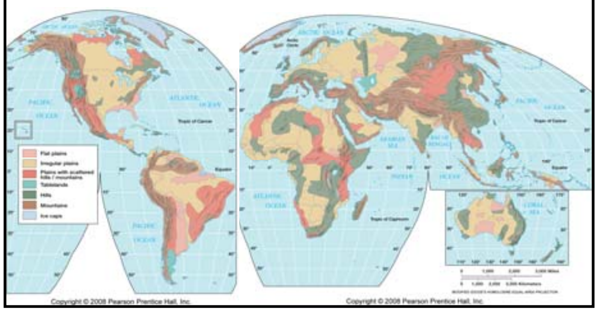
Chapter 13

Rocks and the lithosphere



Minerals

- A naturally occurring inorganic substance with a specific composition
- Building blocks of rocks

Minerals

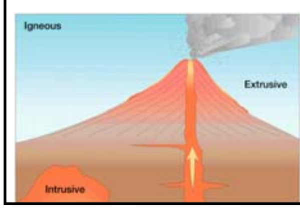
- 99% of crust consists of only 8 minerals
- Four minerals (iron, oxygen, silicate, and magnesium) comprise approx. 92% of Earth
  - Oxygen and silicate most abundant
- Silicates are produced primarily by the cooling of molten rock or magma

Rocks

- An inorganic substance containing one or more minerals
- Three basic rock types, each having a different origin:
  - Igneous
  - Sedimentary
  - Metamorphic

Igneous rock

- New rock
  - formed from molten (melted) rock (magma)
- Two classes of igneous rocks



Igneous rocks formed from magma (molten rock)
Associated with:

volcanism (***ex***trusive igneous rocks): above ground
plutonism (***in***trusive igneous rocks): below ground

Extrusive Igneous Rocks

- Cools rapidly
- No visible crystals→ fine grained rocks
  - Ex: obsidian (volcanic glass)
- Magma spewed out at earth's surface into air or water
  - Called LAVA
  - Volcanic rocks

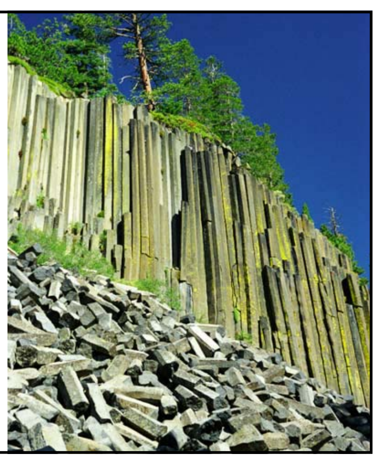
Extrusive igneous rock - cannot see crystals with naked eye

Tuff = volcanic ash welded together

Igneous rocks are usually not laid down in layers

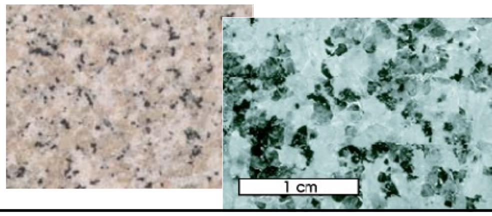
Jointing is common as rock cools...

Columnar basalt



Intrusive Igneous Rocks

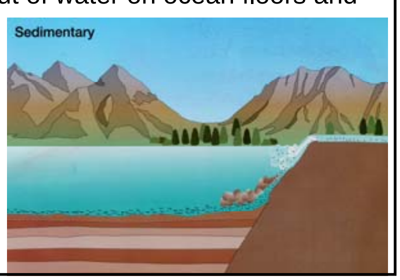
- Plutonic rocks (Pluto: God of Underworld)
- Magma does not reach the surface
  - Cools slowly
- Large crystals – can see them
  - Granite

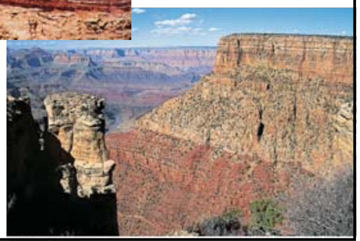


Intrusive igneous rock…can see crystals with naked eye

Sedimentary Rock

- From sediment deposited by water, wind, or ice, then cemented together into rock
- Most settle out of water on ocean floors and lake bottoms





- Particles in sedimentary rock range in size from boulders to microscopic
- Can form from:
  - Inorganic material (like sand)
  - Plant and animal remains → peat → coal
  - Skeletal remains of shellfish, corals
  - Dried lake beds → precipitated calcium carbonate

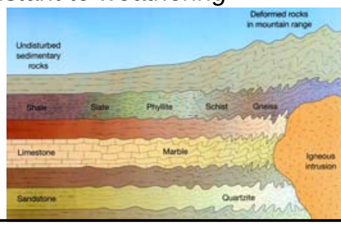
Can feel particles/sand

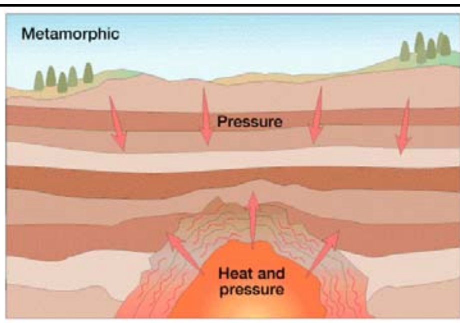
Limestone with fossils

- Limestone
- Sandstone

Metamorphic Rock

- Changed rock: formed from other rocks
- By intense heat and pressure
  - often associated with tectonic activity
    - forces rock down to lower levels or
    - magma rises through the crust
- *Very resistant to weathering*





Contact metamorphism: site specific, find metamorphic and igneous rocks adjacent to each other

Regional metamorphism: large amounts of metamorphic rock

Metamorphic rock - note linear bands

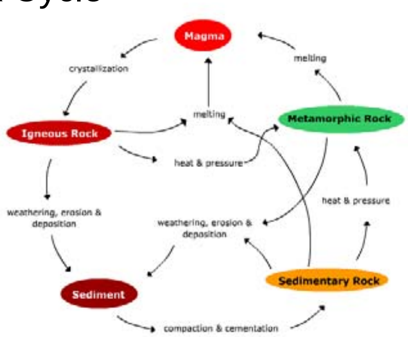
Metamorphosed rocks

- Marble – from limestone
- Quartzite – from sandstone

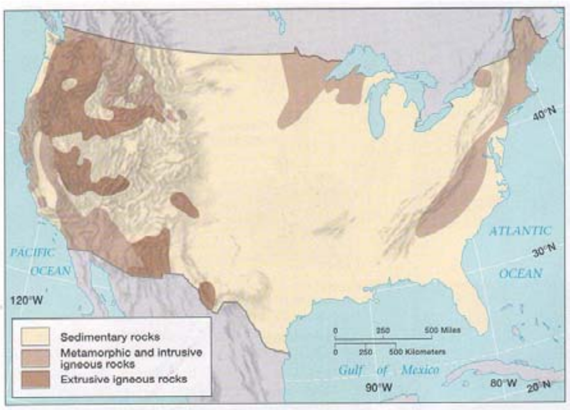
Rock cycle

- Three classes of rocks interact in a specific way based on the way they form
- Igneous rock: New rock
- Sedimentary rock: Minerals, organic material, and used rock
- Metamorphic rock: Changed rock

Rock Cycle



Geographic distribution of rock in the lower 48



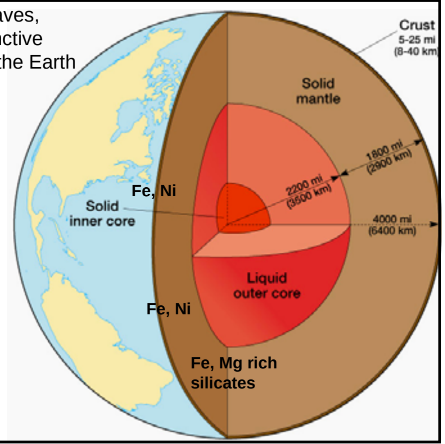
Oceanic and Continental rocks

- Continents (*primarily*):
  - Sedimentary
  - Igneous (granite)
- Ocean (*primarily*):
  - Basalt (igneous)
  - Makes oceanic crust denser than continental

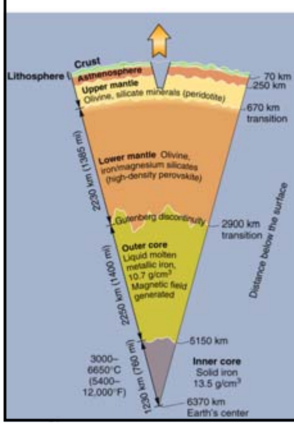
Earth's Interior

- Need to know about Earth's interior to understand the processes and landforms on the surface
- How do we know what interior of earth is like?
  - Deep drilling goes down about 6 miles or 0.15% of way to center of earth
- Know about interior from seismic waves
  - Earthquakes

From seismic waves, there are 4 distinctive densities inside the Earth



Earth’s structure



Each area marks a change in density, composition, and/or mass

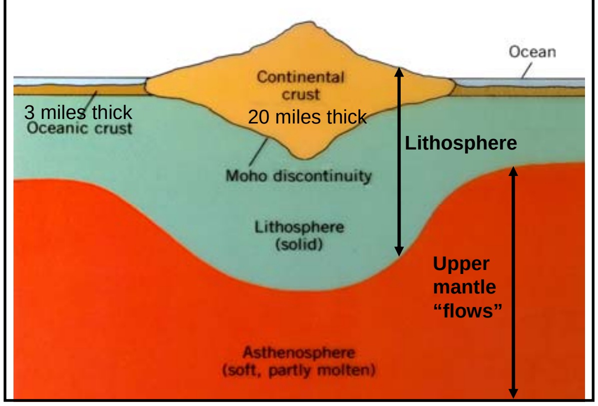
Crust (where we live): only 1% of Earth’s mass

Mantle: Becomes more like plastic towards surface

Outer core: slightly liquid

Inner core: solid iron and nickel

Lithosphere: the crust and the upper mantle

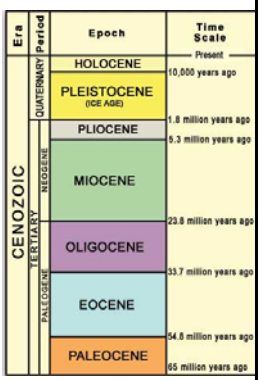


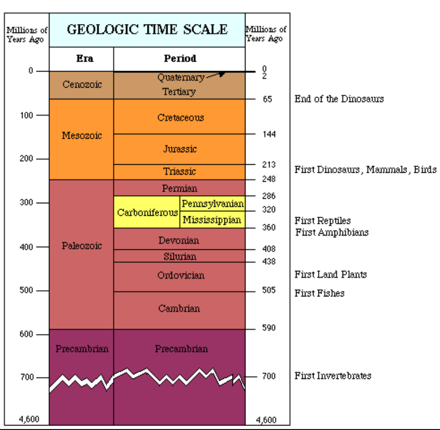
Crust

- Continental
  - Thicker (up to 20 miles thick)
  - Silica-aluminum rich, less dense
  - Age varies (can be 3-4 billion years old)
- Oceanic
  - Thinner (usually about 3 miles thick)
  - Silica-magnesium rich, more dense
  - Age generally less than 2 million years

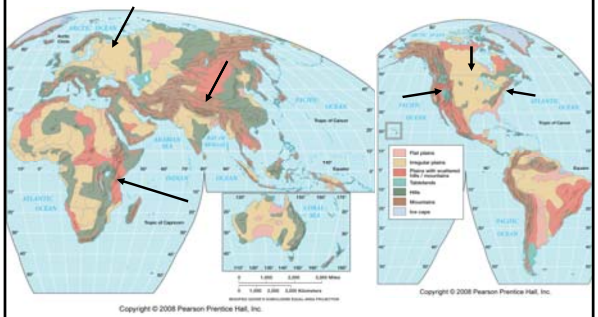
Geologic time

- Radiometric dating puts age of Earth at about 4.6 billion y.o.
- A lot of time is needed to create the landforms we see today.
- Currently reside in the Holocene (for last 12,000 years), which proceeded the Pleistocene (Ice Age)



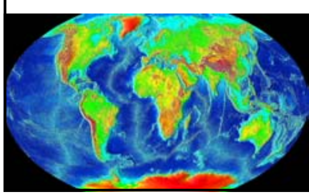


How did landforms come to be shaped the way they are and located where they are?



Landforms

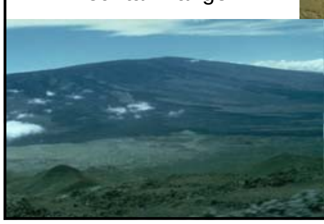
- Study of the processes and landforms resulting from those processes that occur on earth
- Look at the topography – shape of earth's surface



Topography

- Shape can be described with specific landforms – or a particular feature
  - Sand dunes
  - A volcano
  - Mountain range

Idaho



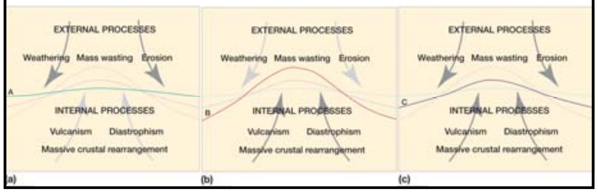
Mauna Loa

Topography

- When analyzing landforms, look at:
  - Structure: how is it arranged?
    - Is it rock? Is it sediment?
  - Process: how was it formed?
    - Floodplain? Volcanic?
  - Slope: what does it look like?
    - Hills? Flat?

Internal & External Geomorphic Processes

- Internal: originate from within Earth
  - Increase relief of land surface
- External: originate from sources above the lithosphere, such as the atmosphere or oceans
  - Decrease relief of land surface



Catastrophism Principle
(Prior to 19th Century)

- Idea used to explain why landforms where shaped the way they were
  - Based on landforms observed in primarily in Europe
- Used a much shorter time scale, so needed cataclysmic event to shape the land rapidly
  - Could not explain everything

Catastrophism Principle

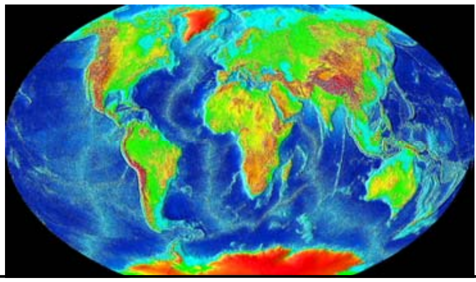
- Central idea was that catastrophes *not operating today* were responsible for the landform development

Uniformitarianism Principle
(accepted ~1850)

- "The present is the key to the past."
- *Laws* that governed landform processes in the past are the same as those that govern processes now and in the future.
- Uses a much longer time span
- Still have rapid construction of a landform but process is still occurring

What is creating landforms?

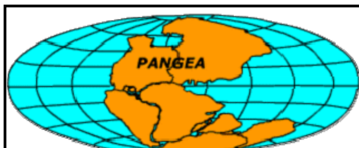
- Need to understand internal processes
  - Get an idea that something is happening because of shape of continents



Previous to 20th century

- Not a clear understanding of
  - Why volcanoes are located where they are
  - Why earthquakes occur and why they occur where they do
  - How the continents got their shape
    - Assumed shape was unchanging
    - Assumed continent's location did not change
    - Some scientists thought maybe continents used to be joined

- 'Fit' of coastlines recognized early
- No mechanism for motion



- 1915, Alfred Wegener proposes theory of continental drift and included idea of a supercontinent.
  - Pangaea ('all-earth') [225mya]: All continents fit together
  - Fragmentation and drift to current positions

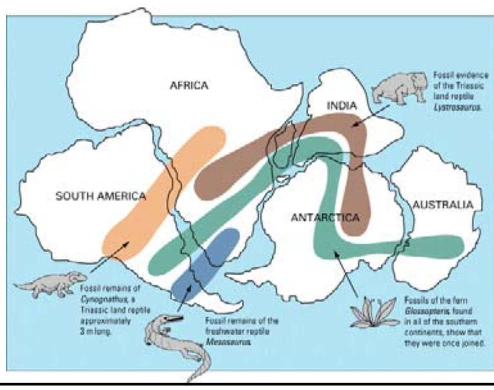
Wegner’s evidence

1. Fit of continents

Grooves carved by glaciers (shown by arrows) provided evidence for continental drift. This diagram assumes the continents were in their present-day locations.

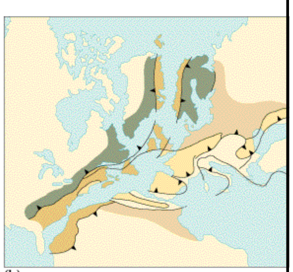
The distribution of glacial features can be best explained if the continents were part of Pangaea.

2. Biological Regions Match



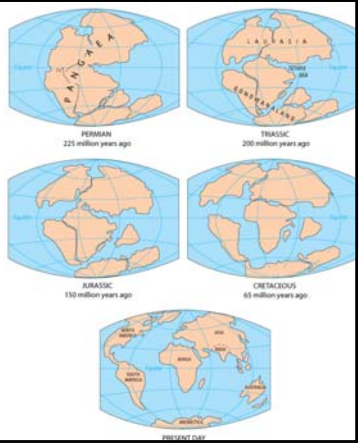
3. Geologic Regions Match

(a)

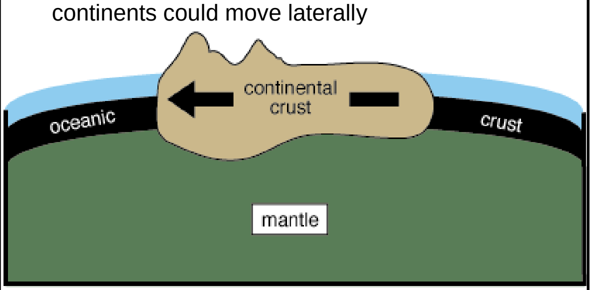


(b)

Breakup of Pangea and continental movement



- Problem with continental drift?
  - No sound mechanism for the 'drift'
  - Not accepted by scientists – did not believe continents could move laterally

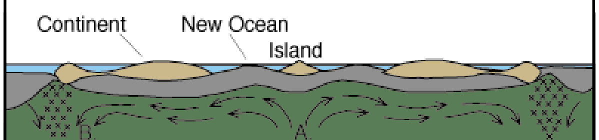


Wegener's proposal that continents plowed through oceanic crust was not accepted by other geologists.

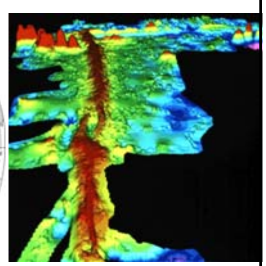
Pangaea and continental drift

- Idea that continents just drifting in ocean not accepted
  - Excluded entire idea because one part was flawed

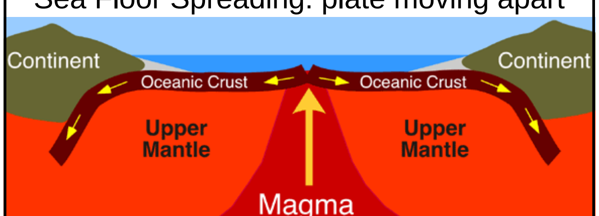
- New theory for motion: (1930s)
  - Thermal convective cells in the upper mantle
    - Like boiling water
  - Theory is largely ignored

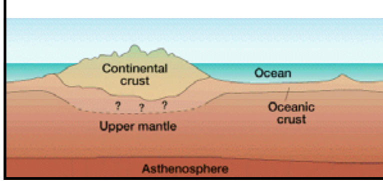


- In the 1960s, scientist propose *sea floor spreading* along *mid-oceanic ridges* for plate motion.



Sea Floor Spreading: plate moving apart



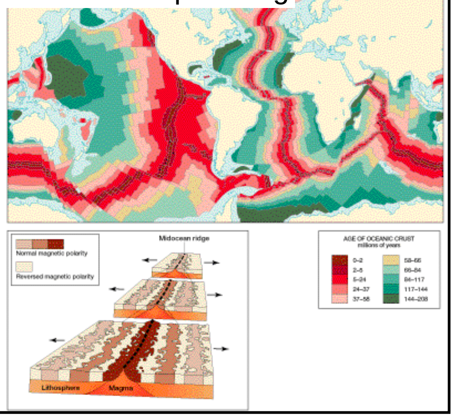


What is a 'Plate?'

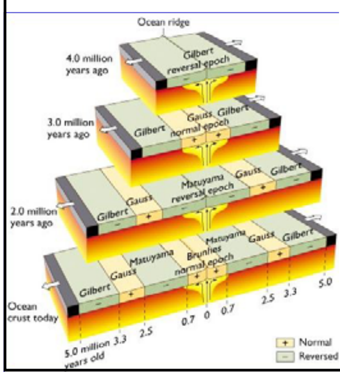
- Crust + upper mantle

Evidence for sea floor spreading

1. Age of oceanic crust



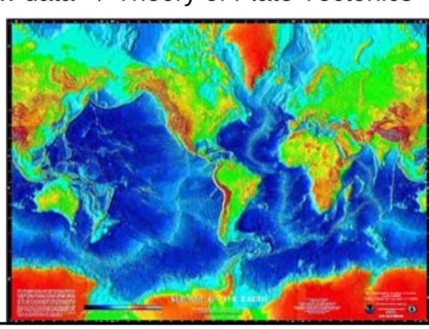
2. Paleomagnetism



- Related to the reversal of the Earth's magnetic field

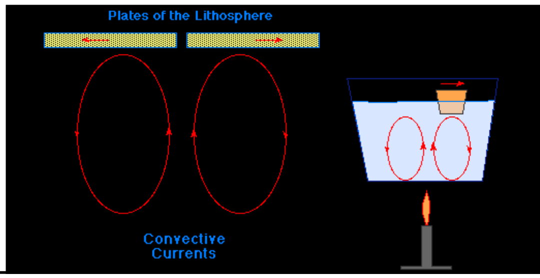
Plate Tectonics Theory

- Continental Drift + Sea Floor Spreading + new data ⇒ Theory of Plate Tectonics



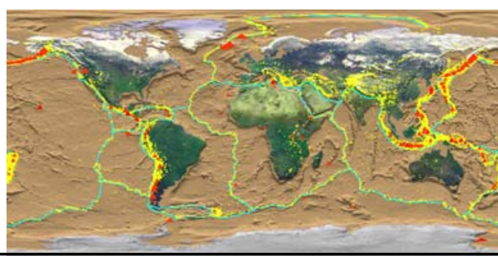
Mechanism: Convection

- A way to transfer heat (energy)
- Heat is moved away from the source in large currents.



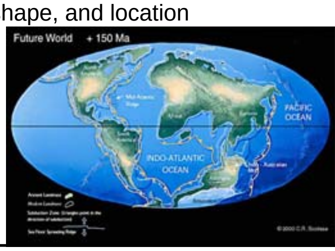
Theory

- The theory of plate tectonics refers to the process of plate formation, movement, and destruction.
- Plate Tectonics Theory helps answer why earthquakes and volcanoes occur where they do



Plates

- Now know that Pangaea was not only supercontinent nor will the last supercontinent
- Processes still ongoing that are moving/changing the oceans and continents
  - Size, shape, and location



Geography of the Plates

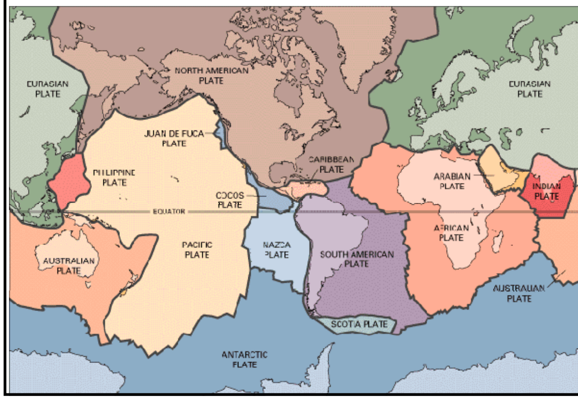
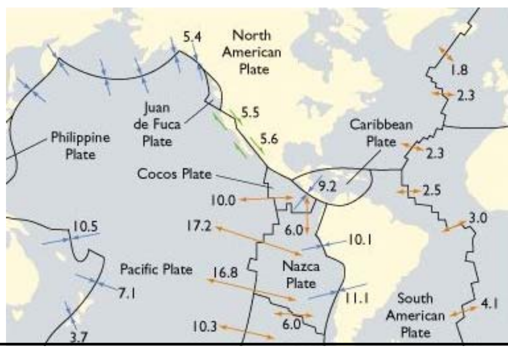


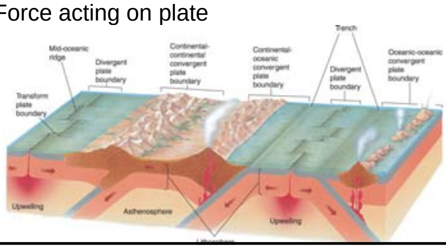
Plate Margins: how do we know?

- Marked by volcanic and tectonic activity



Types of plate boundaries

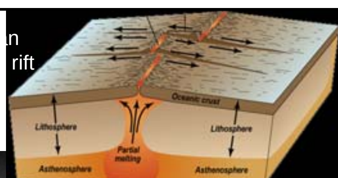
- Need to know so we can understand the resultant landforms
- Two things to consider:
  - Type of plate
  - Force acting on plate



Divergent Boundaries

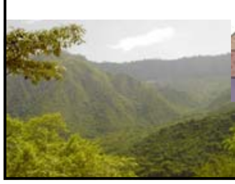
- Sea floor spreading (process)
- Plates pushed away from each other - about the speed that fingernails grow
  - Lava fills in void
  - New rock
- Ocean to ocean plate diverging boundaries creates mid-ocean ridges
  - Mid-Atlantic Ridge – mostly under Atlantic Ocean except Iceland

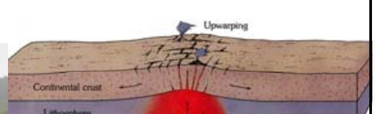
n
rift



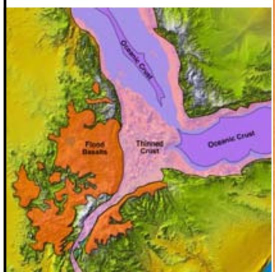
Divergent plate boundary: Continents

- Continent pushed apart creates rift valley
  - Rift connected by series of linear lakes
  - Lava flow from fissures and volcanic activity
- East African Rift Valley pulling Africa apart
  - Connect to Red Sea





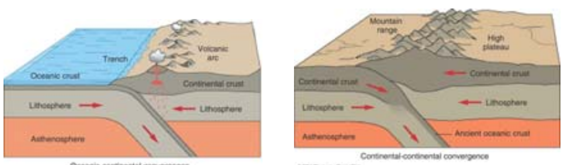
Divergent Boundaries
...pulling apart on land
Rift valleys



East African Rift Valley

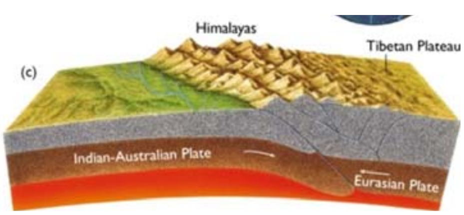
Convergent Boundaries

- Plates coming together
- Results of collision depends on the type of plates that are colliding
  - **Continent to continent**
  - **Ocean to continent**
  - **Ocean to ocean**

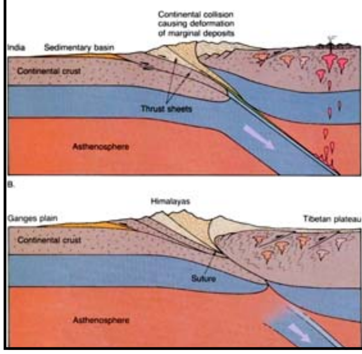


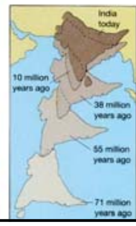
Convergent boundary: Continent to continent

- Plates are approximately equal in density
- Plates forced upward
- Collision results in high mountains and a high plateau –Example: Himalayas



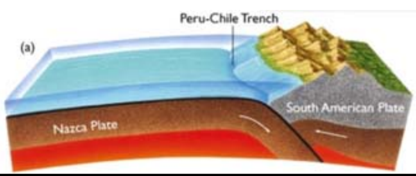
Example: Himalayas





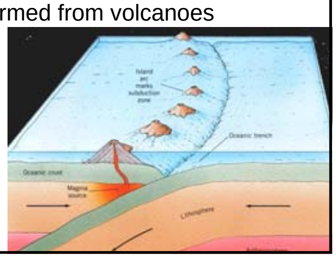
Convergent boundary: Continent to ocean

- Denser ocean plate *subducted* (pushed beneath) continental plate
  - Subduction zone: Deep oceanic trenches
  - Loss of ocean plate
- Volcanic mountain range on continental plate
  - Washington, Oregon, northern California
  - Indonesia

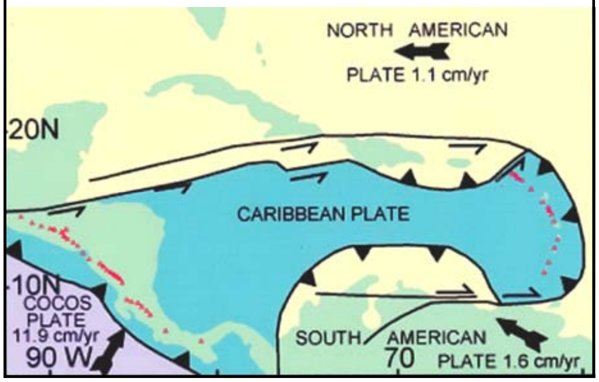


Convergent boundary: Ocean to ocean

- One plate is subducted underneath the other
  - Also called a subduction zone
- Formation of volcanic island arc
  - Series of islands formed from volcanoes
  - Aleutian Islands
  - Japanese islands
  - Lesser Antilles

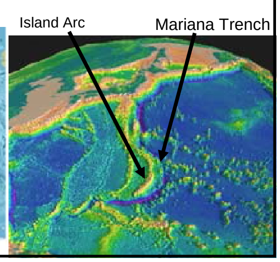


Island arc example: Lesser Antilles



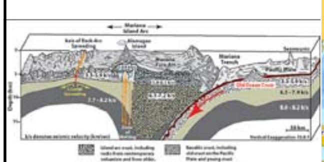
Subduction zone features

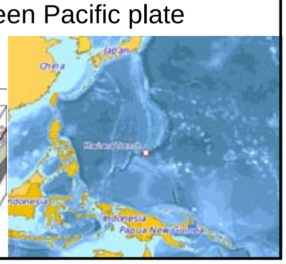
- Island volcanic arcs
- Volcanoes on continent
- Trenches - where converging plates meet and one plate is pushed below other plate
  - Deepest part of ocean



Mariana Trench

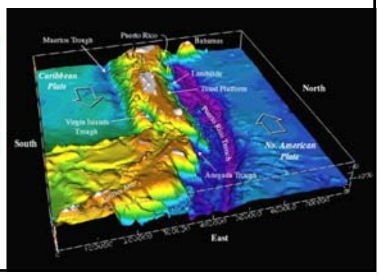
- Deepest part of the ocean
  - Deepest trench in world – 36,200 feet below water's surface
    - Mount Everest is 29,035 feet tall
- Subduction zone between Pacific plate and Mariana plate


Cross-Section Sketch of Mariana Arc



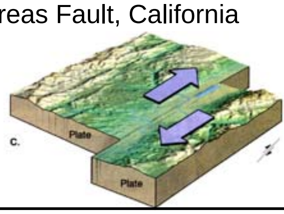
Caribbean Plate

- Puerto Rico Trench
  - Deepest part of Atlantic Ocean
  - 27,000+ feet below surface

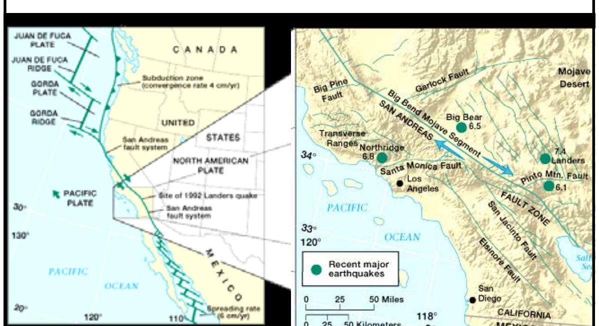


Lateral boundary

- Plate type does not matter
- Plate slide past each other – plate material not created or destroyed
- Transform faults responsible – type of tectonic fault
- San Andreas Fault, California



Lateral plate boundaries



...sliding past each other