Earth major plates:

1. African plate
2. Antarctic plate
3. Eurasian plate
4. Australian plate
5. Indian plate
6. N. American plate
7. S. American plate
8. Pacific plate
9. Atlantic plate

Earth minor plates:

1. Arabian plate
2. Coco plate
3. Nazca plate
4. Philippine plate
5. Caribbean plate

Concept of plate tectonic:

1. Explains the global distribution of seismicity, volcanism, continental rift, and mountain building.
2. In terms of formation, destruction, and movements
3. Plate are relatively moving towards each others and changing in shapes and size.
4. Most of earthquake occurs in the boundaries.

Super plume:

1. Magma that rises from the mantle into the crust.
2. It erupts as lavas when reach the surface.
3. It produces volcanic rocks when it's remains below surface.
4. Africa and Pacific.

Subduction zone:

1. The edge of one lithosphere plate is forced below the edge of another.
2. The denser plate will sink down.
3. The plate will generate seismic and volcanic activity in the above plate.
4. Japan, S. America, and Indonesia.

Convection:

1. Heat transfer in gas or liquid by circulation of currents from one place to another.
2. When a fluid is heated from below.

Continental & oceanic crust:

	Continental	Oceanic
Rock types	Sedimentary and metamorphic	Mafic
layers	Upper: granitic (50% silica) Lower: basal (30 % silica)	1st: unconsolidated sediments 2nd: pillow lavas & sheeted dike 3rd: gabbro
Thickness	35-40 km (exceed 70 km)	Less than 10 km
Density	Low (2.7 gm/cm^3)	High (3.3 gm/cm^3)
Age	4 billion years old	180 million years old

Upper & lower contintal crust:

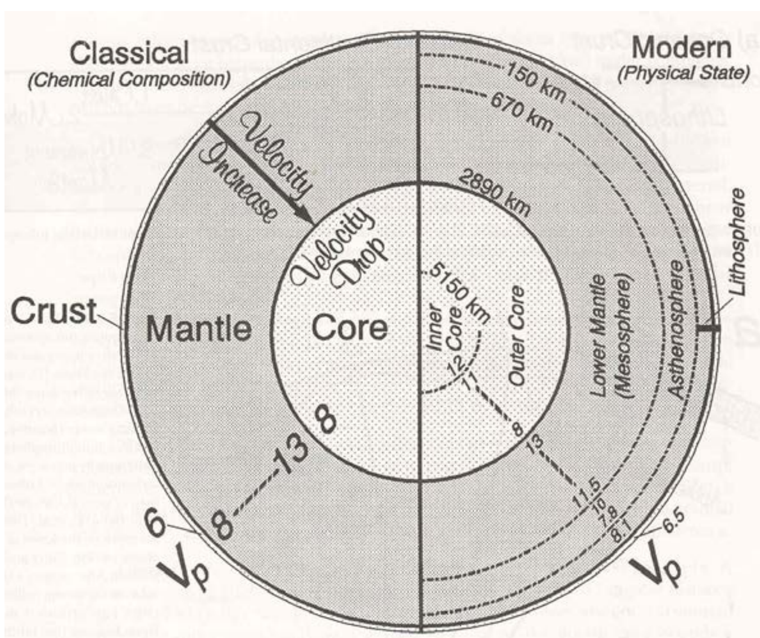
	Upper	Lower
Rock types	Felsic (peridotite)	Mafic (olivine)
Density	Low (2.7 gm/cm^3)	High (3.1 gm/cm^3)
Vp/Vs	Low (1.74)	High (1.84)

Physical layers:

Layer	Thickness	Type
Lithosphere	200 km (continental & oceanic)	Hard solid
Asthenosphere	600 km (upper mantle)	Soft and weak with high T & P
Mesosphere	660 – 2900 km (lower mantle)	Rocks are very hot and flow
Outer core	2270 km (magnetic field)	liquid
Inner core	3486 km (stronger than outer core)	Behave like a solid

Chemical layers:

Layer	Rock types	Thickness
Crust	Igneous, metamorphic, and sedimentary	Continental (35-40) oceanic (5-10)
Mantle	Igneous rocks	2900 km
Core	Iron-nickel	3400 km



Deformation:

1. All changes in the original form, size, and shape of a rock.
2. It also changes in location and orientation of the rock.

Stress:

1. Force acting in unit area (F/A).
2. Unit in Pascal = 1 N/m^2
3. Types:
    1. Normal "tensional": when stress tend to stretch a rock unit perpendicular to the face of the rock.
    2. Shear "differential": when stress is applied unequally in different directions parallel to the face of a rock.

Strain:

1. The resulting deformation of stress.
2. Rocks move relative to each other without any change in size or shape.
3. Types:
    1. Elastic: Deformations which are recovered after the external forces have been removed. Seismology focus on this type.
    2. Plastic: When deformation remain after removing the external forces. Rupture occurs.

Moho:

1. Is the layer that separates the crust from the upper mantle.
2. Chemical boundary.
3. Ranges from 5-40 km.
4. Deepest one is 70 km depth beneath Tibetan Plateau.

Plate motions forces:

1. Slab pull "subduction tectonic plate".
2. Ridge push.
3. Convection currents.

Seismic waves:

Body wave		Surface wave	
P-wave	S-wave	Rayleigh	Love
Compressional wave	Shear wave “no volume change”	Motion dies down with depth	Perpendicular to the wave propagation direction “ no vertical movement”
Particles moves at the same directions as the wave’s propagation direction	Particles move parallel to the wave’s propagation direction	Amplitude decrease with depth	No vertical movement
Used for oil “shallow” exploration	Travel half of the speed of Vp	No volume change because of shear stress	Surface wave are noise waves

Seismic velocities:

Layer	V_p	V_s
Crust	7.6 km/s	4.4 km/s
Upper mantle	7.8 km/s	4.5 km/s

Strength of continental crust:

1. Thickness of the crust (decrease with increasing the thickness)
2. Mafic composition of the lower crust.

Strength of oceanic crust:

1. Thickness of the crust.
2. The rule of plastic flow.

Poisson's ratio:

1. Changes of the diameter proportional to the change of length.
2. Material is stretched in one direction it tends to get thinner in the other direction.
3. High Poisson's ratio indicates mafic composition of the crust.
4. The range for most materials is from 0-0.5. Continental is 0.256 and oceanic is 0.30.
5. Poisson's ratio can be affected by:
    1. Temperature and pressure: the ratio will increase with increased pressure.
    2. Minerals contents.
    3. Silica contents: more silica will decrease the ratio.

Felsic & mafic:

	Felsic	Mafic
Color	Black/dark brown	Light
Mineral	High % of heavy minerals	Low % of heavy minerals
Rich in	Olivine	Quartz
Eruptions	Gently	Violently
Represent	Deeper materials	Melting of crustal materials
Vp/Vs	1.7	1.81

Strength of a material:

1. Can be measured by one of the elastic modulus: Bulk Modulus, Shear Modulus, Young's Modulus, and Poisson's ratio.
2. The higher the value of the modulus, the stronger the material.

Bulk Modulus:

1. It is defined as the pressure increase needed to cause a given relative decrease in volume. Its base unit is Pascal.
2. The material will be smaller by applying more force.

Shear Modulus:

1. It is defined as the ratio of shear stress to the shear strain.
2. Shear modulus is usually measured in GPa.

Young's Modulus:

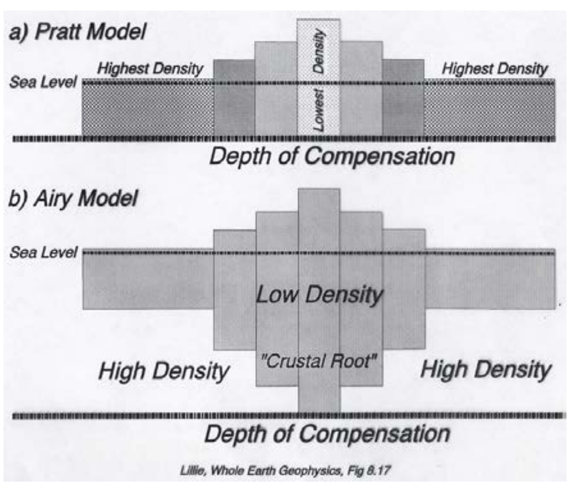
1. It is defined as the ratio uniaxial stress to the uniaxial strain.
2. Young's modulus has the unit of pressure (Pascal).

Bouguer gravity anomaly:

1. The difference between the expected value of gravity at a given location and its actual value.
2. It corrects the observed gravity value for latitude and elevation variations.

Free air anomaly:

1. The difference between observed gravity and theoretical gravity that has been computed.
2. It measures the mass excesses and shortage within the earth.



Seismic reflection data:

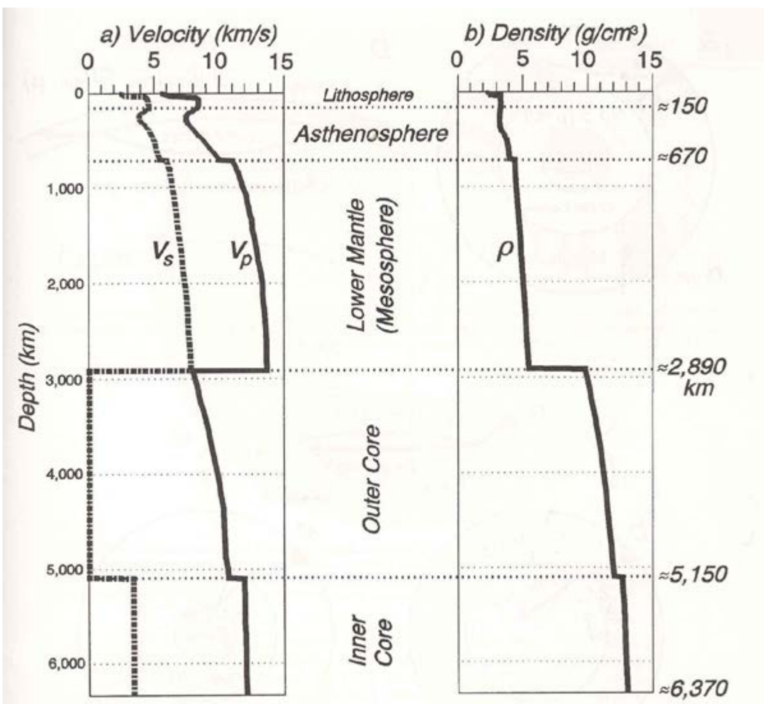
1. Provide details of the lower crust and the Moho.
2. Good for oil and gas exploration.
3. Show better details of the structure beneath the surface.
4. Can create geology cross-section.

Seismic refraction data:

1. Provide constraints on crustal thickness changes and seismic velocities.
2. Used to find the depth of bed-rocks.
3. Provide information about structure composition of layers below the surface.

Seismic velocities:

1. Provide constraints on the composition of the earth.
2. Show details of layering of the deeper crust.
3. Velocities depend on physical properties of earth materials such as densities and elastic moduli.



Rift zone:

1. A large area where plates of the crust are moving from each other.
2. They form system of fractures and faults. It is a feature of some volcanoes like Hawaii.

Continental rift extension forces:

1. Normal fault or an extensional fault. The hanging wall moves downward, relative to the footwall
2. Lower crustal attenuation.
3. Lower crustal intrusion forming plutons.
4. As in East African Rift where the entire tectonic plates are in the process of breaking apart to create new plates.

Earthquakes deeper than 700 km:

1. Layer of convection and slabs do not go deeper than 700 km.
2. The end of subduction zone at this depth.

Low amplitude of recorded Ps conversion means:

A weak Moho transition zone.

Thickened area of the crust corresponds:

The zone of reduced velocity in the upper mantle.

420 km discontinuity:

1. The velocities of seismic wave’s changes.
2. Corresponds to changes in the elastic properties of the earth’s materials.

Coda waves:

Are the directed converted phase (Pms), and the multiplies waves (PPms and PSmS)

Receiver functions:

1. A way to model the structure of the earth.
2. Image the depth to major velocity discontinuities in the crust and the uppermost mantle.
2. Use information from teleseismic earthquakes data recorded at three components seismograms "the first arrival is a refracted P-wave".
3. Receiver functions calculated by the de-convolving the vertical from the radial and tangential components.

Rock types:

Rock types	Composition	Examples
Igneous	Form as molten rock cools and solidifies	Basalt, gabbro
Sedimentary	The products of mechanical and chemical weathering	Limestone, coal, and quarts
Metamorphic	produced from preexisting igneous, sedimentary, or even other metamorphic rocks	Marbles, schist, and slate

Seismic velocities depends on:

1. Elastic constants (bulk, young's, shear, Poisson's)
2. Density of the material.

Continental rift hypothesis:

1. There was a supercontinent called Pangaea.
2. It begun to break apart about 200 million years ago.

Seafloor spreading hypothesis:

1. Upwelling of mantle materials along the mid-ocean ridges create new seafloor.
2. The old seafloor descends into the mantle.

Types of plate boundaries:

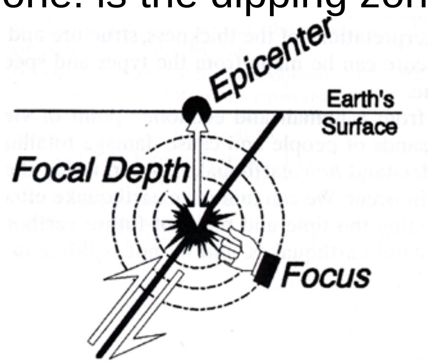
1. Divergent (construction margins): the direction of motion is perpendicular to the boundary as in Mid-Atlantic ridge.
2. Convergent (destruction): the direction of motion is at right angles of the trench as in Nazca, The Himalayas, and S. America.
3. Transform (construction): the relative motion is parallel to the fault as in San Andreas Fault.

Earthquakes:

1. Can be predicted by time, location, and magnitude.
2. Occur along existing faults.

Focus, epicenter, and Wadati-Benioff zone:

1. Focus: is the actual point/rupture within the earth.
2. Epicenter: is the point on earth's surface above the focus.
3. Wadati-Benioff zone: is the dipping zone of earthquakes.



Focal depths:

1. Shallow: 0-70 km occurs in all plate boundaries.
2. Intermediate: 70-300 km occurs in convergent plates.
3. Deep: 300-700 km occurs in convergent plates.

Velocity structure of the earth:

1. Velocities increases with depth because of pressure.
2. Sudden drop of P-wave at the outer core.
3. Sudden change in velocity and density at 670 km.
4. Low velocity area at depth of 200 km.

Ductile deformation:

1. When rock turn to flow.
2. Depend on temperature, pressure, and composition.

Separation rate for oceanic ridges:

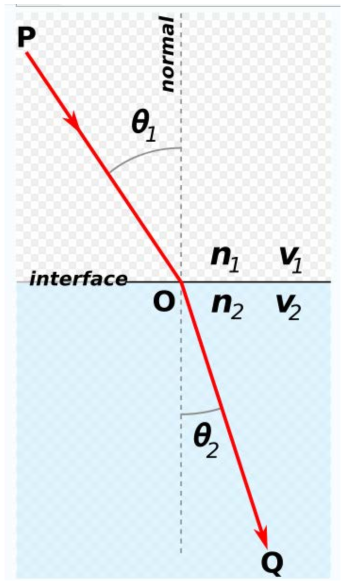
1. Fast: > 9m mm/yr as in East Pacific Ridge.
2. Intermediate: 50-90 mm/yr as in Northern East Pacific Rise.
3. Slow: 10-50 mm/yr as in Atlantic Ridge.

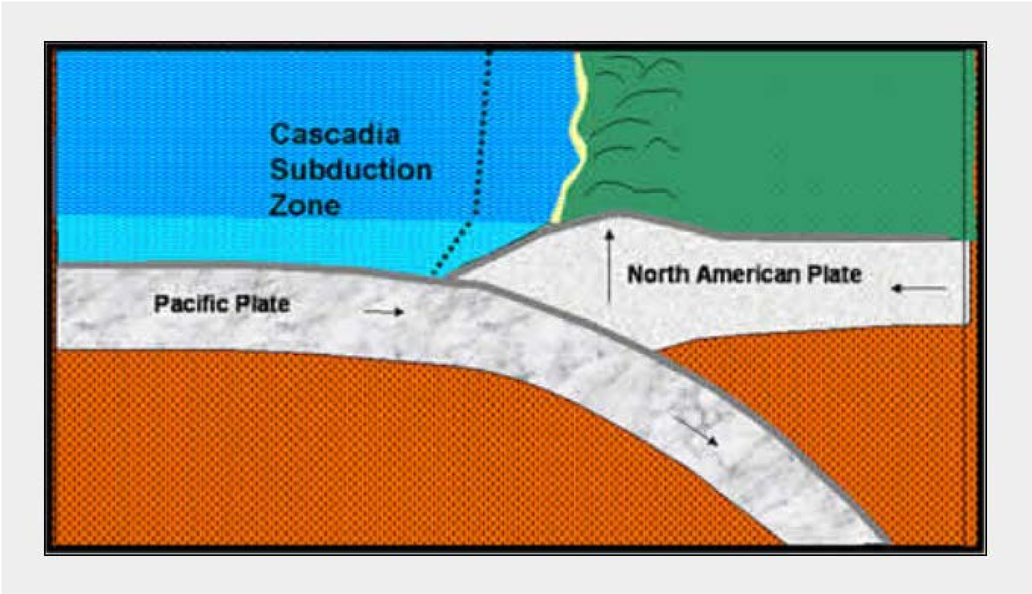
Active & passive rifting:

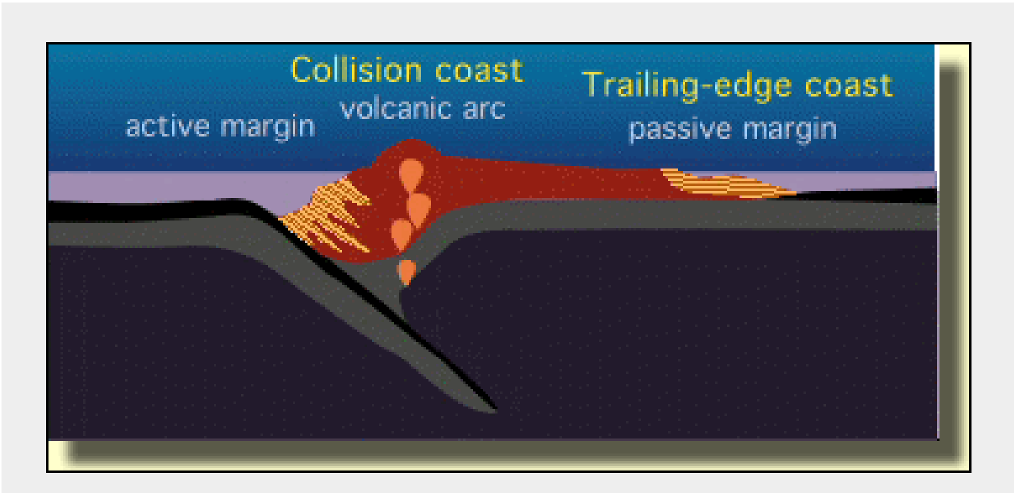
1. Active: results from local tension and drive by mantle plume.
2. Passive: response to regional far field stress drive by slab pull.

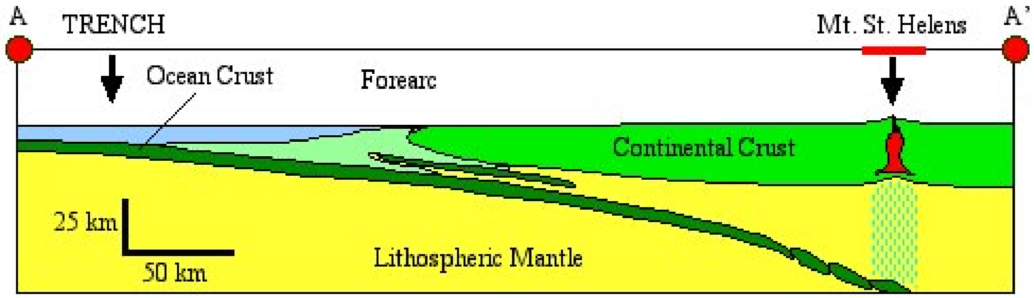
Snell's law:

1. It is a formula used to describe the relationship between the angles of incidence and refraction passing through a boundary between two different media.
2. The law says that the ratio of the sines of the angles of incidence and of refraction is a constant that depends on the media.




Cascadia
Subduction
Zone
North American Plate
Pacific Plate


Collision coast
volcanic arc
active margin
Trailing-edge coast
passive margin


A
TRENCH
Mt. St. Helens
A'
Ocean Crust
Forearc
Continental Crust
25 km
50 km
Lithospheric Mantle

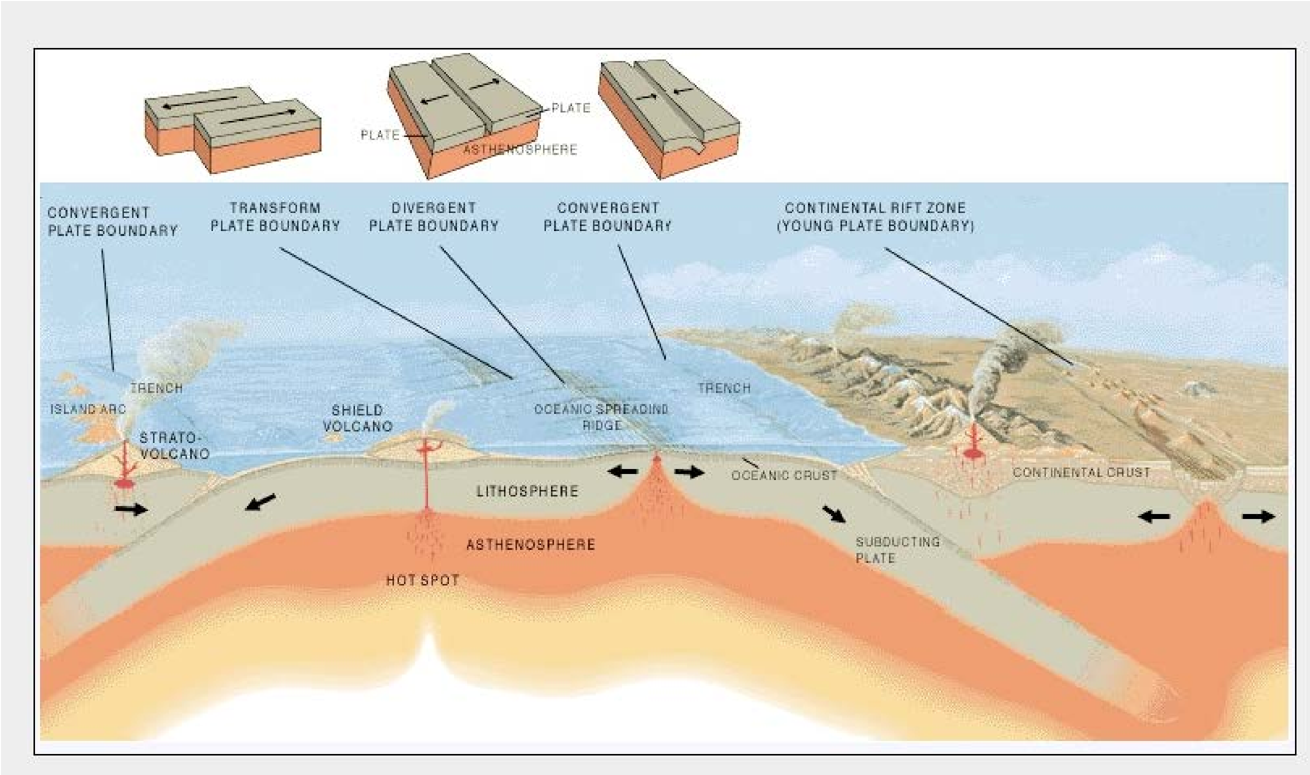
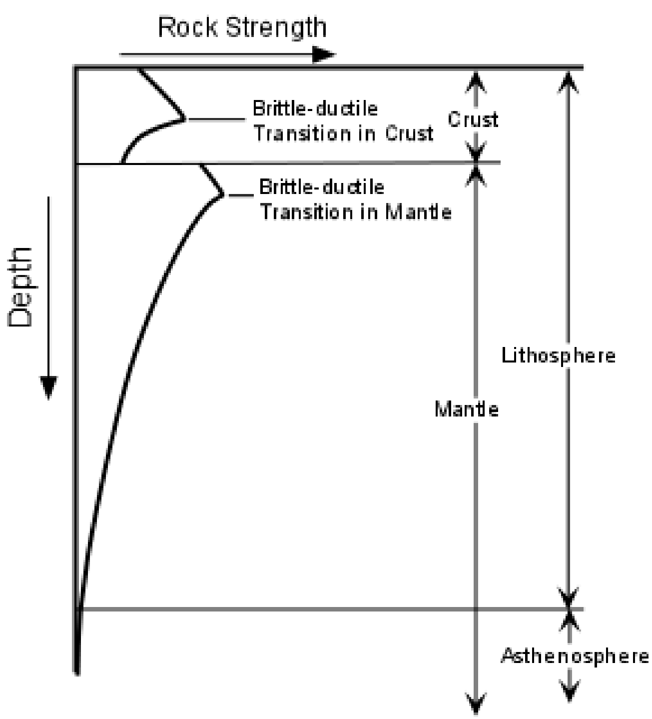
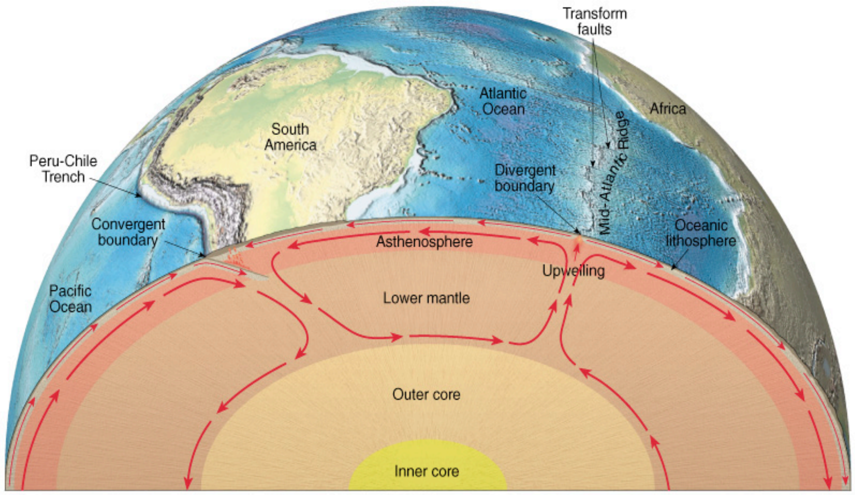
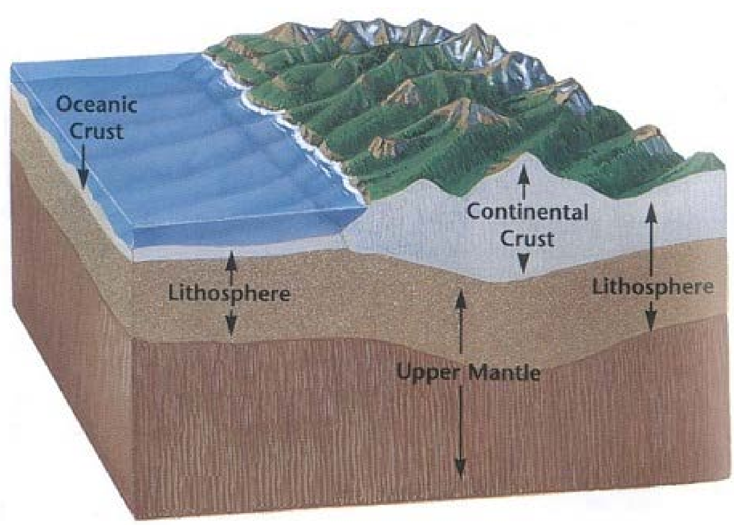
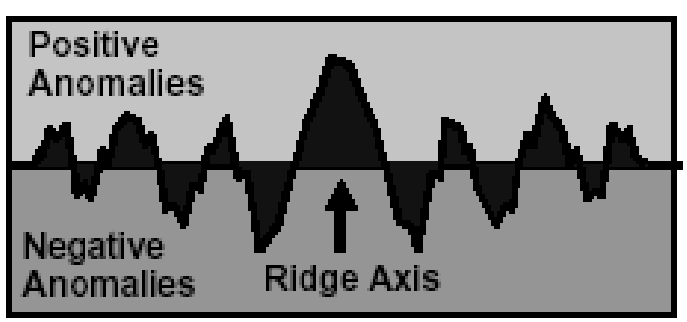


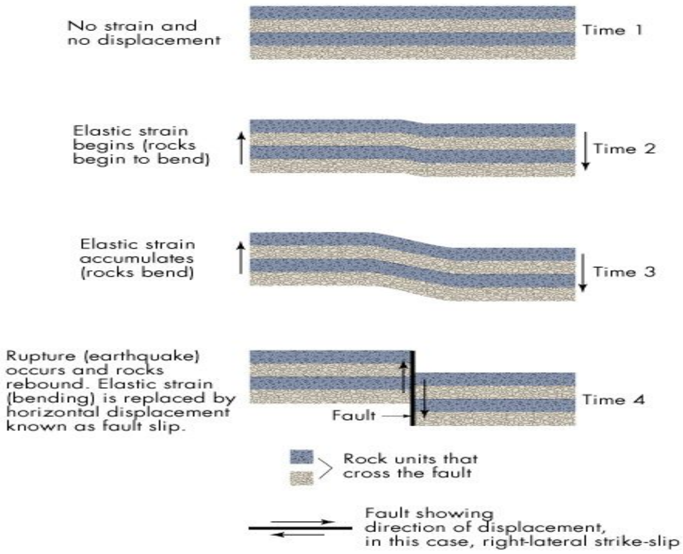
PLATE
PLATE
ASTHENOSPHERE
CONVERGENT PLATE BOUNDARY
TRANSFORM PLATE BOUNDARY
DIVERGENT PLATE BOUNDARY
CONVERGENT PLATE BOUNDARY
CONTINENTAL RIFT ZONE (YOUNG PLATE BOUNDARY)
TRENCH
ISLAND ARC
STRATO-VOLCANO
SHIELD VOLCANO
OCEANIC SPREADING RIDGE
TRENCH
OCEANIC CRUST
CONTINENTAL CRUST
LITHOSPHERE
ASTHENOSPHERE
HOT SPOT
SUBDUCTING PLATE

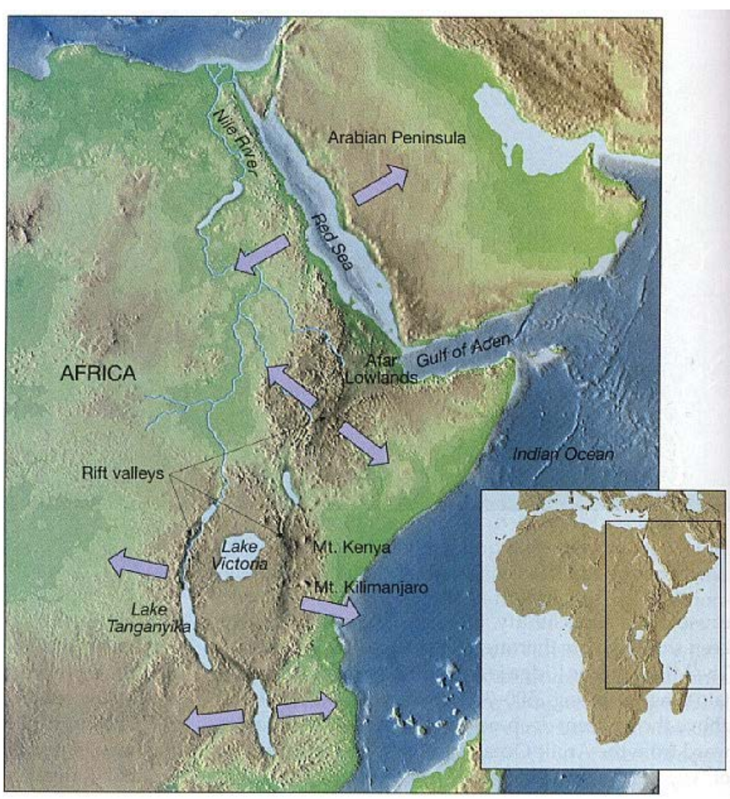

Rock Strength
Depth
Brittle-ductile Transition in Crust
Crust
Brittle-ductile Transition in Mantle
Lithosphere
Mantle
Asthenosphere

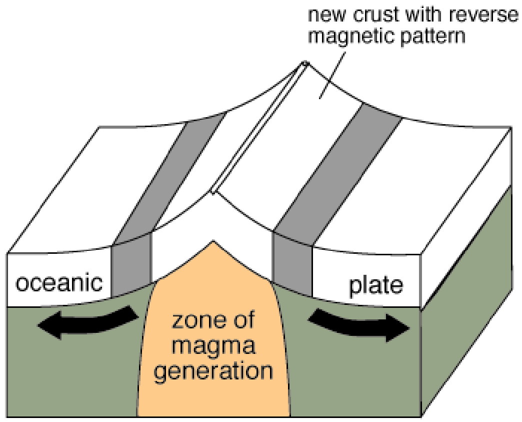

Transform faults
Atlantic Ocean
Africa
South America
Peru-Chile Trench
Divergent boundary
Mid-Atlantic Ridge
Convergent boundary
Asthenosphere
Oceanic lithosphere
Upwelling
Pacific Ocean
Lower mantle
Outer core
Inner core


Oceanic Crust
Continental Crust
Lithosphere
Lithosphere
Upper Mantle

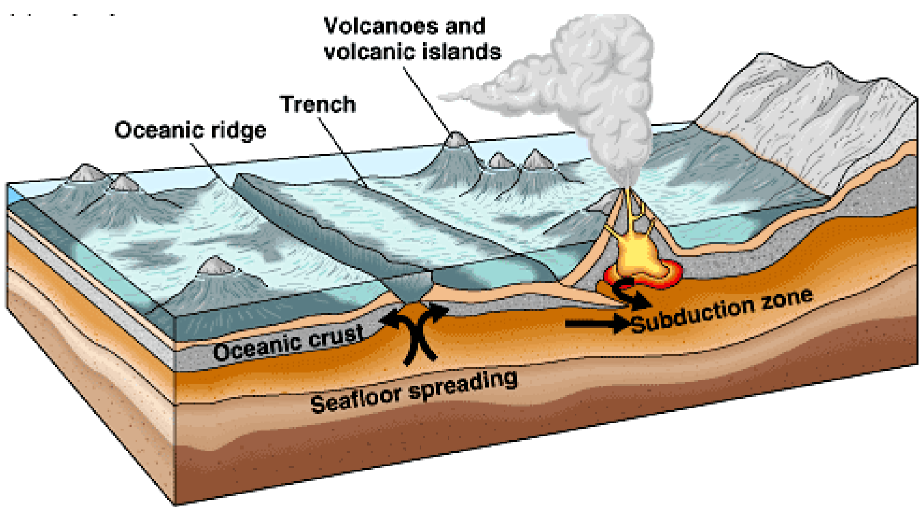

Positive Anomalies
Negative Anomalies
Ridge Axis


No strain and
no displacement
Time 1
Elastic strain
begins (rocks
begin to bend)
Time 2
Elastic strain
accumulates
(rocks bend)
Time 3
Rupture (earthquake)
occurs and rocks
rebound. Elastic strain
(bending) is replaced by
horizontal displacement
known as fault slip.
Fault
Time 4
Rock units that
cross the fault
Fault showing
direction of displacement,
in this case, right-lateral strike-slip


Nile River
Arabian Peninsula
Red Sea
Afar
Lowlands
Gulf of Aden
AFRICA
Indian Ocean
Rift valleys
Lake
Victoria
Mt. Kenya
Mt. Kilimanjaro
Lake
Tanganyika



If the magnetic pole is in the southern hemisphere, the rocks record a reverse magnetic pattern.



(b) Events at plate boundaries