Plate Tectonics (continued)

Sea-floor Spreading

Mid-ocean ridges (mid-Atlantic Ridge) - sites of sea-floor spreading

found in all of the major oceans
form a continuous mountain range which extend for ~40,000 mi
represent >20% of the earth's surface
elevated positions (1-3 km)

1) High heat flow
2) Upwelling of mantle material - volcanism
3) Convection cells due to unequal distribution of heat in the mantle
    a) earth's internal heat drives plate tectonics
4) area where new ocean floor (new crust) is created
5) rift zones - numerous faults - grabens
6) plates move apart
7) earthquake epicenters plot in valleys in mid - ocean ridges.

Divergent Boundary - at mid-ocean ridge.

Upwelling of mantle material
Convection cell due to unequal distribution of heat in the mantle
area where new ocean floor is created
plates move apart

Plates are consumed at **convergent boundaries - subduction zones**

Trenches - located along subduction zones or convergent boundaries

external expression of subduction zones.
most of them in Pacific Ocean

Is earth expanding? - shouldn't be due to compensation of divergent boundaries at convergent boundaries where oceanic crust is destroyed.

Paleomagnetism provided the best test of sea-floor spreading.

Earth's magnetic field periodically reverses polarity.

Present day field - **normal polarity**
opposite magnetism - **reverse polarity**.

Curie Temp. - 580^{o} - orients to earth's existing field reversed polarity encountered some distance away from the ridge, and further away back to normal polarity.

magnetic anomalies symmetrical about ridge because:
sea-floor spreading generates crust equally on both sides of ridge.

Can measure sea floor spreading rates with paleomagnetic reversal dates:
North Atlantic 1-2 cm/year; East Pacific Rise-3-8cm/yr.
Age of ocean basins ~165 - 175 Ma.
Ocean basins are relatively young.

Continents are older than the ocean basin(s)!

The outer rigid lithosphere consists of several individual segments called **plates**.

About a dozen large plates have been recognized.
a) can contain both continental and oceanic crust.
b) activity is centered at plate boundaries.
c) plates can have different types of boundaries.
e.g. North American Plate - spreading at mid-Atlantic ridge, subduction and transform faults along west coast.

Plate Boundaries

events happen at three types of plate boundaries:
1) **divergent**
a) plates move apart
b) upwelling of material from the mantle
c) creation of new sea floor.
2) **convergent** -
a) plates come together
b) denser slab of lithosphere is consumed into mantle
c) crust destroyed
3) **transform**
a) plates slide past each other.
b) crust preserved

Divergent Boundaries
- at mid-ocean ridge.
Upwelling of mantle material
area where new ocean floor is created
plates move apart

Passive Continental Margins
New continental margins are produced during the breakup of a continental landmass

1) upwelling of the mantle material causes doming of the continental rock, and stretches and fractures the crust.
a) forms rift valley
nonmarine clastic sediments can accumulate rapidly to great thicknesses.

Sediments include

a) conglomerates from the steep valley walls

b) **red beds** - alluvial plain deposits.

c) lacustrine deposits form within the elongate valleys

e.g. Newark Basin - failed rift - where we sit! This basin passed far inland and never opened wide enough to allow the sea to invade

2) as sea-floor spreading continues, the stretched and fragmented crust is wedged away from the zone of upwelling where gradual cooling leads to subsidence. They become flooded by shallow seas: Red Sea Phase

3) sediments carried from adjacent highlands begin to accumulate on the young continental margin resulting in additional subsidence.

the continental borders, which were tectonically active when they were still close to the spreading zone, become what are termed **passive margins**. Having descended below sea -level, these tectonically inactive areas of continental crust accumulate sediment along shallow shelves.

Convergent Boundaries

subduction zones where lithosphere is absorbed into the mantle. When two plates collide, the leading edge of one is bent downward at angles of 35-90 degrees.

compressional features

Can occur between two oceanic or continental plates, or a mix.

a) When oceanic converges with continental, the denser oceanic slab sinks into the asthenosphere

subduction zone - where oceanic plates descends into asthenosphere. The bending produces a **deep-ocean trench**.

Trenches maybe thousands of kms long and 8-11 km deep.

oceanic-continental convergence

oceanic plate is subducted into the asthenosphere.

at ~100km, partial melting of water rich oceanic crust and the mantle

generates basaltic or andesitic magmas.

less dense than the surrounding rock

can intrude continental crust where it can crystallize at depth, or flow onto the surface where it can give rise to explosive volcanics.

Can produce volcanic mountains - **volcanic arc.**

e.g. Mount St. Helens; **Andes Mountains**

oceanic-oceanic convergence

one slab subducts and initiates volcanic activity - **island arcs**.

e.g., Japan, Philippines, Alaskan Peninsula

continental-continental convergence

no subduction due to low density, buoyant nature of continental rocks.

A volcanic arc can be generated by the destruction of the remaining sea floor. This generates a volcanic arc, adding large amounts of material to the sediment already on the continental margin. When masses collide, sediments would be compressed, folded, and deformed into a mountain range.

e.g Himalayas - produced when India rammed into Asia

Transform boundaries

transform fault - located where plates slide past one another without the production of crust.

San Andreas Fault - boundary of Pacific and N. America plate

Data Supporting Plate Tectonics

Earthquakes

plate tectonics model accounts for global distribution of earthquakes

90% at plate boundaries -found at all 3 types of boundaries

1) location of shallow earthquakes along oceanic ridge system.
lack of deep focus earthquakes at ridge.

2) Note distribution by trenches:
Shallow focus earthquakes occur within or adjacent to trenches, while intermediate and deeper occur towards the mainland - **subduction zones.**

shallow earthquakes are produced as the descending cold plate interacts with the overlying lithosphere, while deeper earthquakes are produced as the slab enters further into the asthenosphere.

Ocean Drilling

Glomar Challenger sampled ocean sediments.
found sediment furthest from ridges were older than sediments closer to the ridges
age of sediment increased with distance from ridge.
sediment thickness increased with distance from the ridge.

Hot Spots

a concentration of heat in the mantle capable of producing magma which rises to the Earth's surface.

Rising plume of mantle material which generates a volcanic area.

As plate moves over plume, it creates a series of linear features which are older progressively away from the plume

These points appear to be nearly immobile
e.g. Yellowstone National Park in Wyoming.

Often a large volcano forms at the surface above a plume that rises through the thin oceanic crust.

As a plate moves over a plume, its successive positions are commonly recorded as a chain of volcanoes such as the Hawaiian Islands.

Hawaii, the largest and easternmost of the islands, is less than 1 million years old., while the small NW island of Kauai is 5.6 Ma.