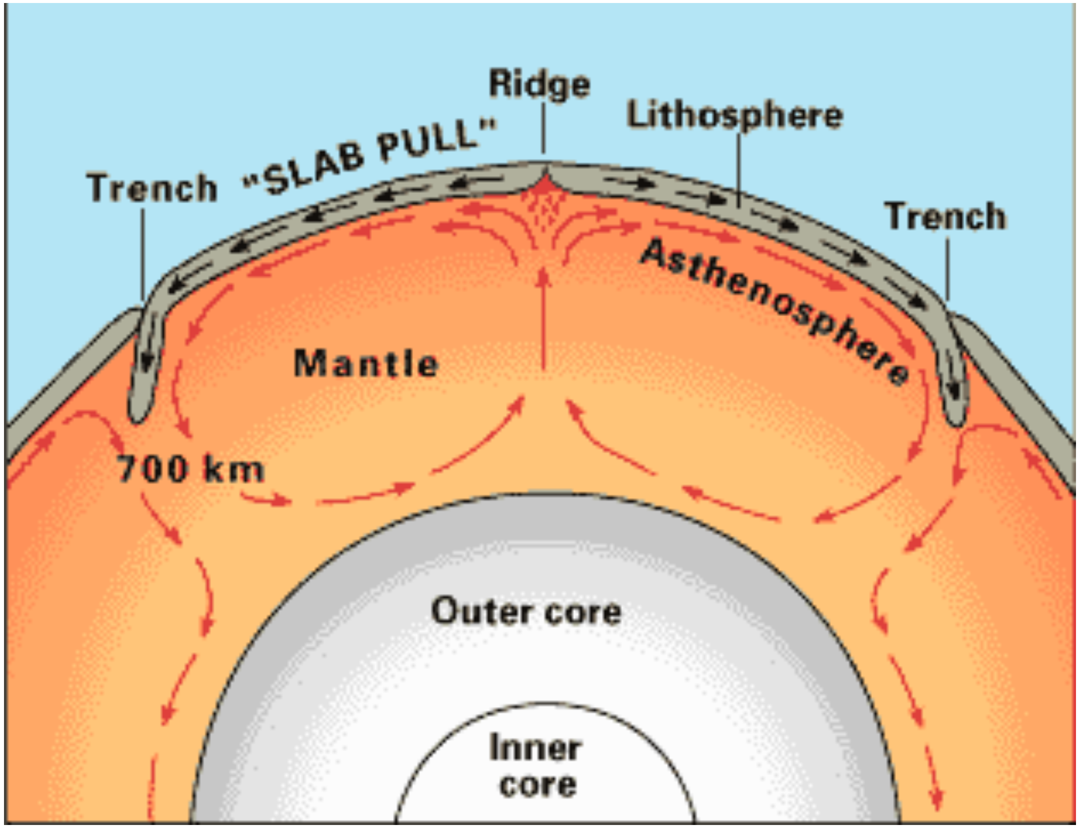


Plate Dynamics

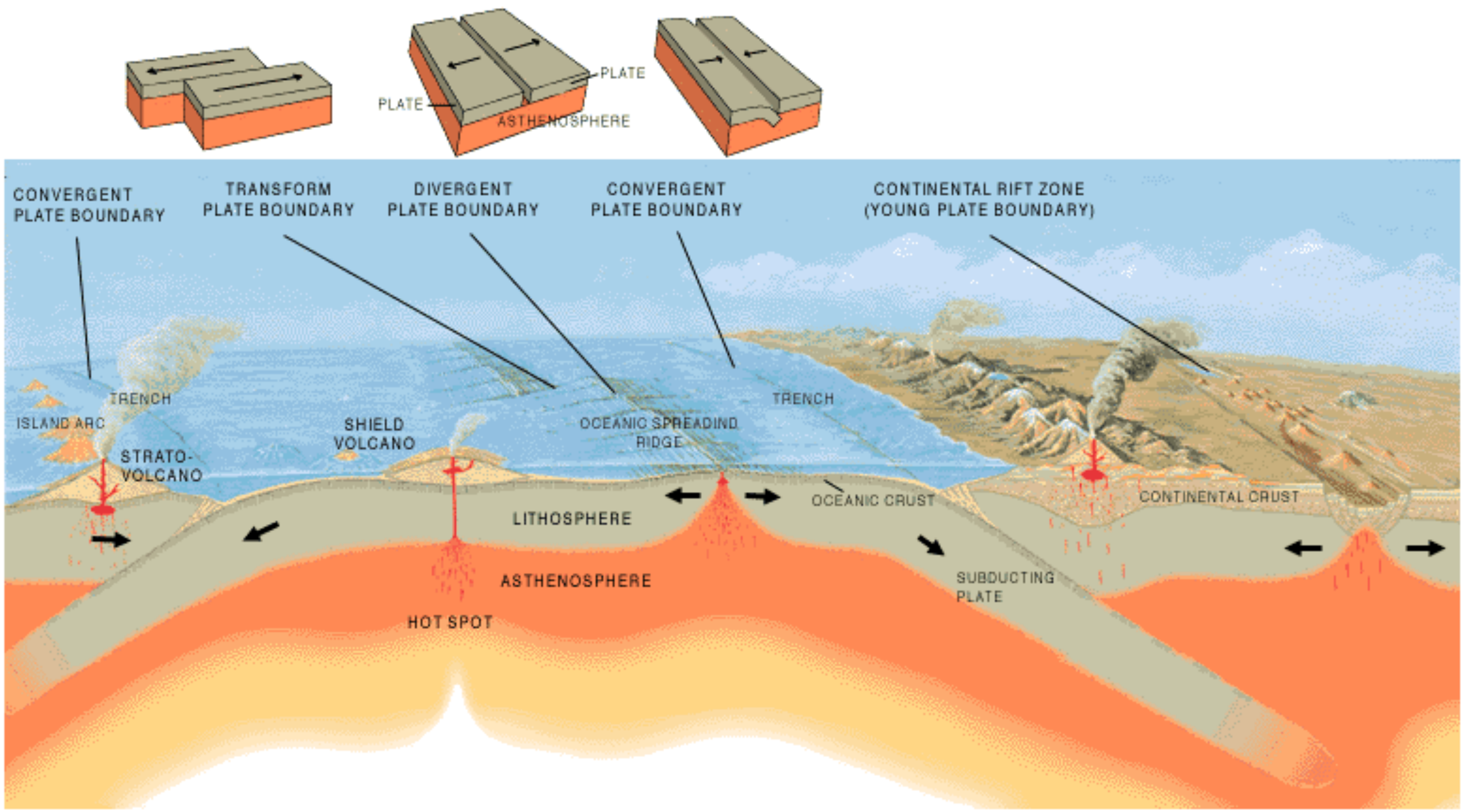
- The lithosphere is the “crust” of the earth. The part that has had time to cool off enough to become solid.
- The plates are parts of the lithosphere that are floating in the liquid part (the mantle).
- The motion of the plates seems very slow to us but because of the size and energy they crash into each other with great force.

Plate Boundaries

There are 3 basic ways that the plates can move in relation to each other.

1) Transform - slide side to side
2) Divergent - slide apart
3) Convergent - slide together

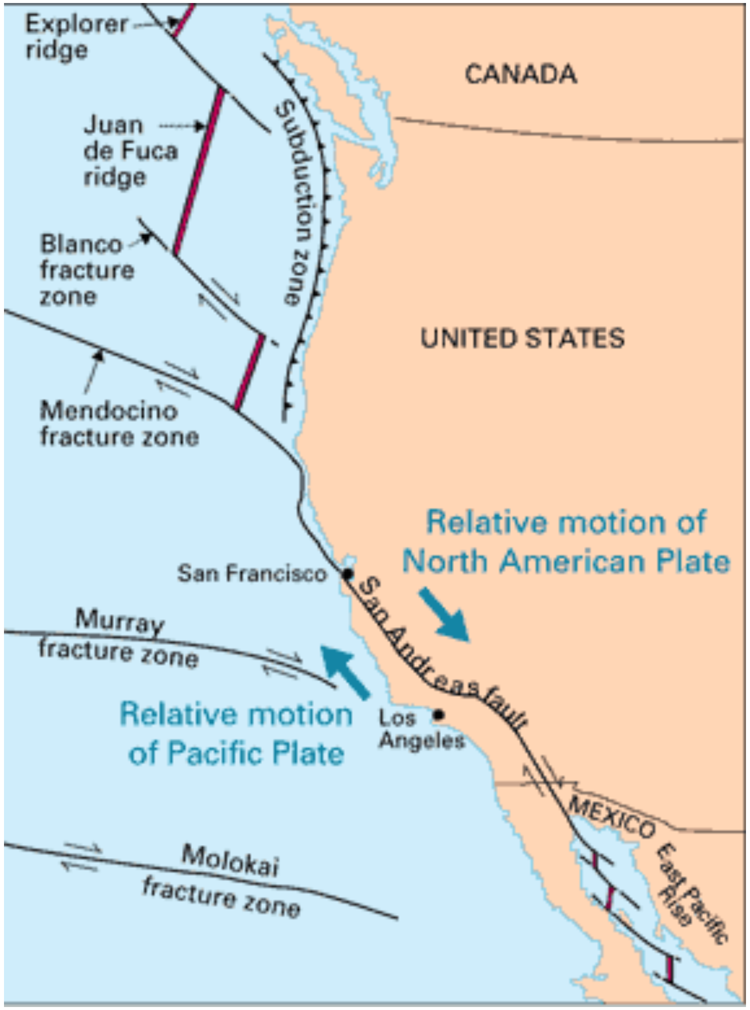
Kinds of tectonic plate boundaries



San Andreas fault

The San Andreas fault near San Luis Obispo

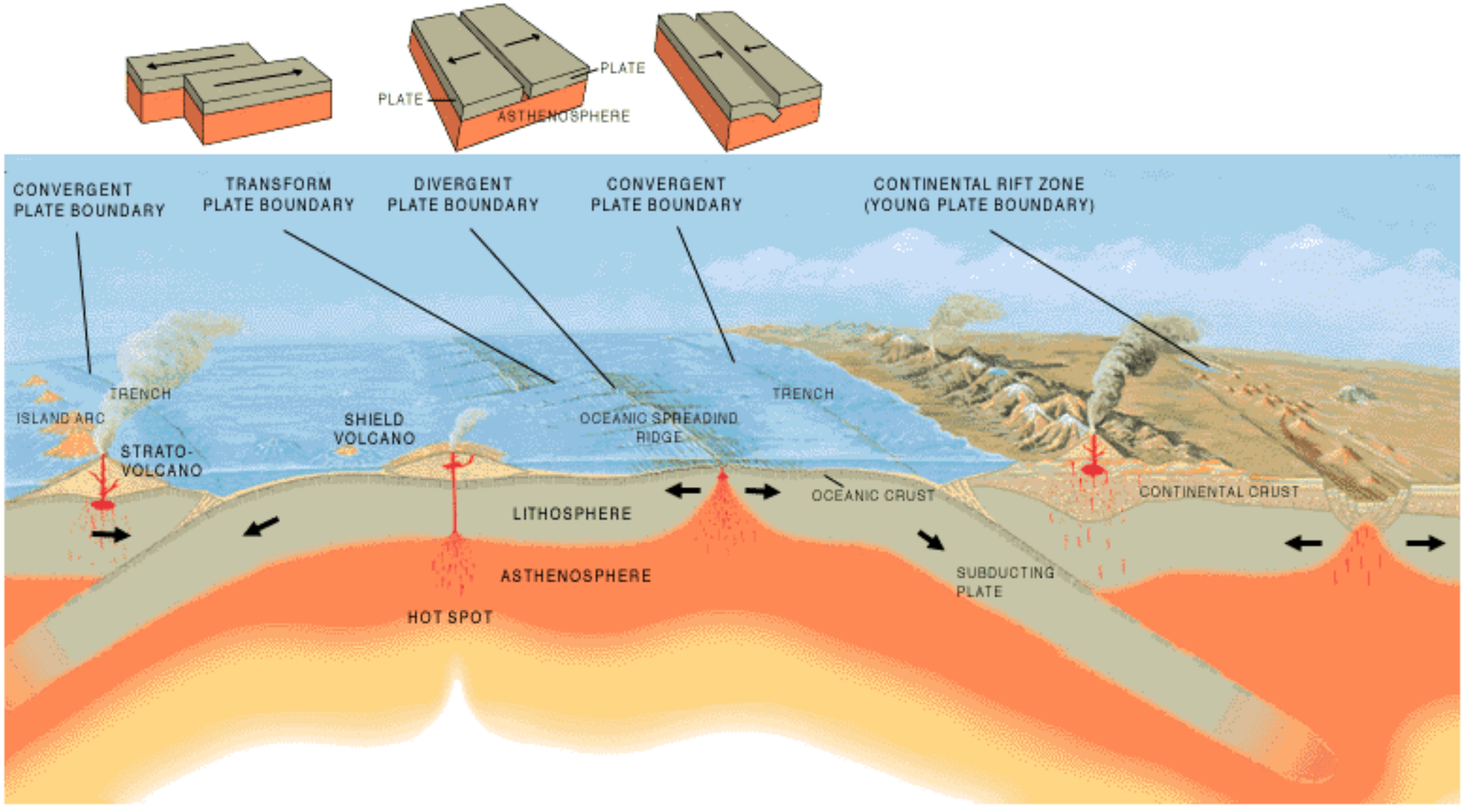
Western US Plate Boundaries

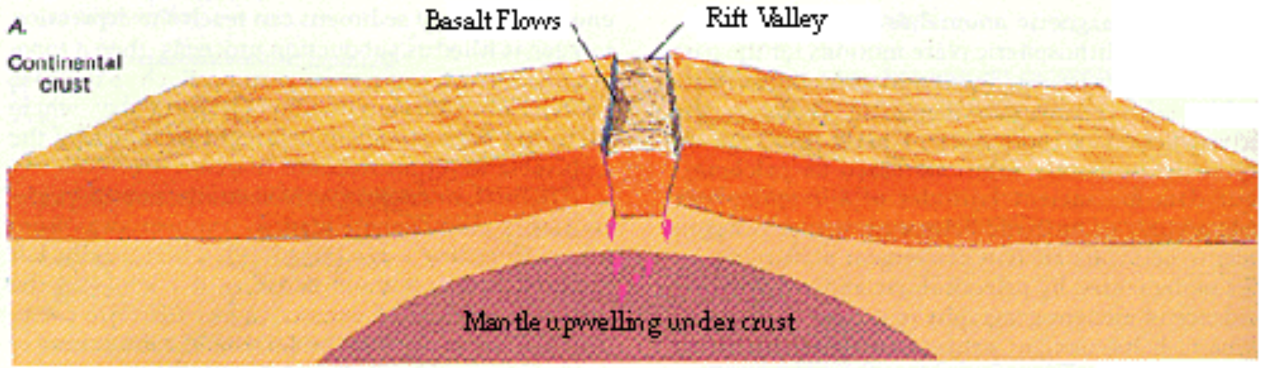


Transform Boundaries

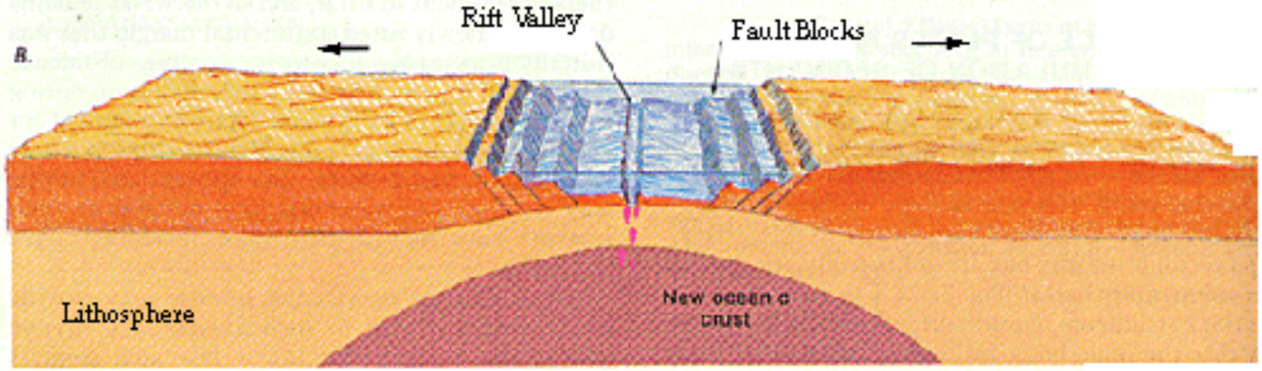
- Transform boundaries when two plates more or less slide along side each other in opposite directions.
- The San Andreas Fault is a famous example of a transform plate boundary.
- San Andreas Fault

Kinds of tectonic plate boundaries

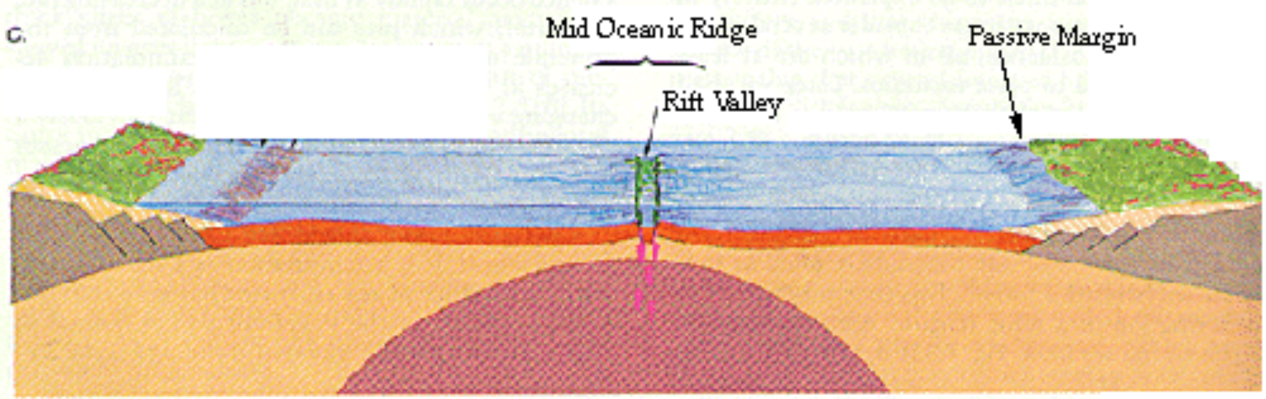




Mantle upwelling breaks up the continent



Spreading continues as seas fill in



Eventually oceanic crust develops in between the continental pieces

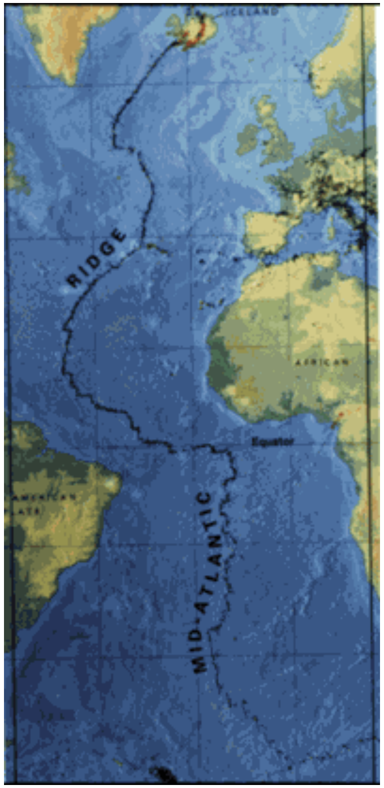
(Adapted From Dott, 1994)

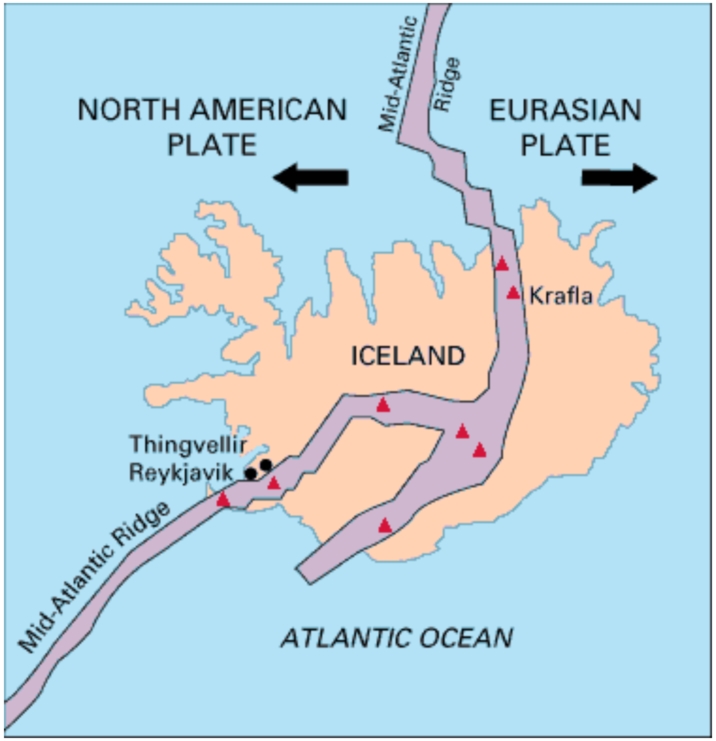
Mid Atlantic Ridge

The Mid Atlantic Ridge is an example of a divergent plate boundary. The plates are spreading apart (very slowly, about 2.5 cm or one inch per year).

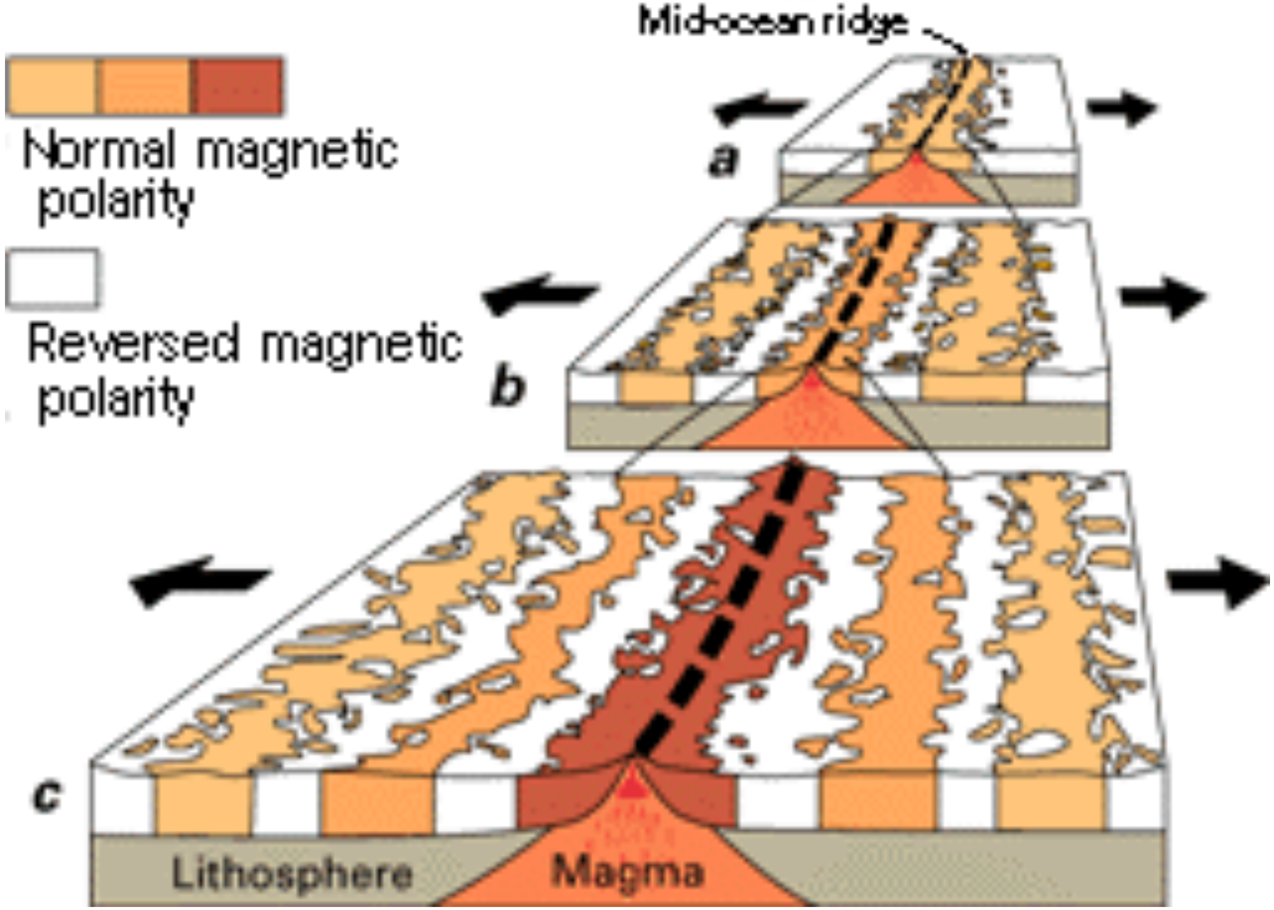
As the plates spread apart liquid rock from the mantle comes up to fill in the crack.

Mid Oceanic Ridge





Sea Floor Spreading



Oldoinhyo Legai

An explosive eruption in 1966 in the East African Rift Zone.

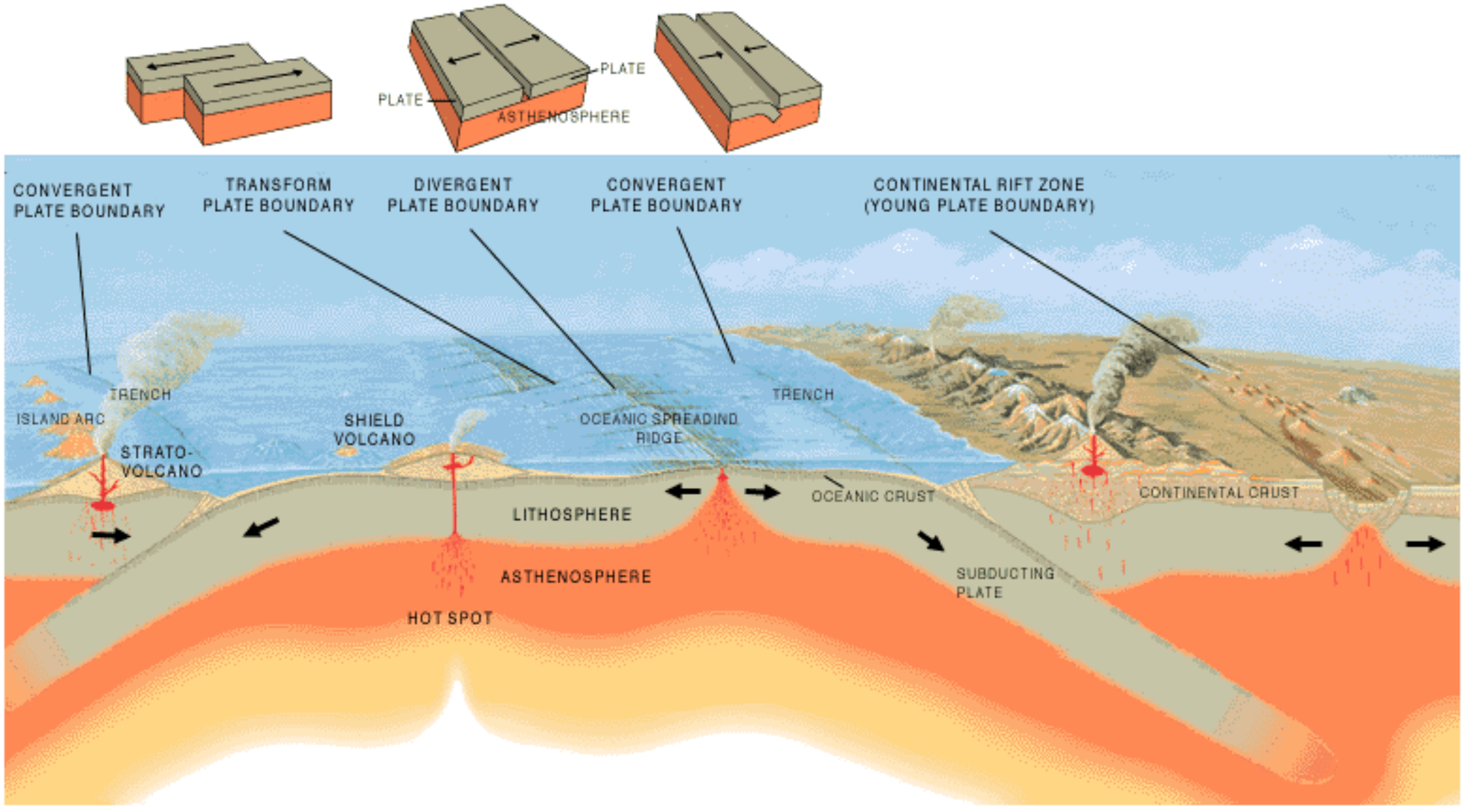
Erta ‘Ale in Ethiopia

Helicopter view of an active volcano in the East African Rift Zone. Two volcanologists are observing the activity from the rim. Red spots are where molten lava is breaking through the solidified black crust.

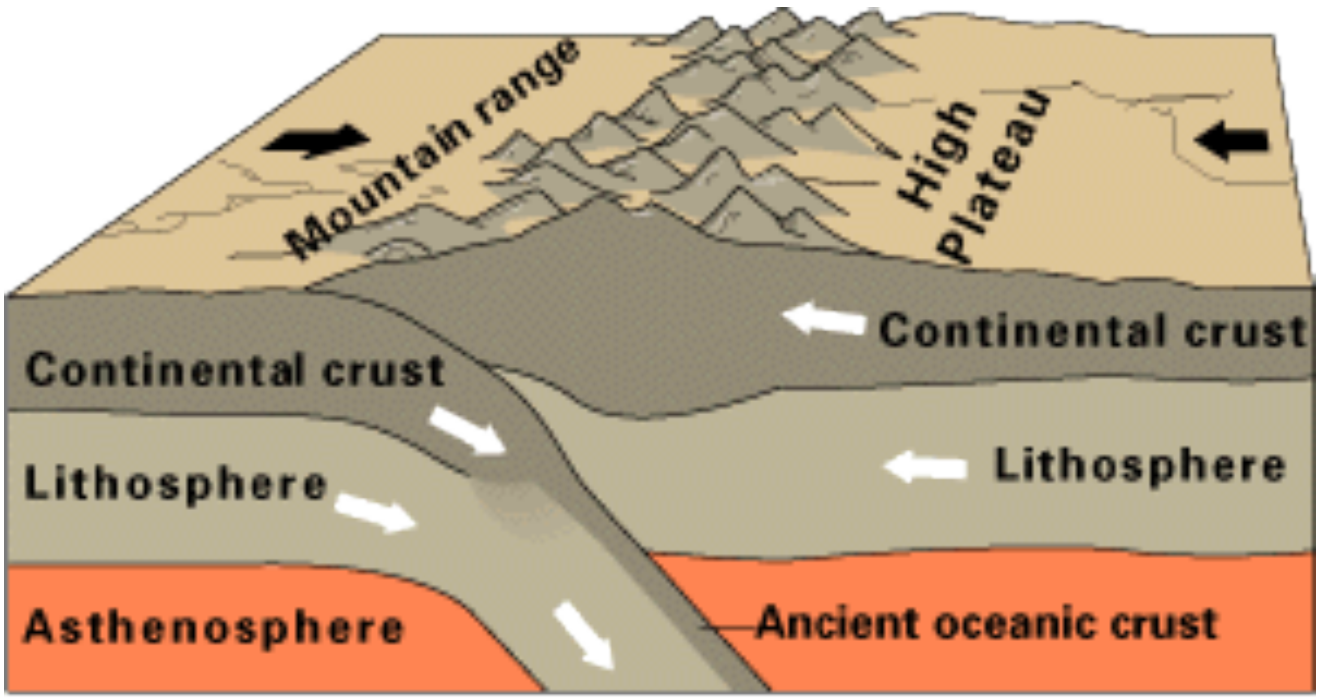
Minnesota's Example

- Mid Continent Rift in MN

Kinds of tectonic plate boundaries

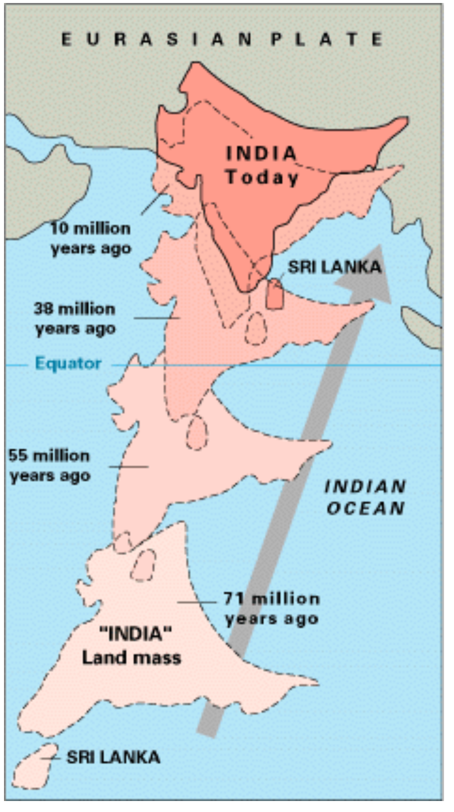


Continental - continental convergence

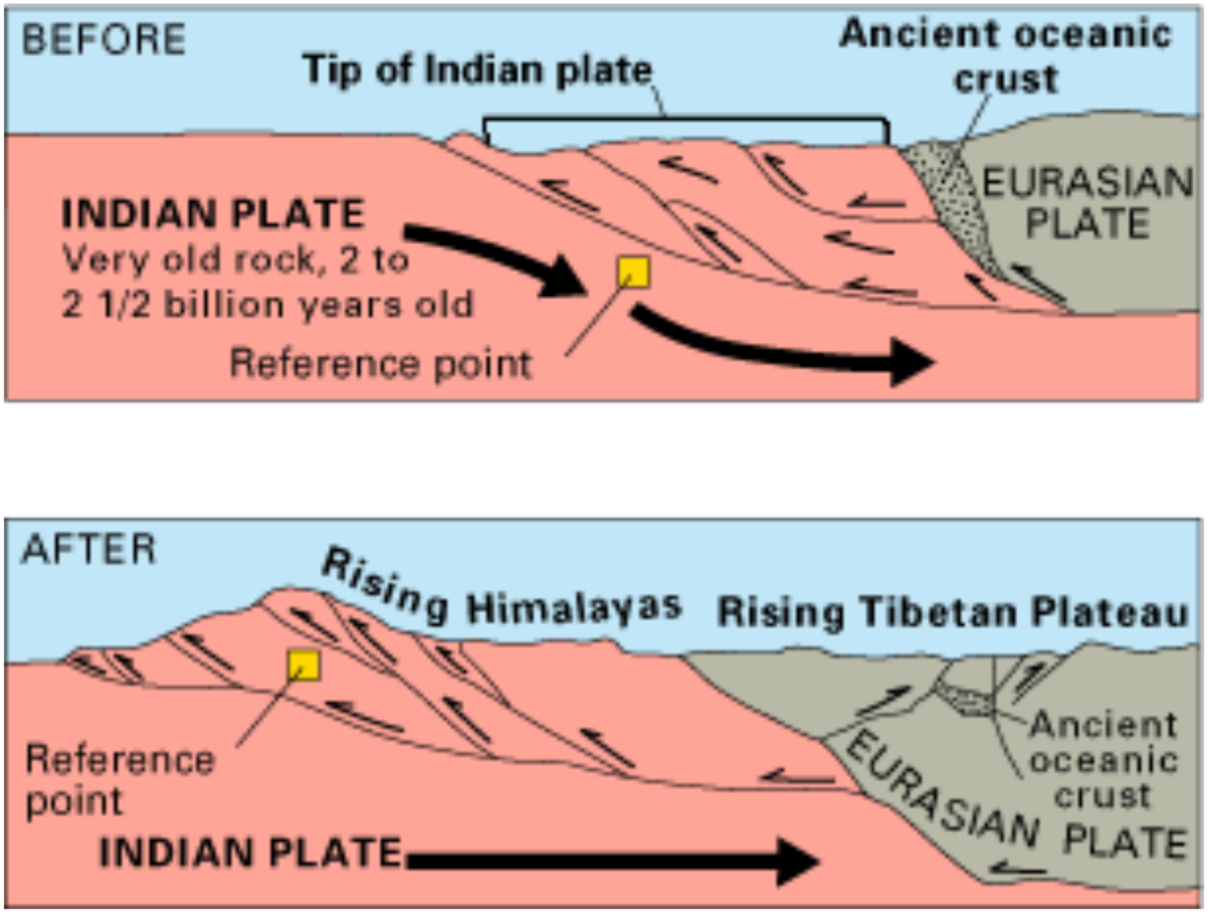


Continental-continental convergence

India Motion - Himalayas

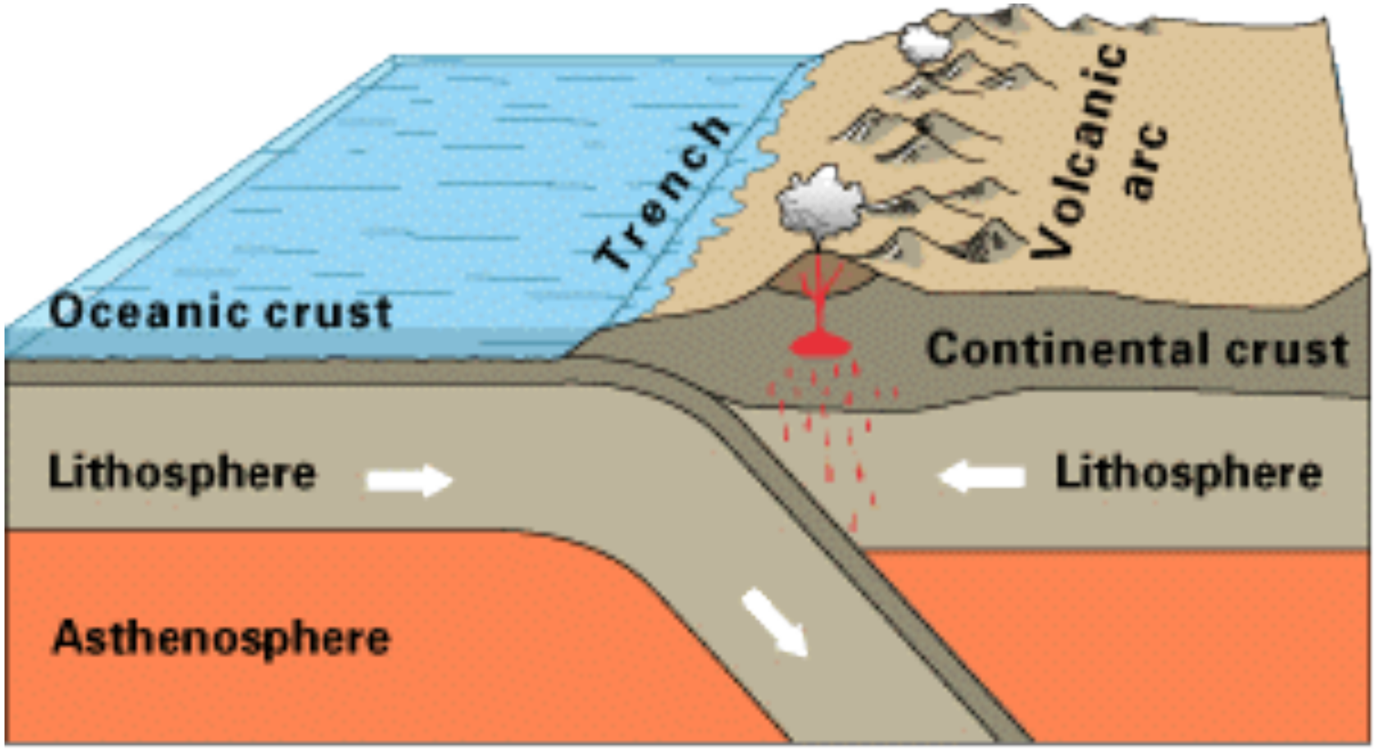


Himalayas Formation



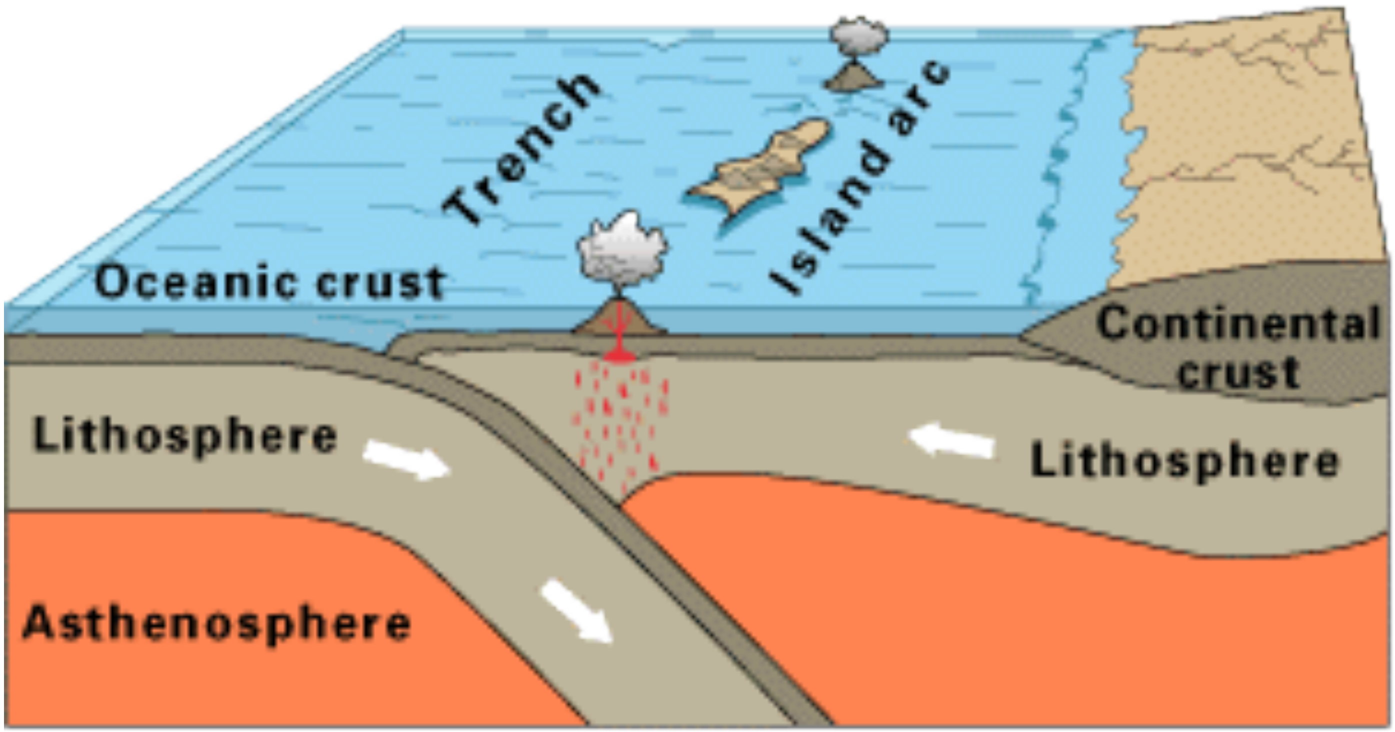
Himalayas Formation

Oceanic-continental convergence



Oceanic-continental convergence

Island Arc Formation



Oceanic-oceanic convergence

MN Island Arc Formation

- MN Converging Plate Boundary

History Sequence of MN Plate Tectonics

- MN Plate Tectonics Summary

MN Volcanic Evidence

- Volcanic Remnants
- MN Bedrock
- MN Rock Cross Section

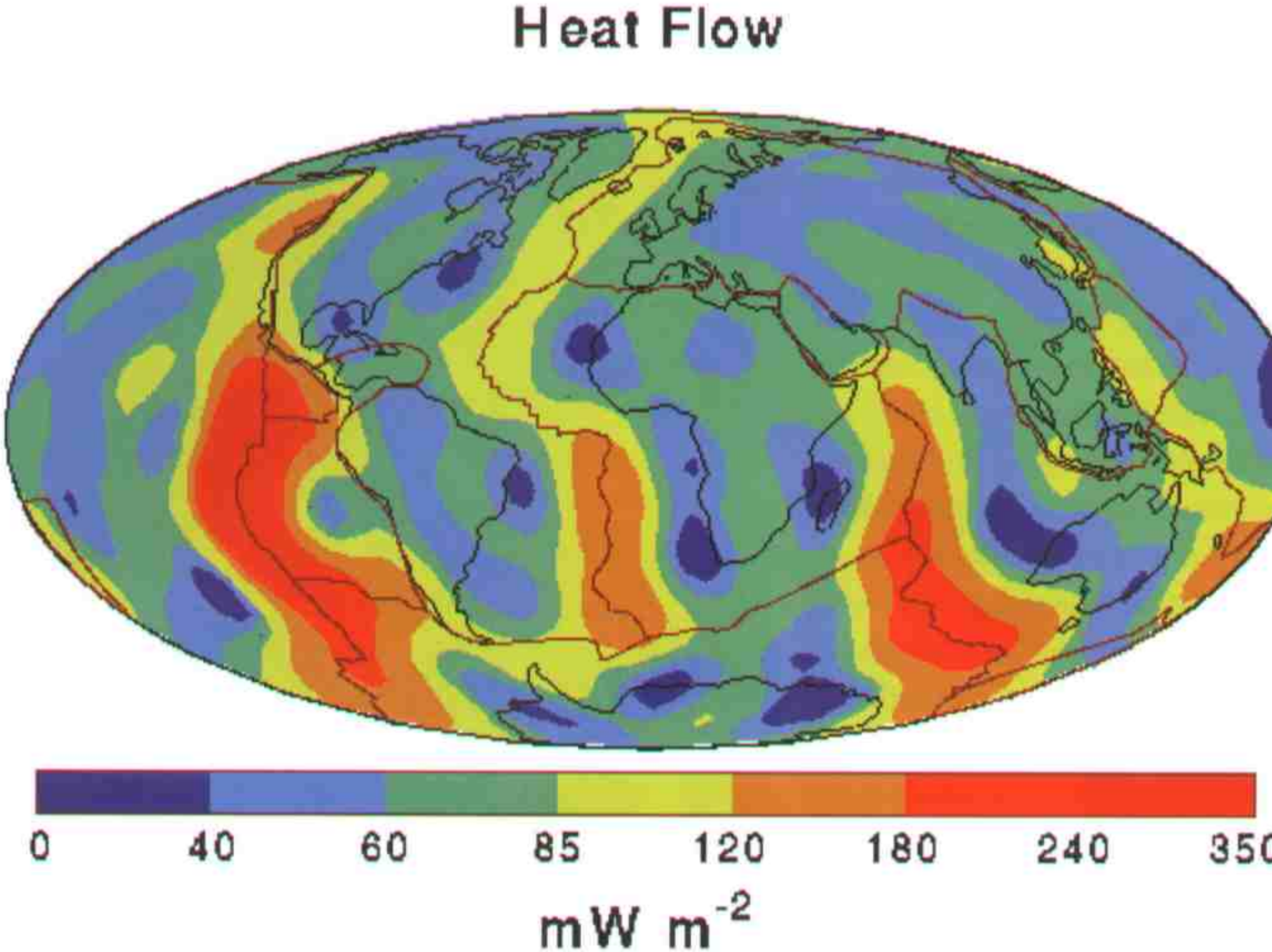
Where does the heat come from?

1) Compression and friction when the earth was formed.
2) Nuclear reactions in the core

Magma Properties

	Basalt	Andesite	Rhyolite
SiO_2	50%	60%	70%
Al_2O_3	20%	17%	14%
$Na_2O + K_2O$	3%	6%	9%
$FeO+Fe_2O_3+MgO+CaO$	25%	15%	5%
Temperatures	≈1050-1200°C	≈1000°C	≈750-1000°C
Volatile content	low	medium	high
Viscosity	low	medium	high

Earth Temperatures



Rock Melting Properties

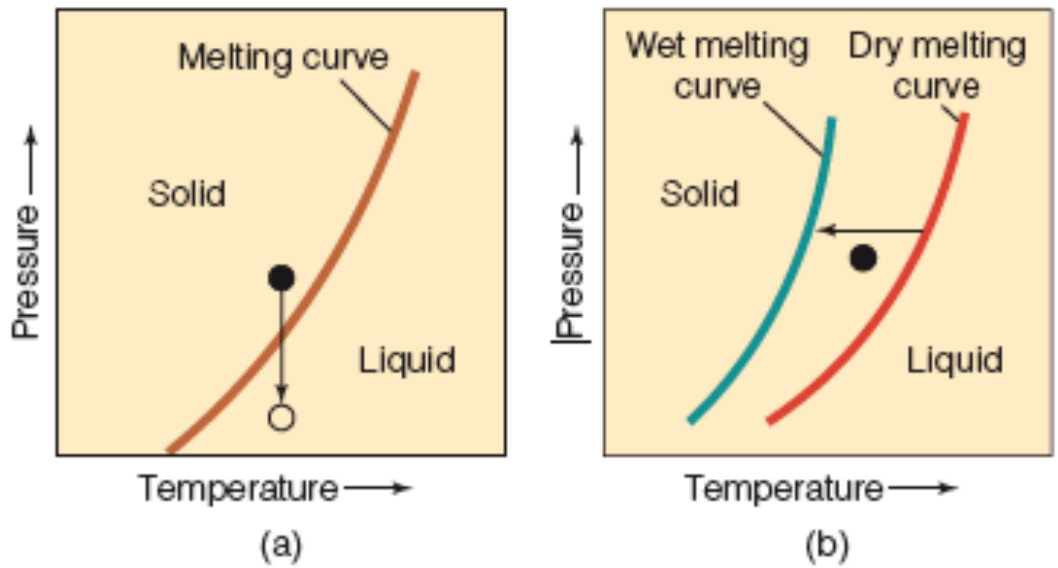
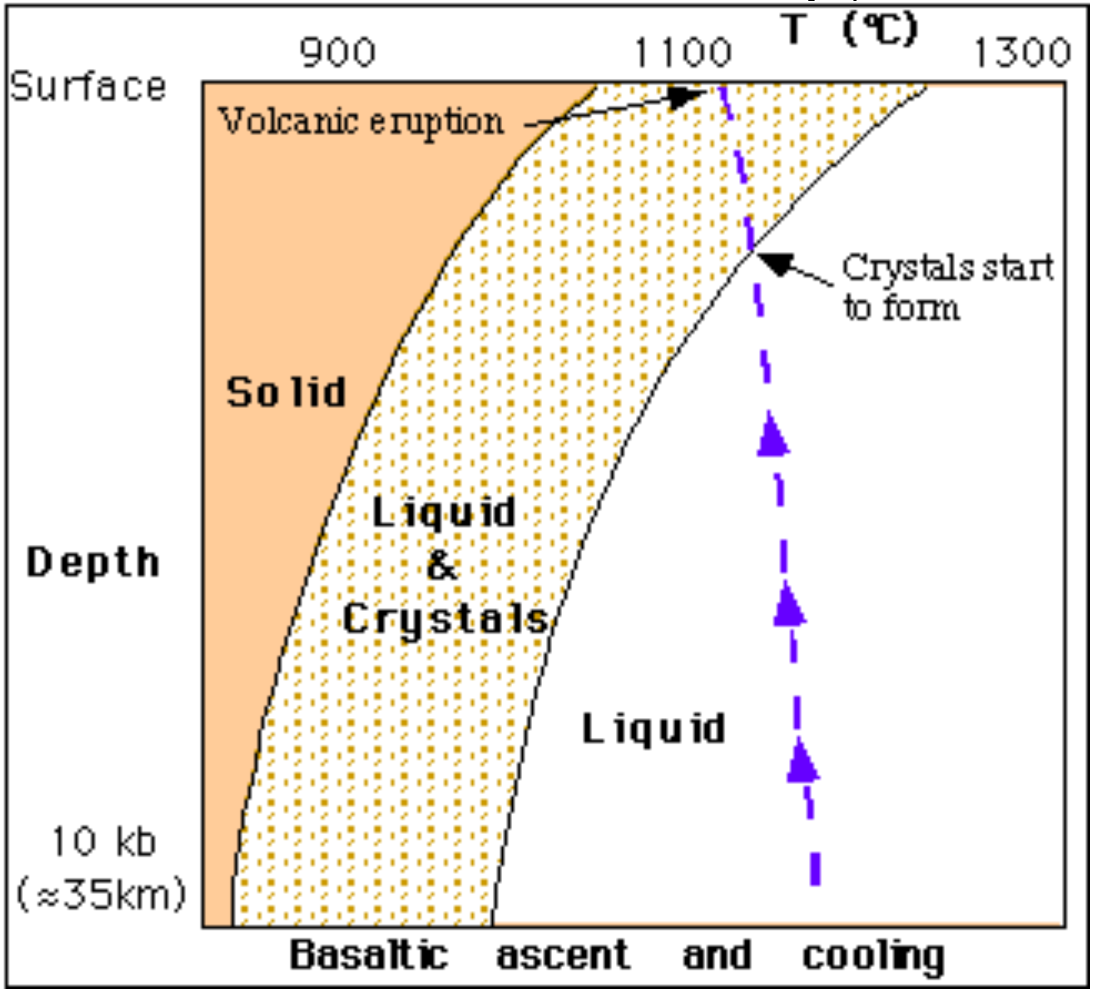


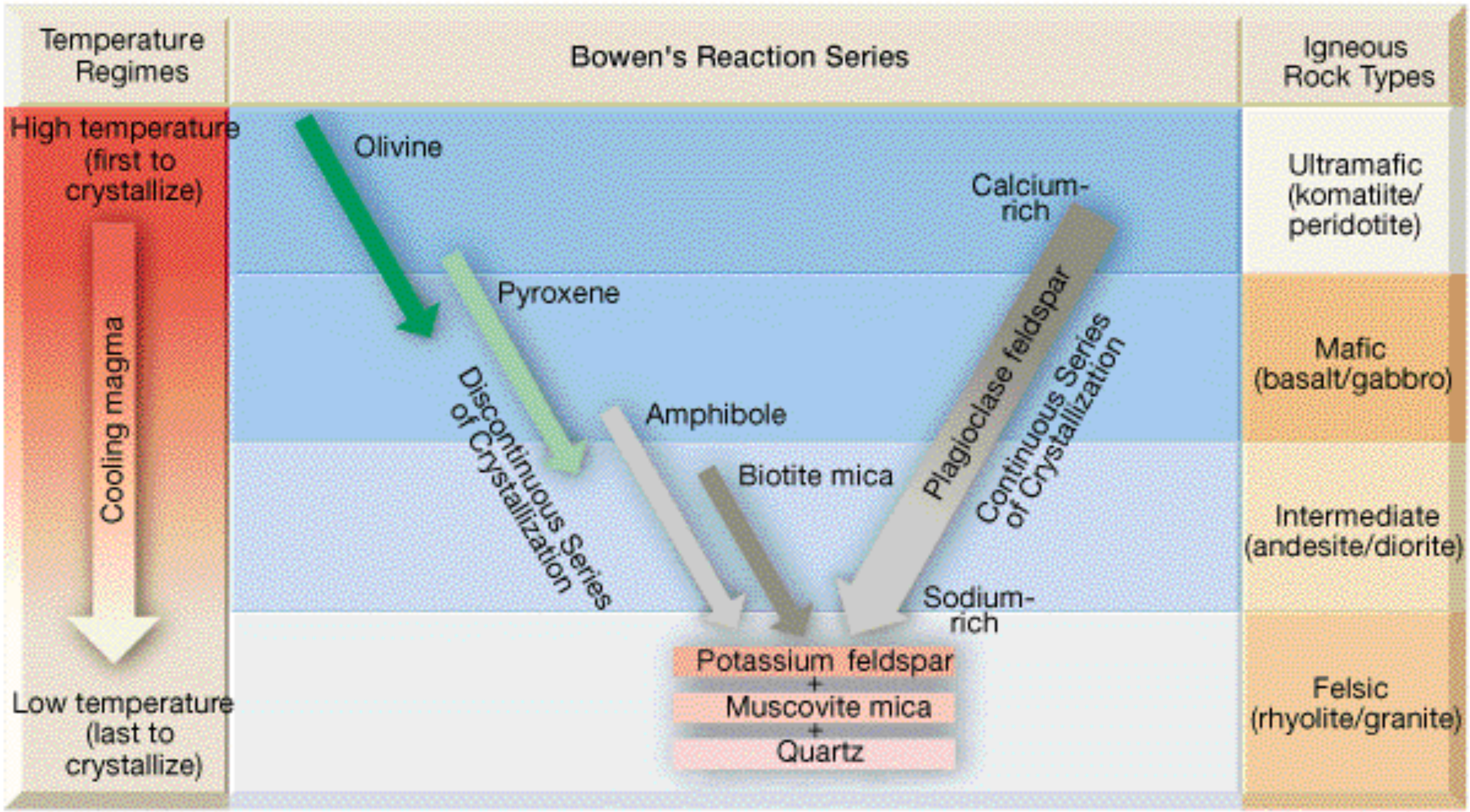
Figure 4.4

The effects of pressure and temperature on melting. (a) As pressure decreases, even when temperature remains constant, melting takes place. The black circle represents rock at high temperature. The same rock (open circle) melts at lower pressure. (b) If water is present, the melting curve shifts to the left because water provides an additional agent to break chemical bonds. Accordingly, rocks melt at a lower temperature (green melting curve) if water is present.

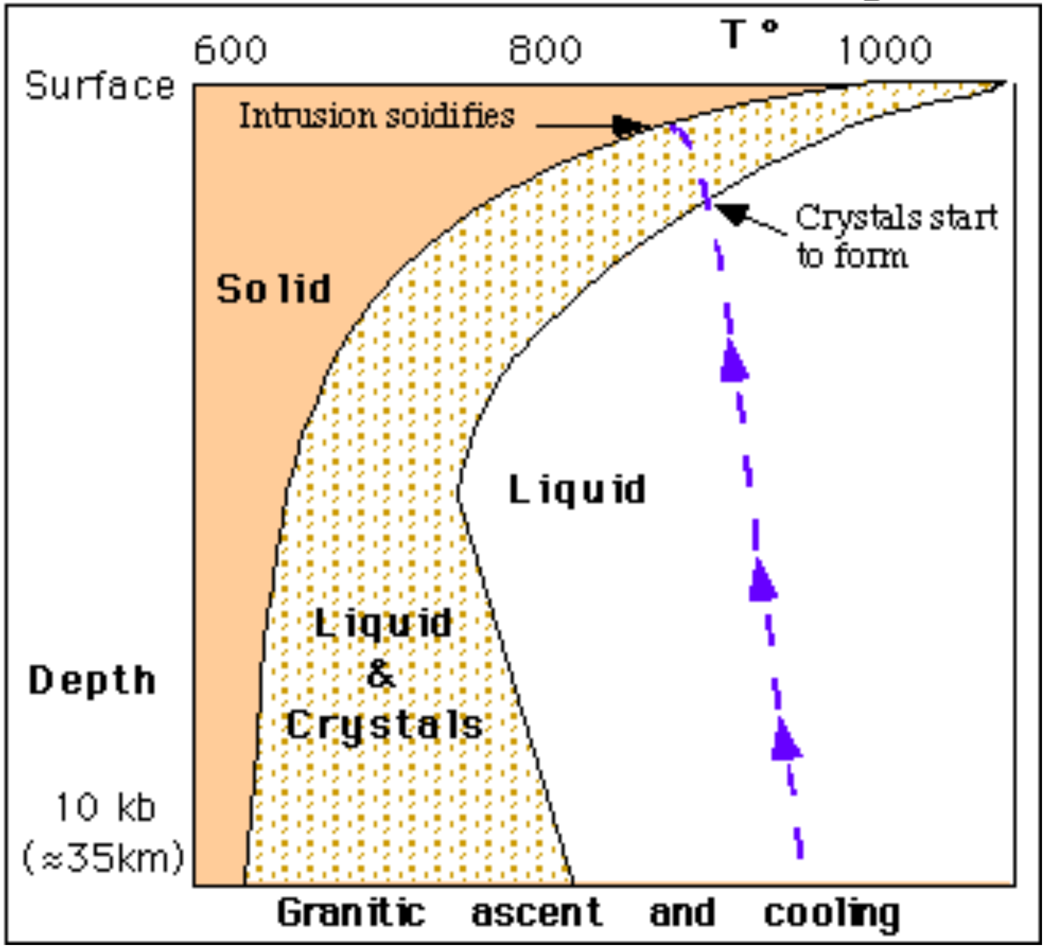
Basalt Melting



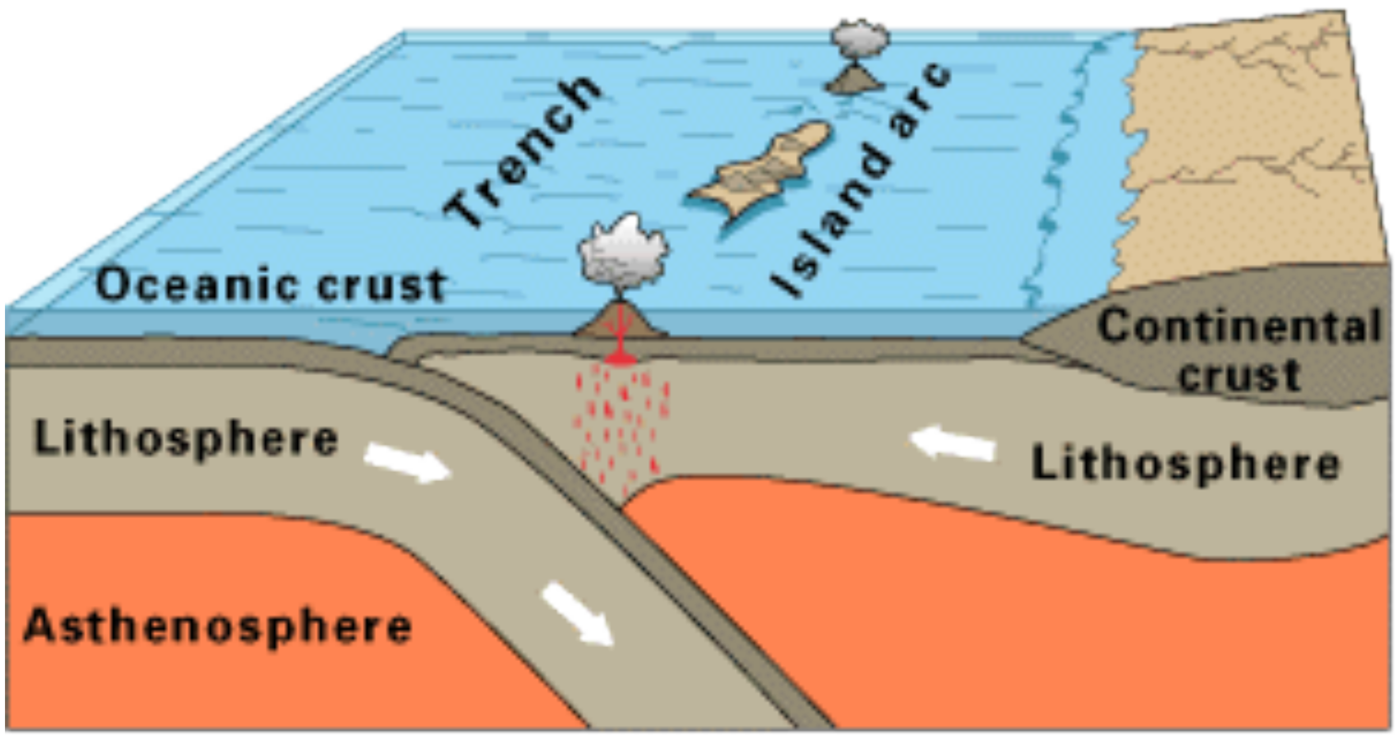
Bowens Reaction Series



Granite Melting



Island Arc Formation



Oceanic-oceanic convergence

Subduction Zone

- When an oceanic plate and a continental plate converge the oceanic plate gets subducted - it is pushed under the continental plate.
- The oceanic plate is more dense so it “rides” lower in the asthenosphere than the continental plate. This is why it is always the oceanic plate that is subducted.

Partial Melting

- As the plate gets pushed down into the earth the temperature rises and it begins to melt
- Because granitic minerals have a lower melting point it is the part of the lithosphere that gets melted first.
- This causes granitic magma to be formed and bubble to the surface.

Volcano Production

- The liquid magma gets forced to the surface and forms a volcano.
- The volcano formed in these situations are very often strato or composite cone volcanoes as volcanic mountains.
- The magma is very viscous often causing explosive eruptions as the escaping gases force out the magma.

Continental Volcanoes

- If the subduction zone is under existing land masses a continental volcano is formed.
- The formation of the volcano is almost always part of the formation of a mountain range.
- The process of forming mountains is called orogeny.

Back Arc Basin

- If the subduction zone is out underneath the near shore ocean a Back Arc Basin is formed
- The Japanese Islands are an example of a back arc basin being formed today.
- The shores of the back arc basin formed in Minnesota cause important geologic and economic deposits of minerals
- MN Back Arc Basin

MN Penokean Orogeny and the Animikie Basin

- Minnesota's Back Arc Basin evidence