

PLATE TECTONICS

I. Introduction

A. General

1. The theory of plate tectonics is a recent development in the geological sciences, really accepted by scientific community since the early 1960's.
2. Earlier in the century geologic paradigm was dominated by the belief that ocean basins and continental land masses were permanent and fixed on the surface of the earth.
3. The theory of Plate Tectonics now recognizes that the positions of land masses are not fixed and that they have moved about the earth's surface over geologic history
 - a. Ocean basins/oceanic crust are continually being created and destroyed through tectonic processes.

B. Terminology

1. "Tectonics" - is a term that refers to the deformation of the earth's crust.
2. "Plate" - refers to the subdivision of the earth's crust and lithosphere into a number of tectonically coherent blocks
3. "Plate Tectonics" - refers to the formation and migration of these lithospheric plates,
 - a. Problem: time spans of plate motion on order of 10' of to 100's of million's of years,
 - (1) theory has been deduced from evidence recorded in earth's rocks, often difficult to interpret and sometimes inconclusive.

II. Overview of Earth Interior

A. Crust- a relatively thin outer layer

1. oceanic crust- thin on order of several km's thick
 - a. volcanic / basalt in composition
2. continental crust-thicker on order of 10's of kms thick
 - a. plutonic/sedimentary/"granitic" in composition

B. Mantle- rocky layer located below the crust and having a thickness of 2885 km

1. Mantle- dense, iron-magnesium silicate rocks

2. "Moho"
 - a. Mohorovicic discontinuity or Moho-seismic discontinuity in which velocity of earthquake waves increases abruptly below a depth of 50 km
 - b. now known to be boundary between crust and upper mantle
 3. Asthenosphere- soft zone of partially melted rock
- C. Lithosphere- outer solid portion of the earth which includes the upper mantle above the asthenosphere and the crust.
- D. outer core- 2270 km thick, possesses characteristics of mobile liquid
1. Liquid, iron-rich,
- E. inner core- 1216 km thick, solid metallic sphere
1. Core- thought to be composed of iron and nickel, very speculative, based on study of meteorites and speculation that they represent the interior composition of earth.

III. Historical Perspective on the Evolution of Plate Tectonic Theory: Continental Drift a Precursor to Tectonic Theory

- A. Continental Drift - Alfred Wegner (German earth Scientist) proposed a hypothesis in early 1900's that the world continents have been drifting about on the earth's surface
1. Supercontinent of "Pangaea" existed 200 M.Y. ago in which all of major world's continents were once amalgamated together, and have since broken apart and migrated or drifted to their present positions/configurations.
 2. Evidence for Wegner's hypothesis of Continental Drift
 - a. Jig-saw puzzle fit of the Continents:
 - b. Fossil Evidence
 - (1) Mesosaurus which is only found on east coast of South America and west coast of Africa.
 - (2) How did these critters migrate across the ocean basins?
 - c. Similar Rock Types and Structural Rock Deformation across ocean basin
 - d. Paleoclimatic Evidence
 - (1) Evidence for glacial conditions 250 m.y. ago are found in similar aged rocks from southern Africa, South America, India and Australia

3. Problem with Wegner's ideas
 - a. not widely accepted
 - b. suggested on the continents were "drifting" not ocean basins
 - c. did not have a viable mechanical explanation as to how continents would "drift"

IV. Modern Plate Tectonic Theory

- A. Basic Model - Based on early work by Wegner, more recent mapping of seafloor, magnetic surveys of earth's magnetic field, and observation of earth's seismic activity or earthquake activity.
 1. Plates- Plate tectonics model suggests that the outer, rigid lithosphere of the earth consists of about twenty rigid segments known as "plates".
 - a. Plate Mobility - it is recognized that each moves as a distinct rigid unit in relation to other plates.
 - (1) These plates move on top of a semi-plastic aesthenosphere, and interact with one another along their boundaries.
 2. Plate Boundaries and Nature of Interaction between Plates
 - a. 3 types of plate boundary interaction: Divergent, Convergent, or Transform fault boundaries
 - b. Divergent Boundaries - boundary condition in which tectonic plates move apart, resulting in upwelling of magma and volcanic material to create new seafloor: i.e. creation of new crust.
 - (1) located at crests of mid-oceanic ridges, where plates move apart and molten rock is injected and cooled to form new seafloor.
 - (2) Seafloor spreading- process of plate divergence and injection of magma.
 - (a) E.g. Atlantic ocean basin, has undergone seafloor spreading over last 165 m.y. at avg. rate of 6 cm/year.
 - (b) e.g. Red Sea in Middle East is an example of a very young ocean basin that is just beginning the process of seafloor spreading.
 - (3) Continental Rifting
 - (a) Pulling apart of continental crust by faulting
 - (b) Incipient seafloor spreading center

- c. Convergent Boundaries- plate boundaries in which two plates move toward one another or collide.
 - (1) Collision of one plate into another results in downbending of one plate and descent of that plate beneath the other,
 - (2) subduction zone- a zone of plate convergence in which where an oceanic plate descends into the upper mantle beneath the overriding plate.
 - (3) trenches - zone where subducting slab dives beneath over-riding plate
 - (4) volcanic arc - an arcuate chain of volcanoes on continental crust that result from subduction of oceanic crust beneath continental crust.
 - (a) Cascade mountains in U.S., Andes in SAM, Sierra Mtns in CA are eroded core of volcanic arc.
 - (b) Forearc region - zone in front of arc, towards trench
 - i) e.g. Willamette Valley, west of Cascades
 - (c) Backarc region - zone behind the arc, away from trench
 - i) e.g. central Oregon, east of Cascades
 - (5) Types of convergent boundaries
 - (a) Oceanic-Continental Plate Convergence-
 - i) e.g. W. Coast of North America
 - (b) Oceanic-Oceanic Plate convergence
 - i) e.g. Japan
 - (c) Continent-Continent Plate Convergence
 - i) e.g. India / Asia / Himalayas
- d. Transform Fault Boundaries: condition where plates slide horizontally past one another along a fault (or fracture along which there is movement)
 - (1) Crust is neither consumed nor destroyed.
 - (2) Transform faults connect convergent and divergent boundaries into a worldwide network of interconnected plate boundaries.
 - (a) (e.g. San Andreas Fault in Ca).

V. Evidence to Support Modern Plate Tectonic Theory

A. Magnetism and Paleomagnetism (result of search for German submarines in WWII)

- 1. Earth has a magnetic field about it with a magnetic north pole and south pole similar to a bar magnet with lines of magnetic force flowing from North to south.

2. Paleomagnetism - iron-rich minerals such as magnetite (Fe_3O_4) act as tiny magnets, when these minerals cool from a magma there is a temperature at which they align with the magnetic field of the earth (curie point),
 - a. Polar Wandering -
 - b. Polar Reversals
 - (1) Normal Polarity -So rocks have been found with paleomagnetism similar to todays polar arrangement termed "normal" polarity
 - (2) Reversed Polarity- rocks which indicate magnetic north pole at current position of south magnetic pole
 - c. Seafloor Stripes

B. Evidence from Seismic Records of Earthquakes

1. the distribution of earthquake foci or origination points of earthquakes was examined around the world and at convergent plate boundaries or subduction zones.

C. Evidence from Ocean Drilling

D. Hot spots

1. Hawaiian Islands

VI. Driving Mechanism for Plate Tectonics: what force causes the plates to move about the earth's surface?

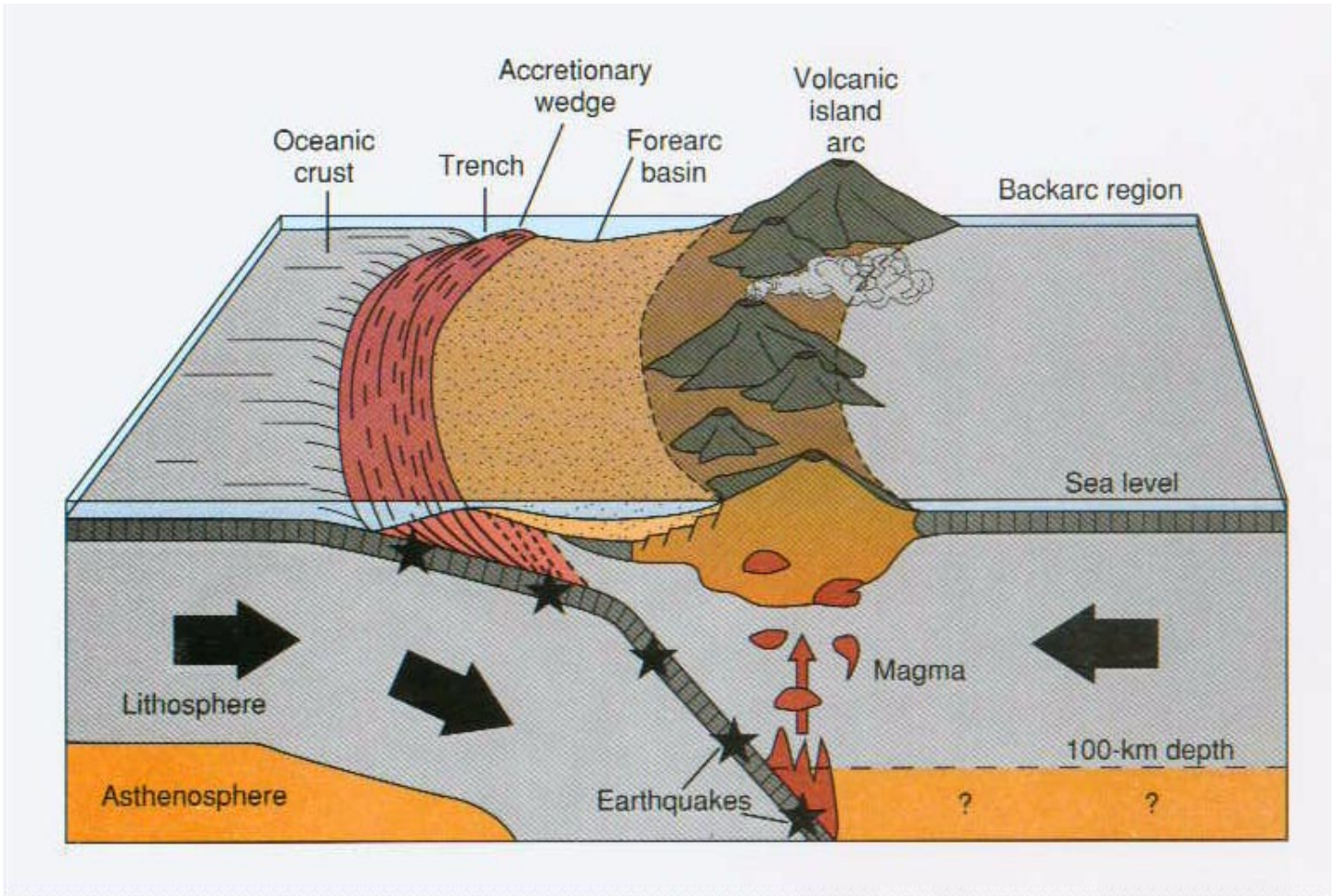
A. Heat Transfer/Convection within Mantle

1. Model: the lower or inner portion of the mantle, near the core, is hotter than the upper mantle, this unequal distribution of heat results in circulation of heated, semi-plastic mantle material...warm, less dense material of lower mantle rises very slowly in regions of spreading centers, spreads laterally, cools, and slowly sinks back into the mantle and reheating process repeats, these mantle convection currents result in shear force being applied to overriding crustal plate and drive plate tectonic motion.

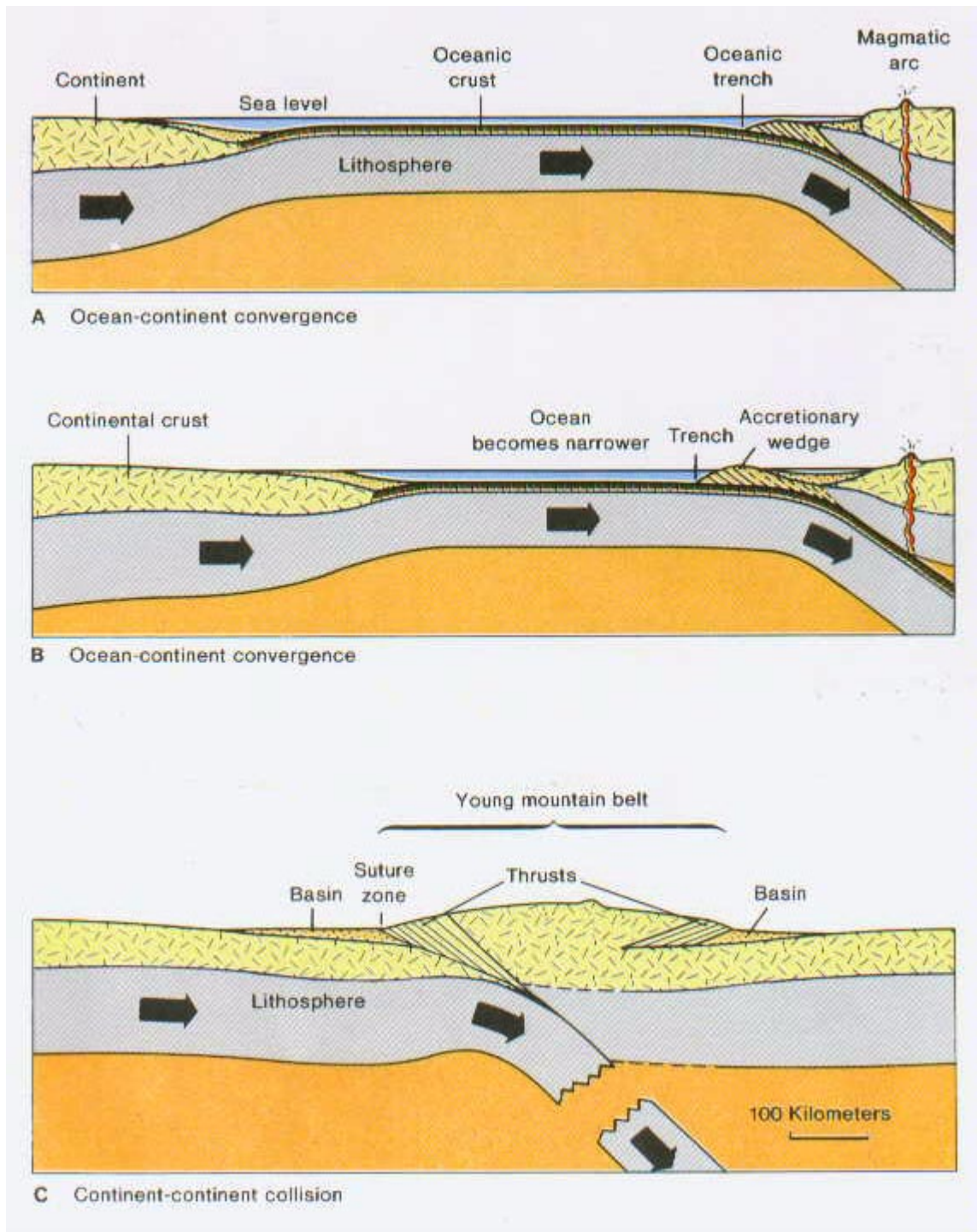
B. Other Ideas

1. active subduction pull
 - a. cold, dense subducting slab pulls plate into interior of Earth
2. ridge push
 - a. active spreading centers push slab into interior of Earth

Oceanic-Oceanic Subduction Zone



E.g. Continent-Continent collision



Oceanic-Continental Subduction Zone

