



IDC 203: INTRODUCTION TO EARTH SCIENCES

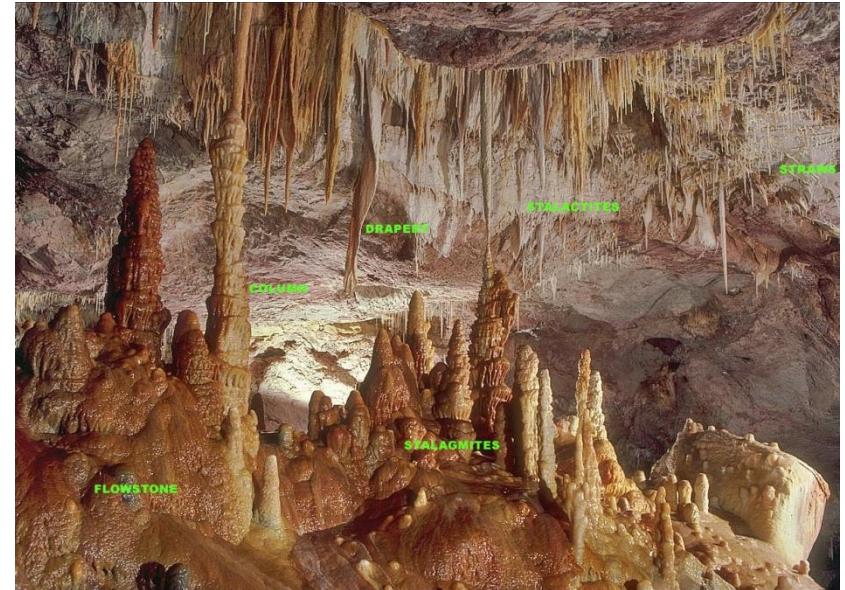


Plate tectonics

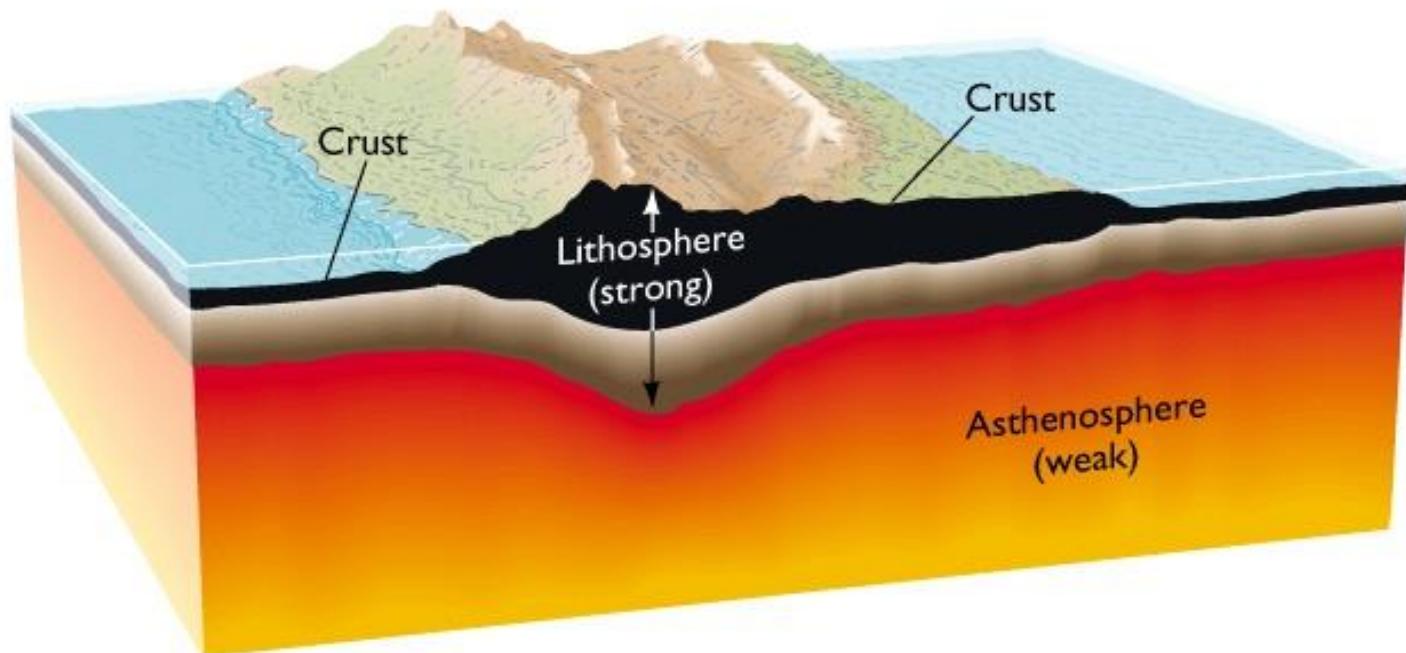
- The unifying concept of the Earth sciences.
- The outer portion of the Earth is made up of about 20 distinct “plates” (~ 100 km thick) that move relative to each other.
- Plates interact with each other along their edges (plate boundaries)
- Plate boundaries have high degree of tectonic activity
 - mountain building
 - earthquakes
 - volcanoes

Plate tectonics

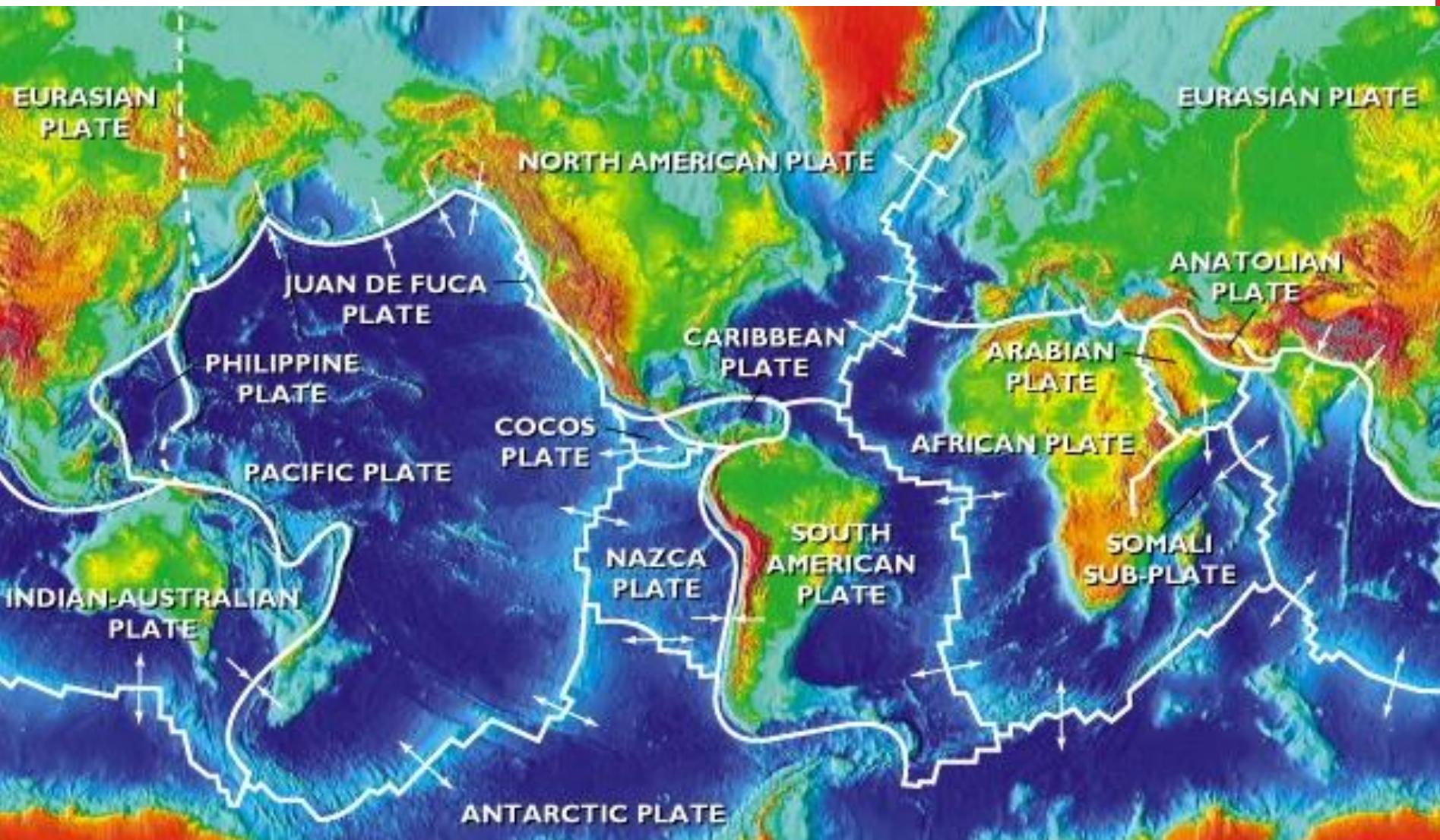
Lithosphere: the outer rigid shell of the earth (~ 100 km). The plates are composed of this material.

Asthenosphere: part of mantle beneath lithosphere.

The lithosphere rides on the top of the Asthenosphere

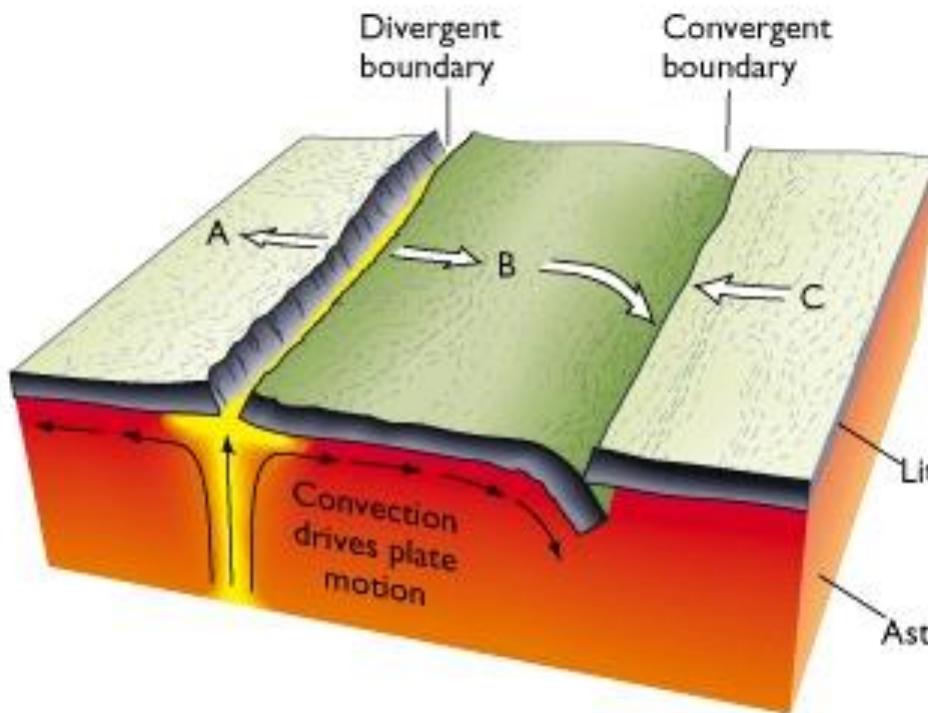


Present day plates

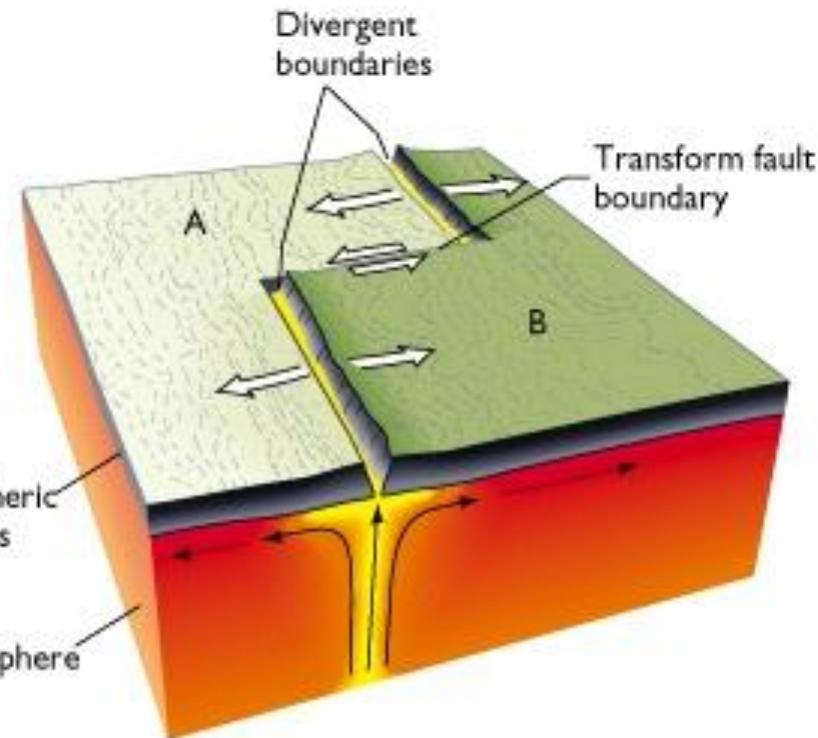


Three types of plate boundaries

1. Divergent
2. Convergent
3. Transform/Conservative



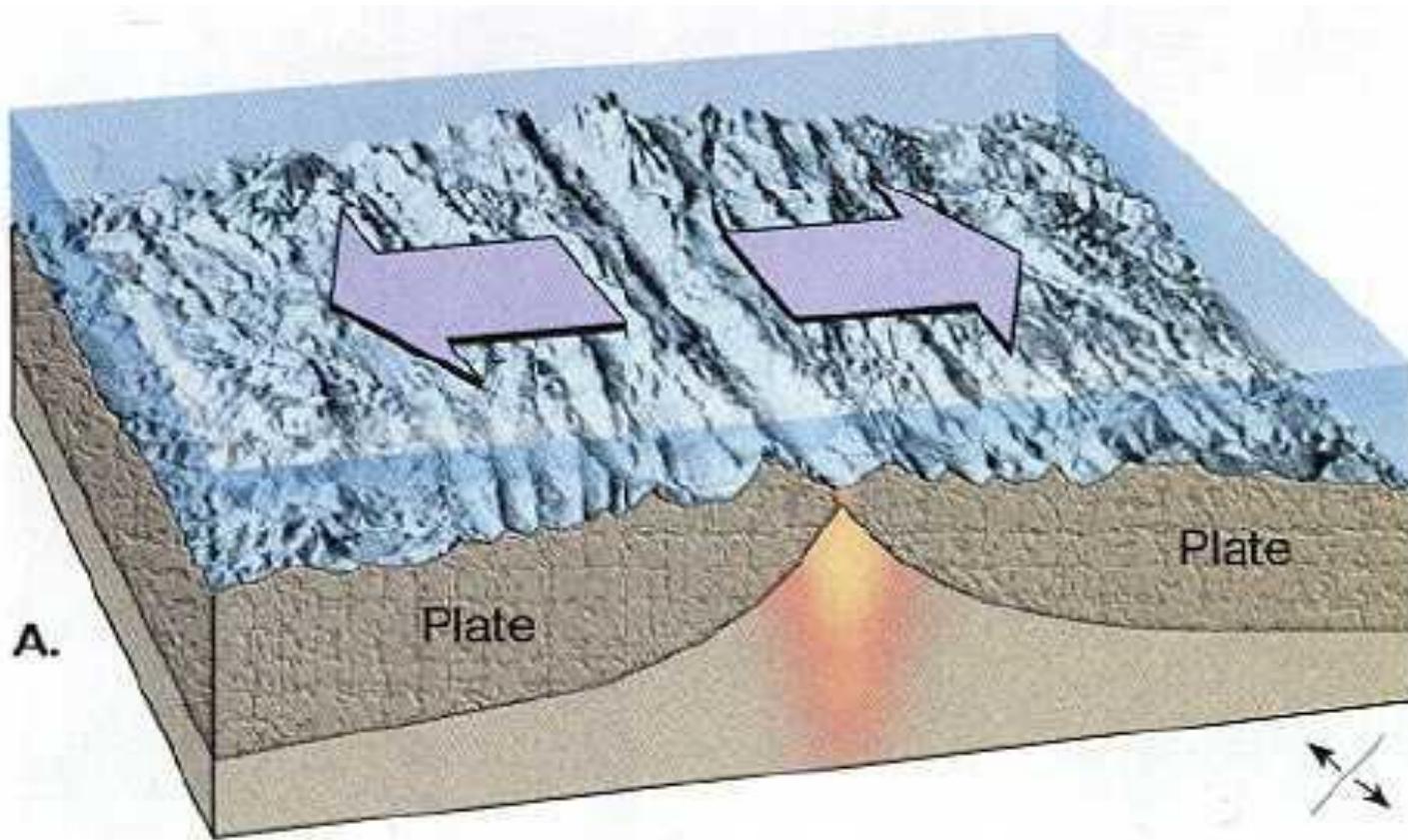
(a)



(b)

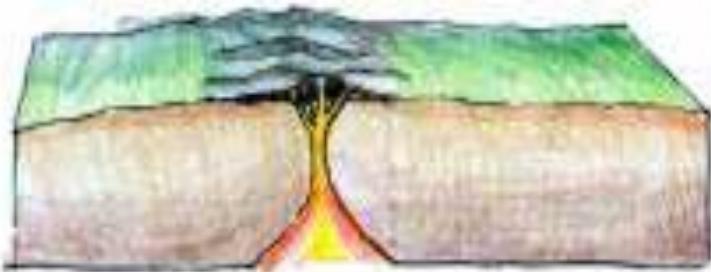
Plate Boundaries

Divergent



Plates move away from each other
New crust is being formed

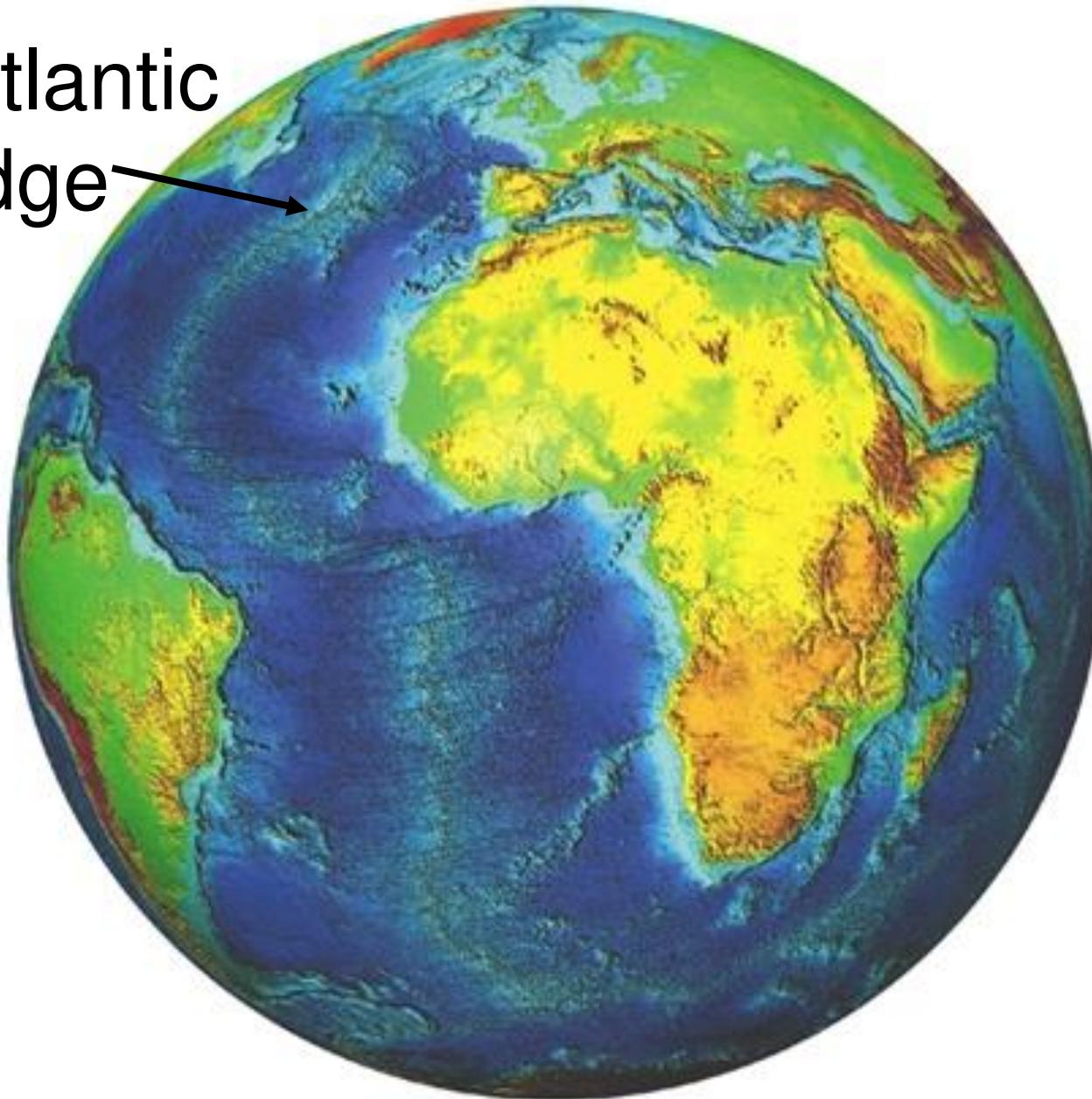
Divergent Boundaries



- Youngest rocks form at ridge
- Older rocks are further from ridge



Mid-Atlantic
Ridge



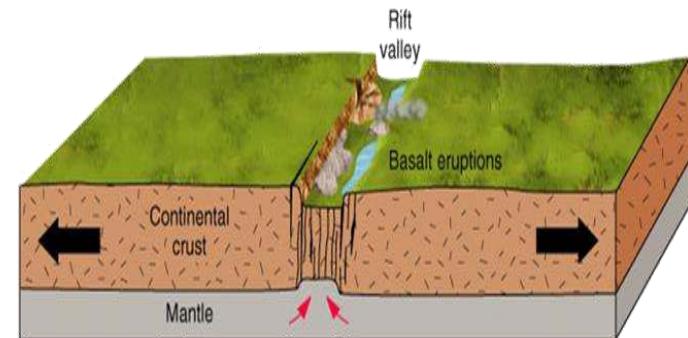
Divergent Boundaries



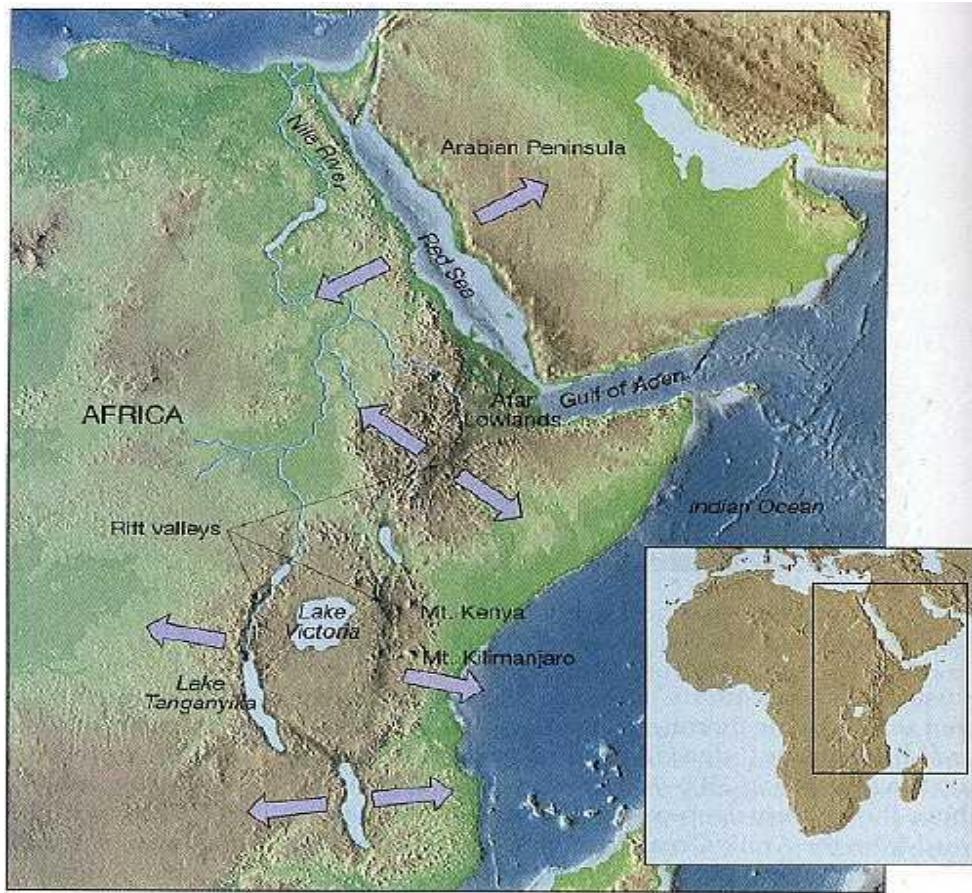
Europe and North America meet near Thingvellir, Iceland, where their two tectonic plates are slowly drifting apart. To the left is the far eastern edge of the North American continental plate, and to the right is the western edge of the Eurasian plate.



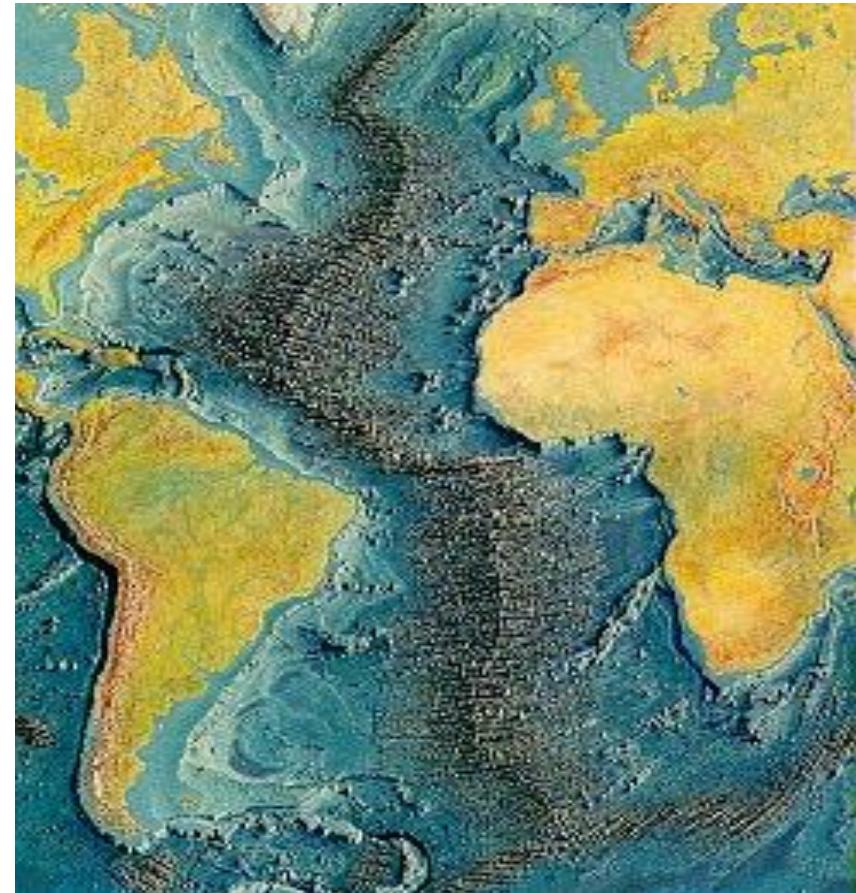
Rift valley
continent-continent



Divergent Boundaries



East African Rift



Mid-Atlantic Ocean Ridge



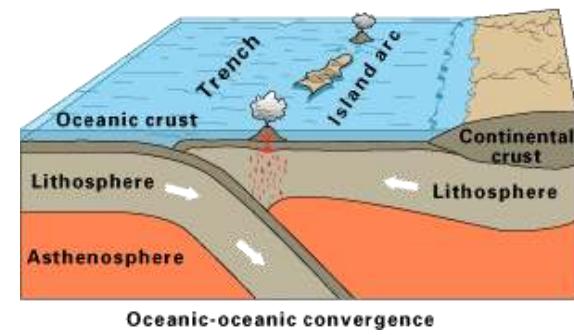
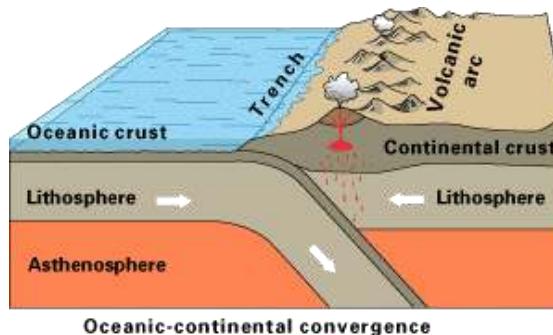
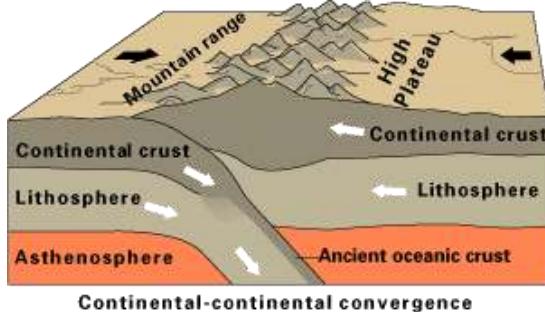
ICELAND IS BEING
PULLED APART AS IT SITS
ASTRIDE THE MID-
ATLANTIC RIDGE.

Convergent Boundaries

- Plates are moving toward each other
- Crust is being destroyed
- Three Types:
 - Ocean-continent
 - Ocean-ocean
 - Continent-continent

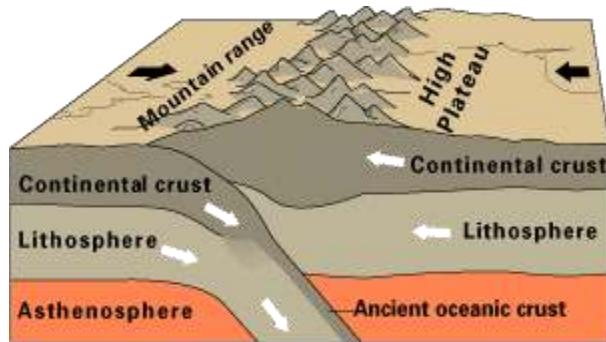
Convergent Boundaries

- Destroys old crust and forms new mountains
- Three types of convergent boundaries



Convergent Boundaries

Continent-continent convergence
Folded mountains



Ex Himalayas
Eurasian/Indian plates



Convergent Boundaries

- **Subduction Zones:** where ocean plates slide under another plate
- Creates magma which moves upward, pushing up the land above it.
- Heat from the magma can change the rock around it. Rock that recrystallizes without melting becomes **metamorphic rock..**

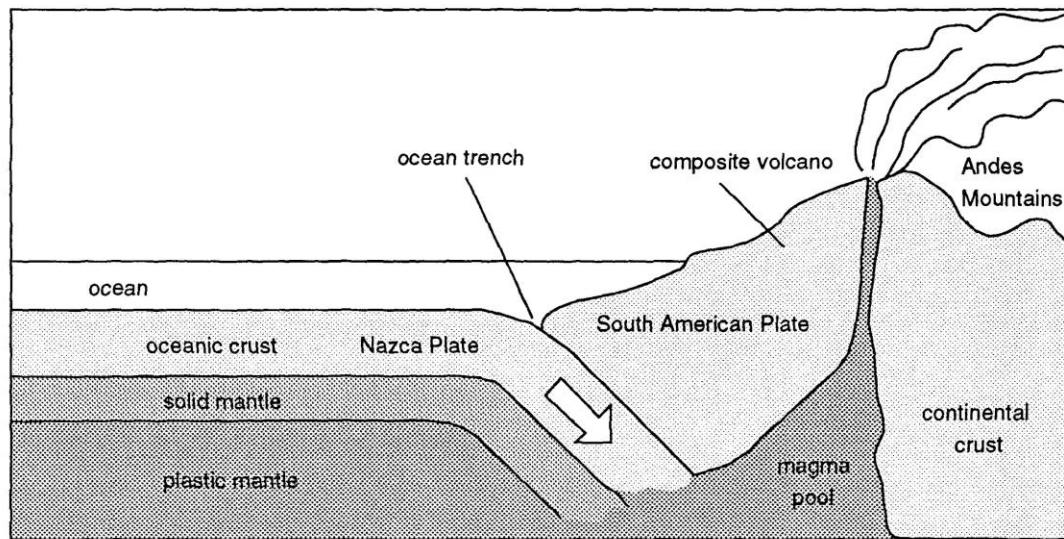


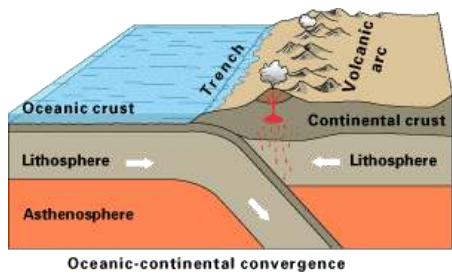
Fig. 8–3. Subduction of the Nazca Plate below the South American Plate forming composite volcanoes

Denser oceanic plates always subduct beneath less dense continental plates

Convergent Boundaries

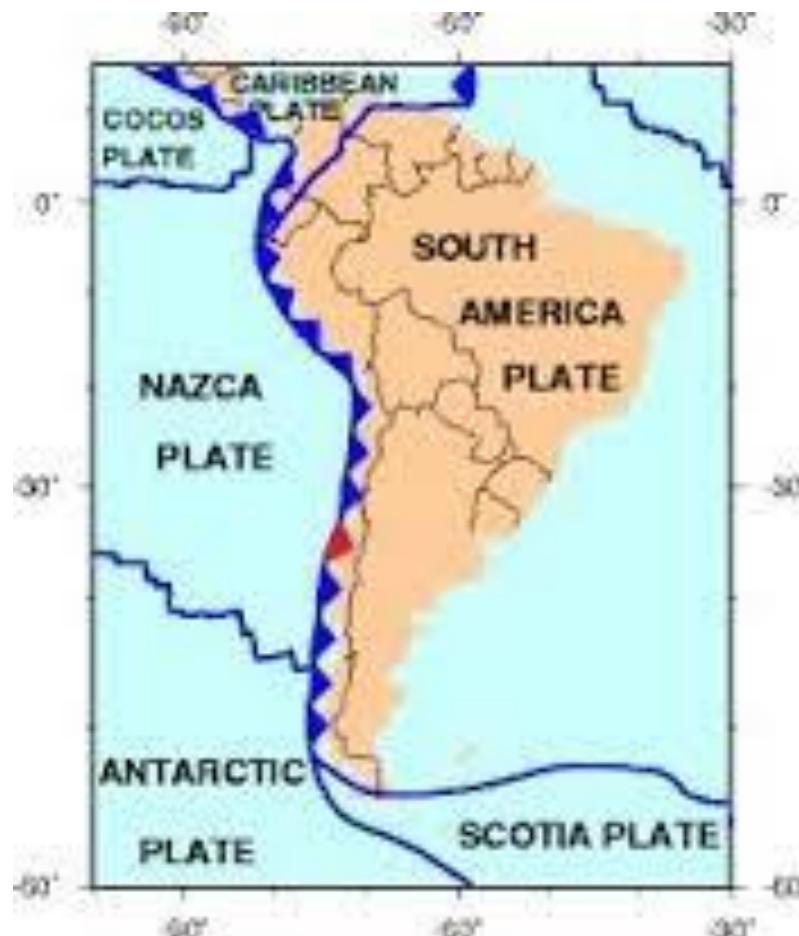
Ocean-continent convergence

Trench & Coastal Volcanoes



Convergent Boundaries

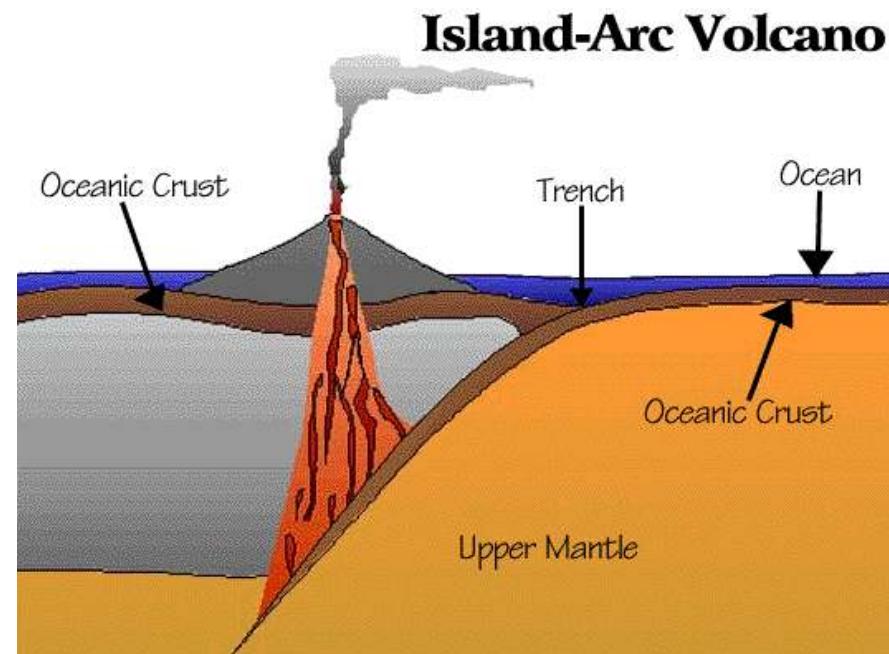
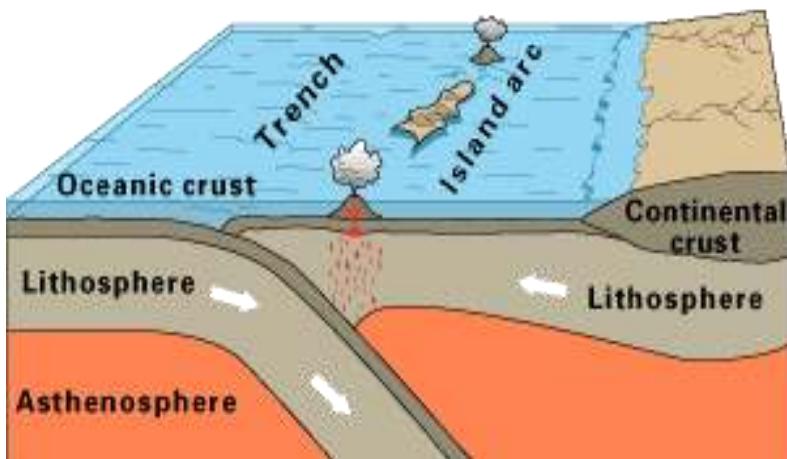
Ocean-continent convergence



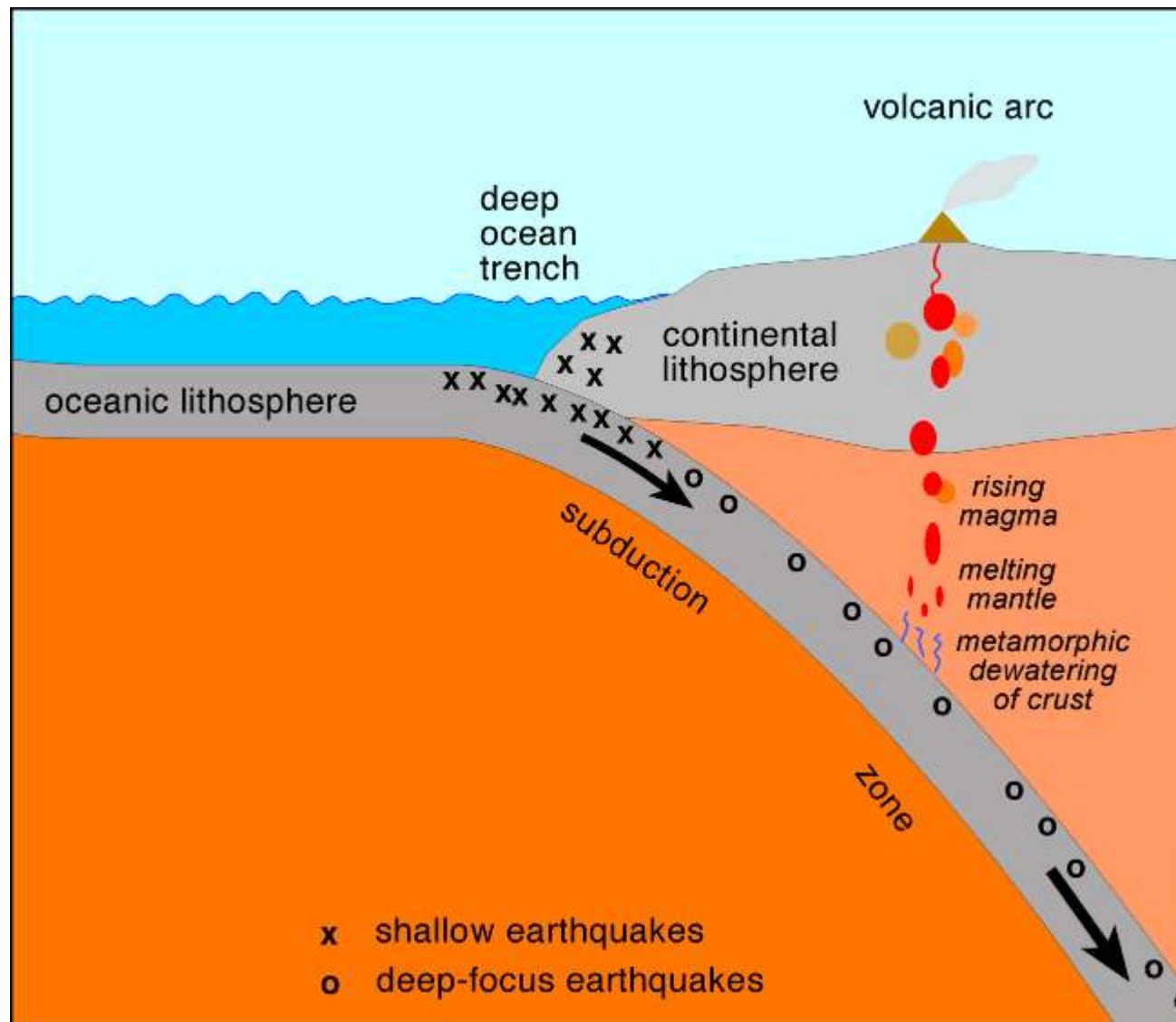
Convergent Boundaries

Ocean-ocean convergence

Trench & Island arc



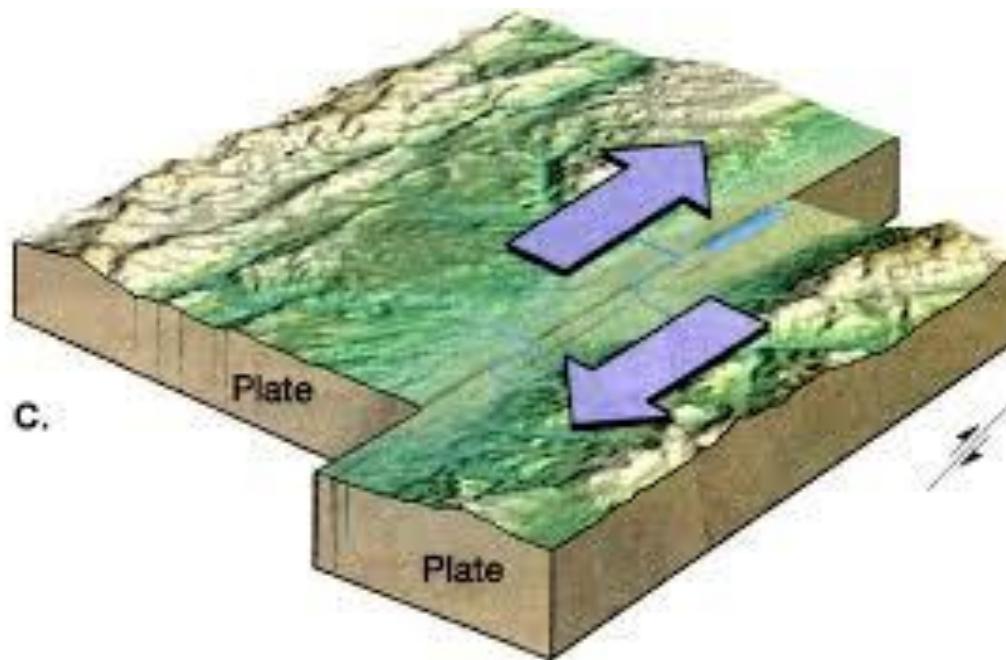
FLUX MELTING



Transform plate boundary

- Crust is neither created nor destroyed

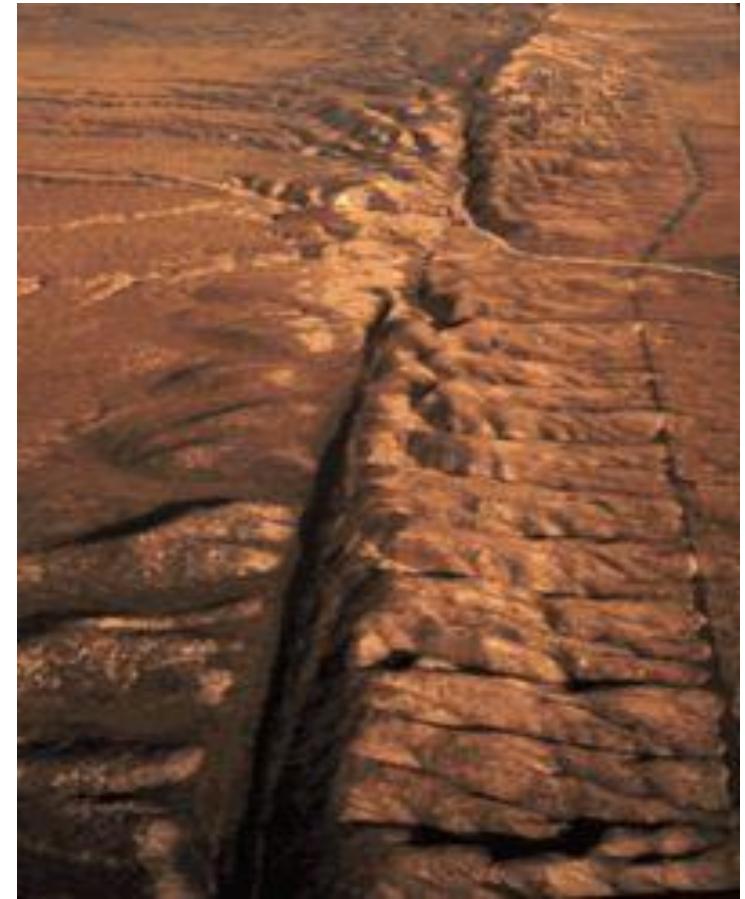
Plates slide past one another



Transform plate boundary

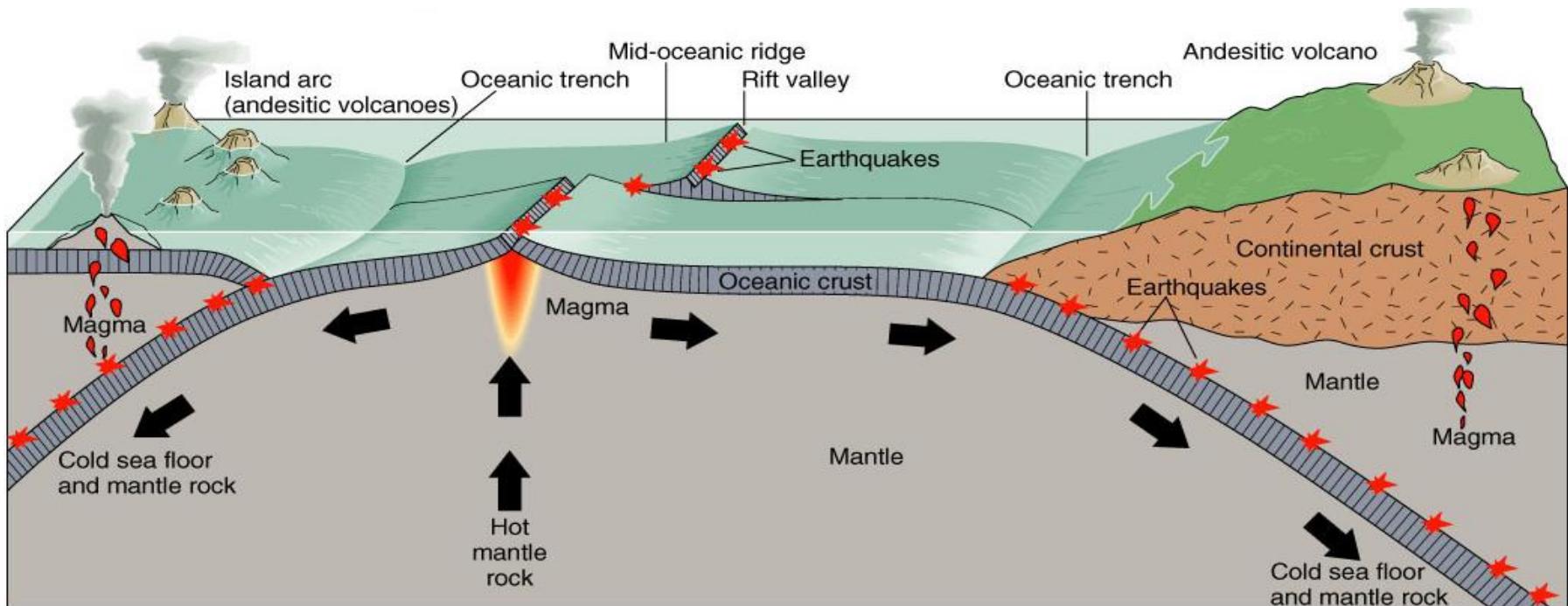


San Andreas Fault



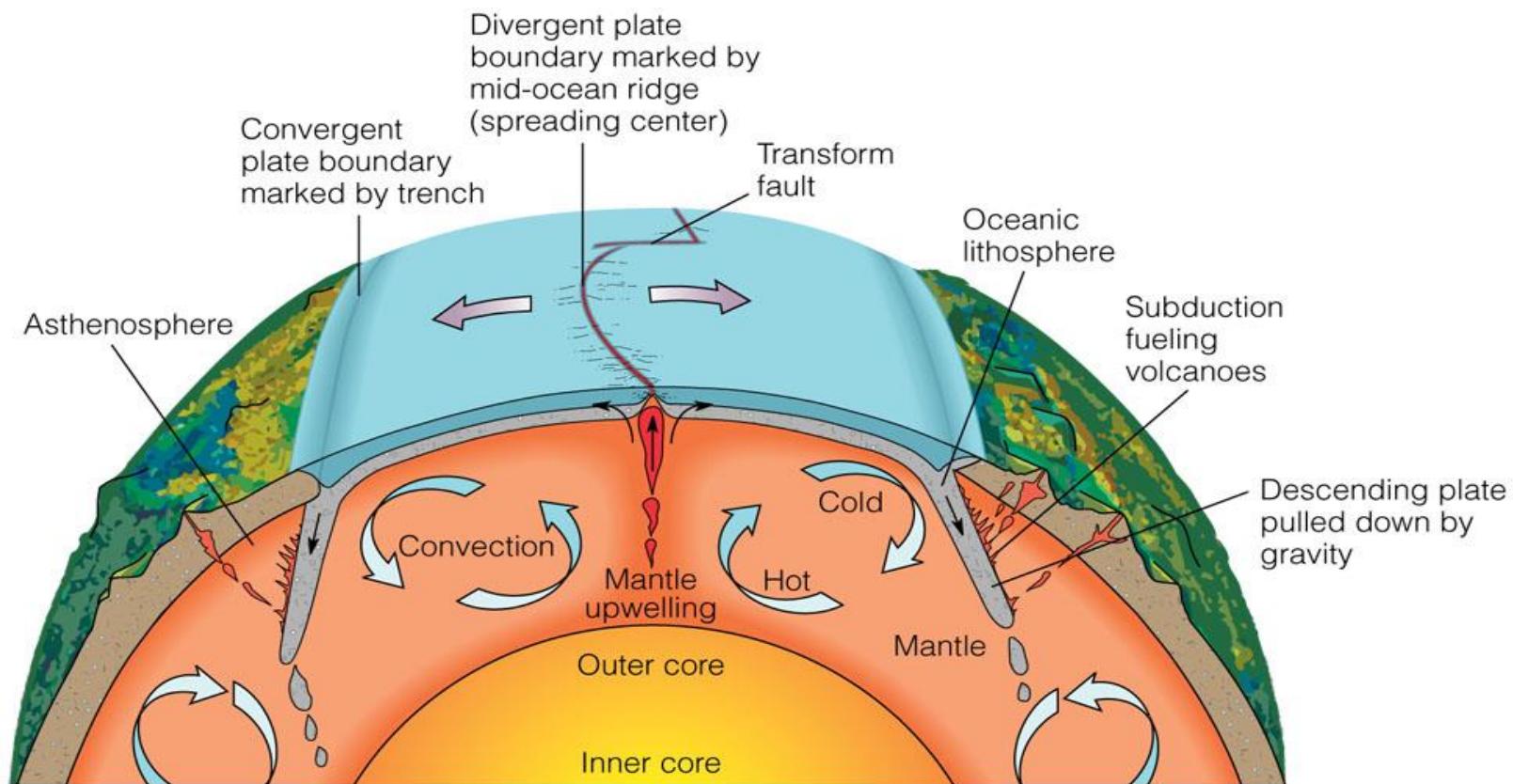
Carrizo Plains, Central California

Summary of Plate Movements



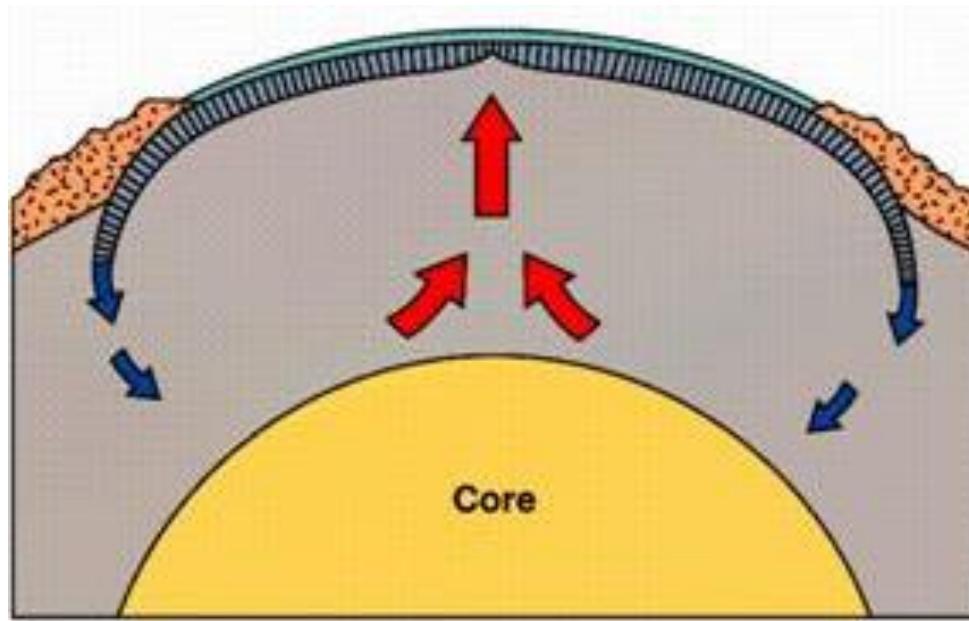
Convection currents

In 1960's convection currents has been proposed as driving force to move continents



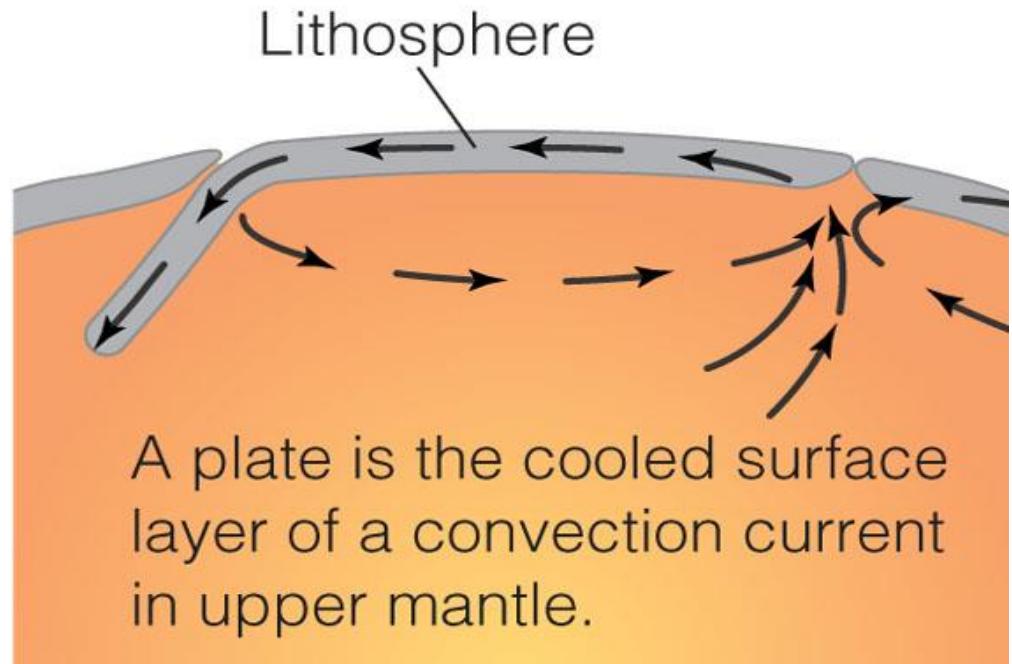
Convection currents

Driving force for convection?



Movement of matter is driven by Earth's internal and external sources of energy

Convection currents



How deep does the convection occurs?

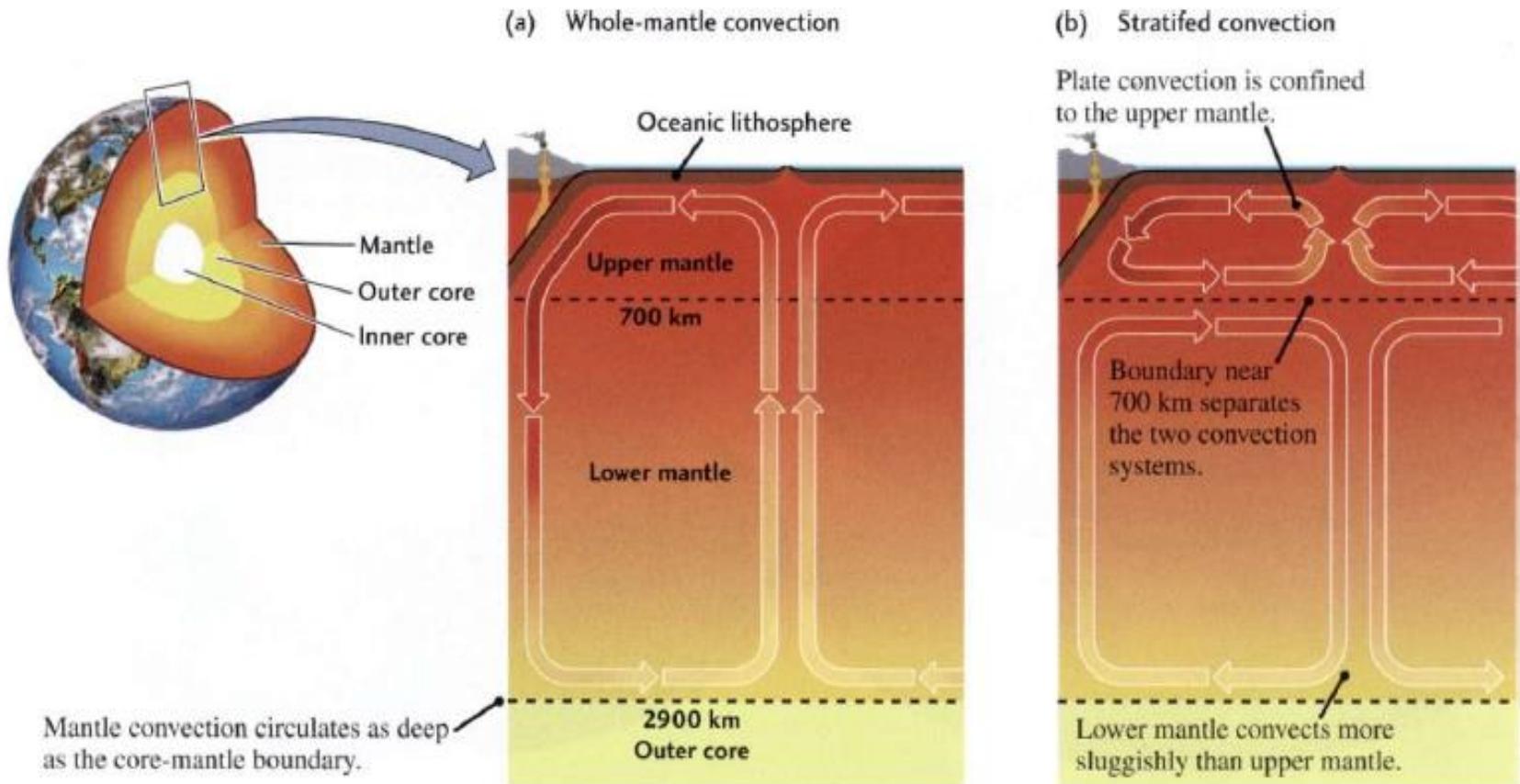


Figure 2.14 Two competing hypotheses for the mantle convection system.

Two competing hypotheses for the mantle convection system

Rates and History of plate movements

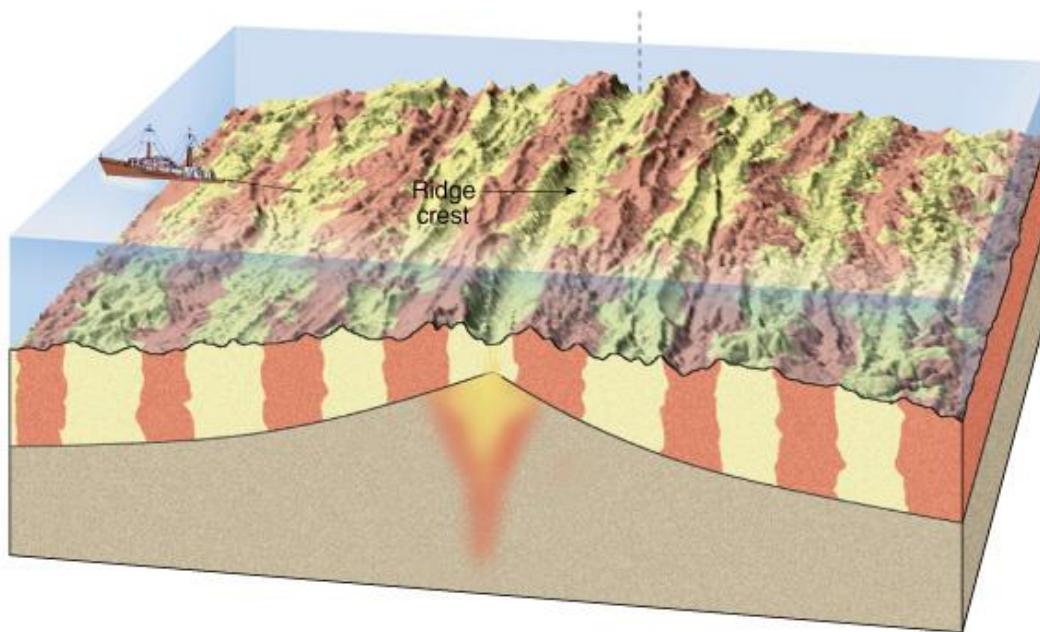
How fast do plates move?

Do some plates move faster than others, and if so, why?

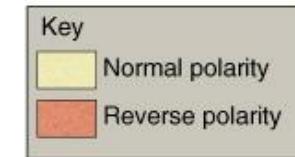
Is the velocity of plate movements today the same as it was in the Geologic past?

Rates and History of plate movements

Paleomagnetism

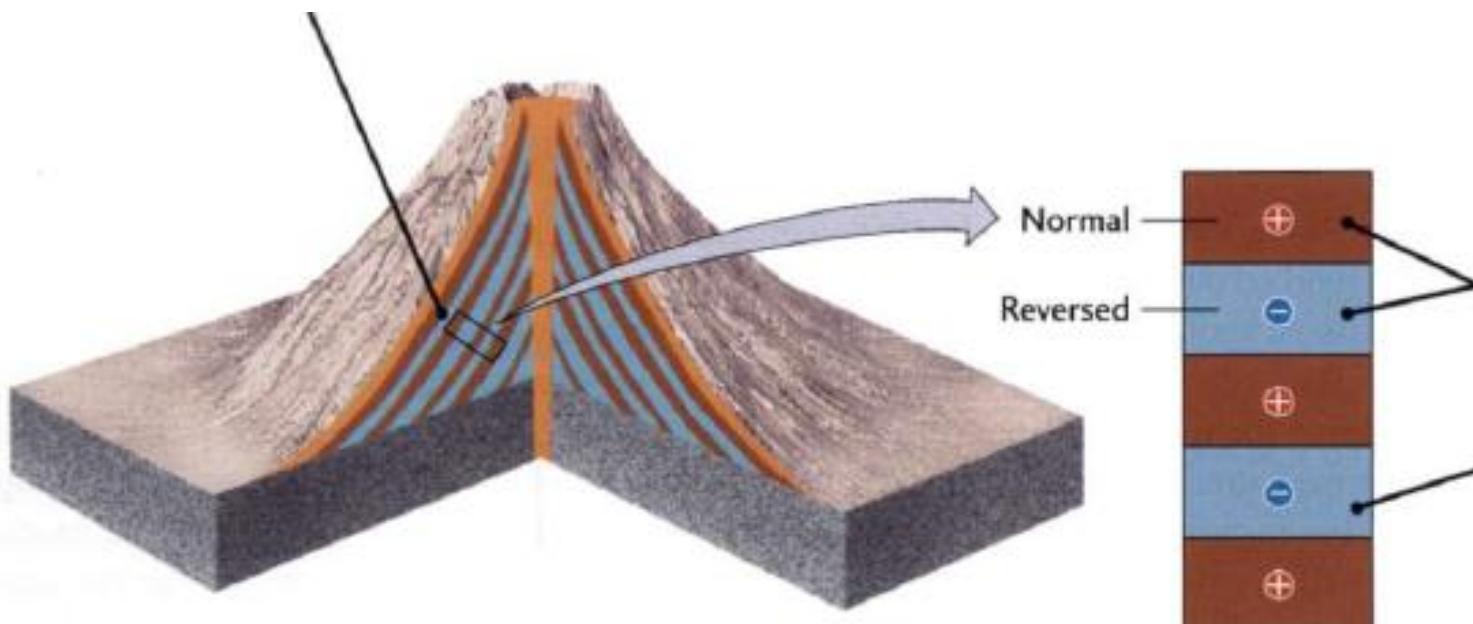


B. Research vessel towing magnetometer across ridge crest

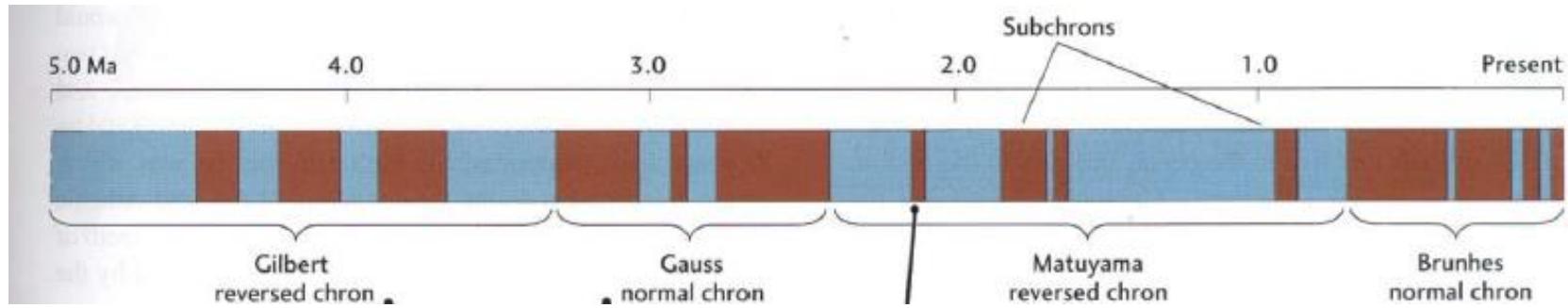


C. Location map

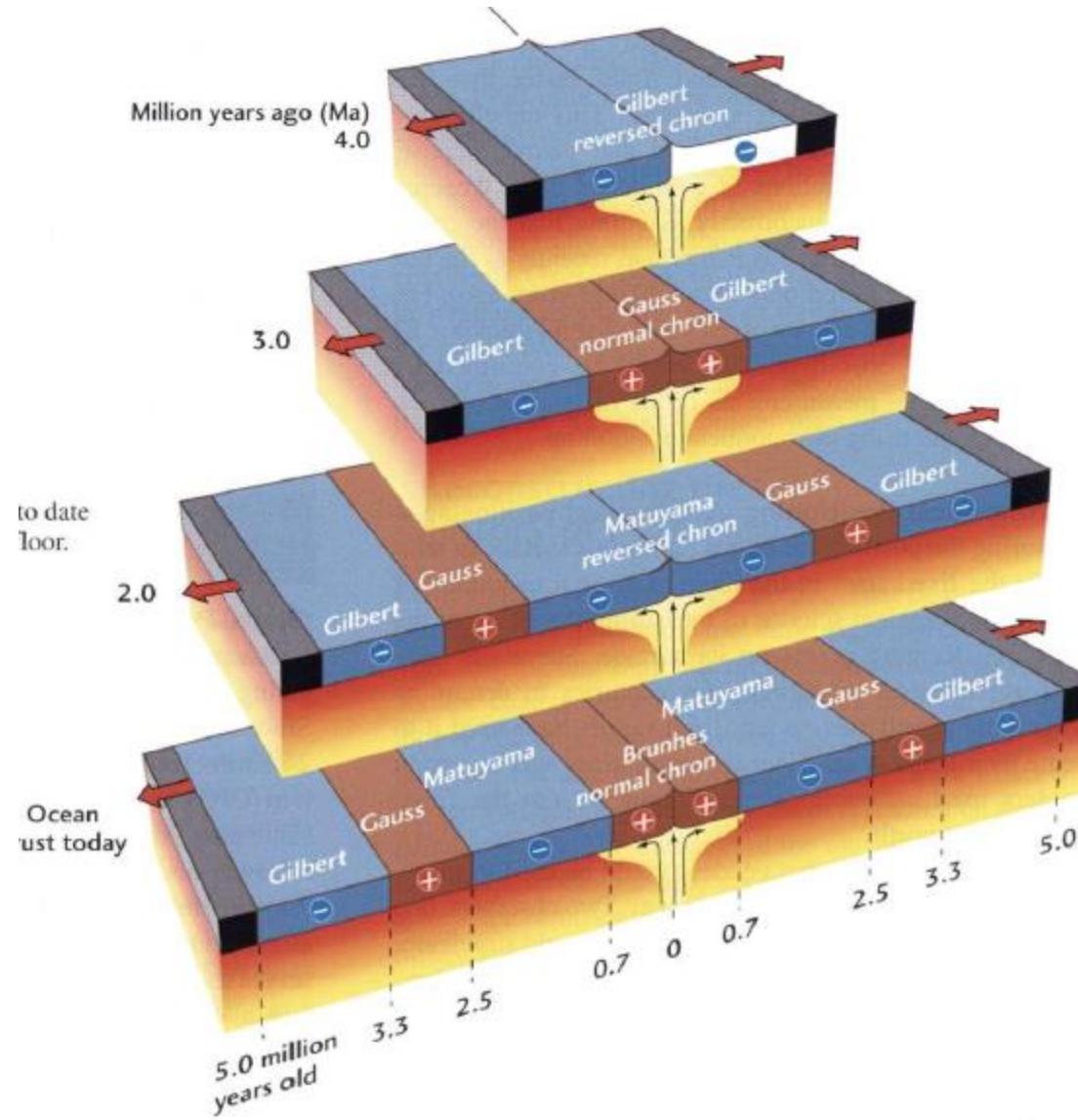
Paleomagnetism



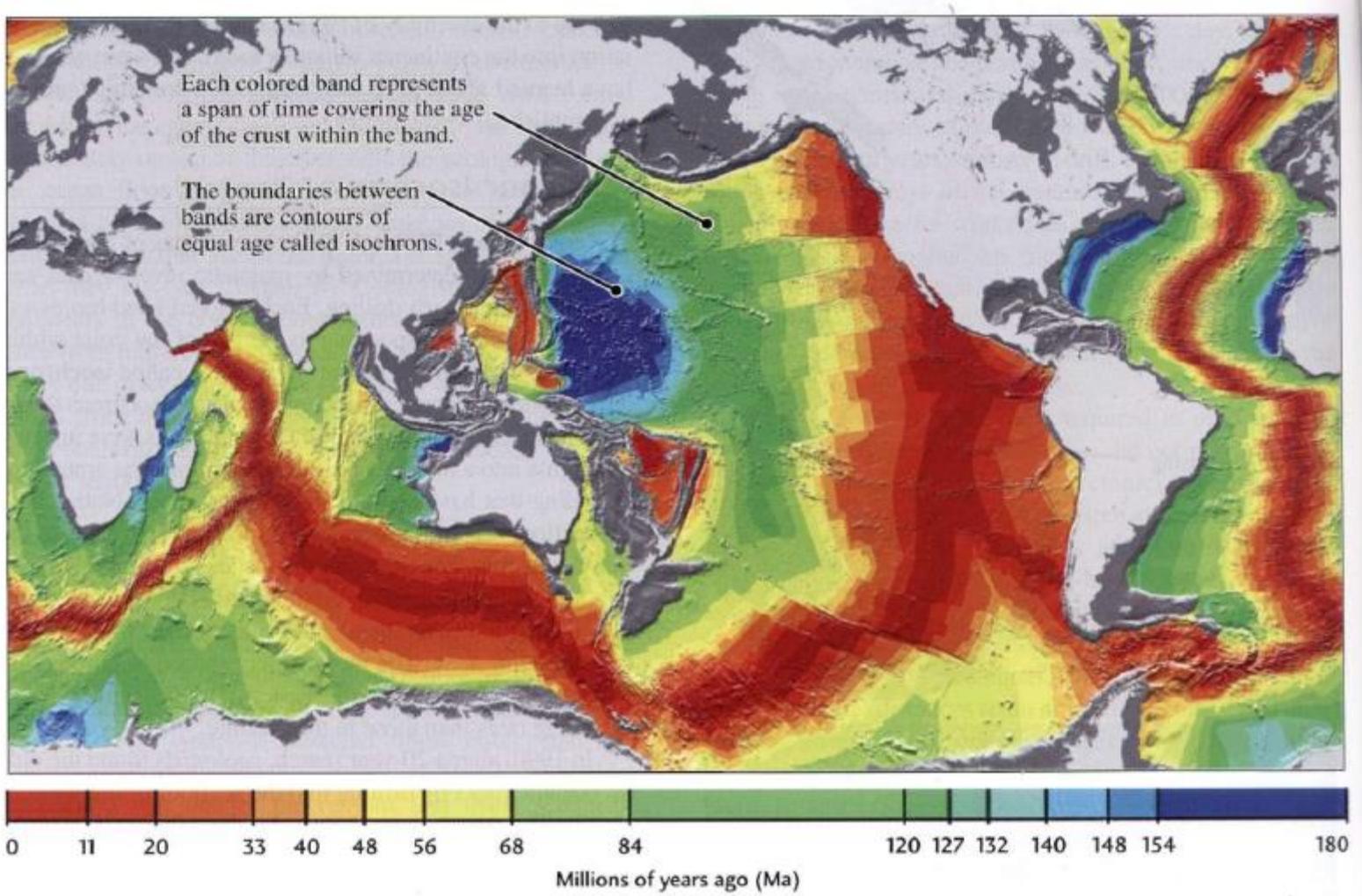
Paleomagnetism



Paleomagnetism



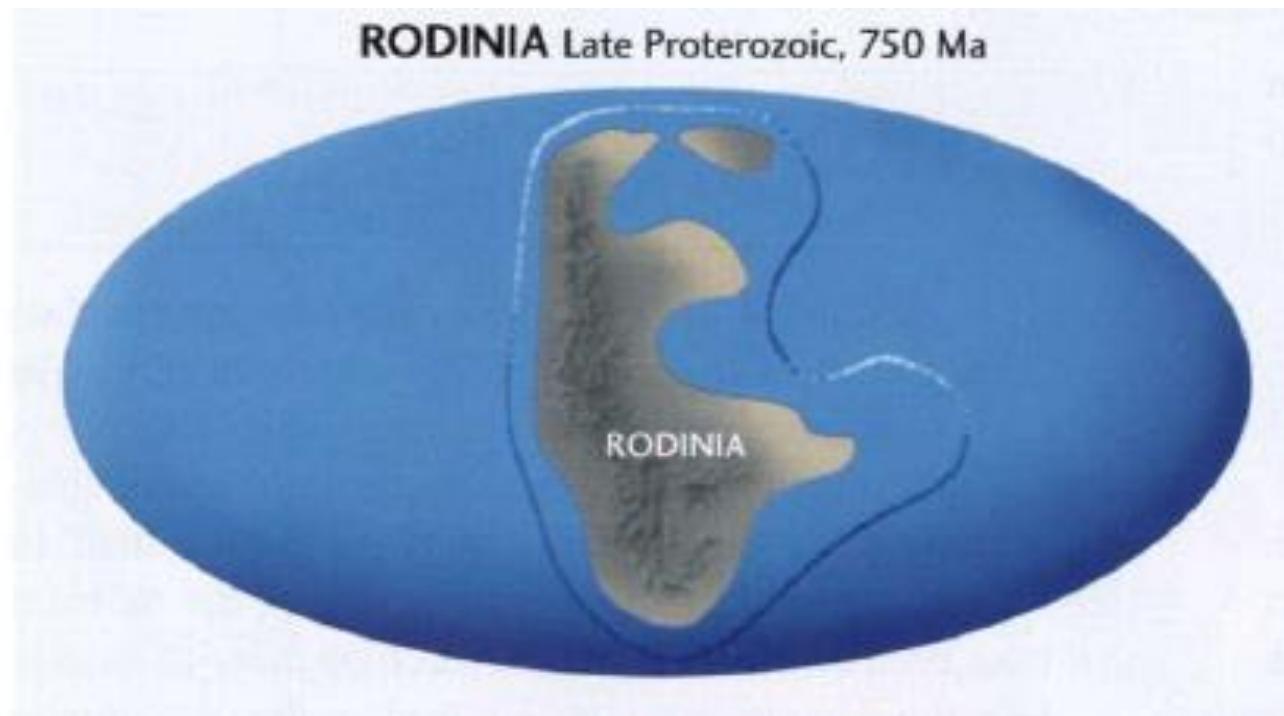
The global isochron map of the ocean floor



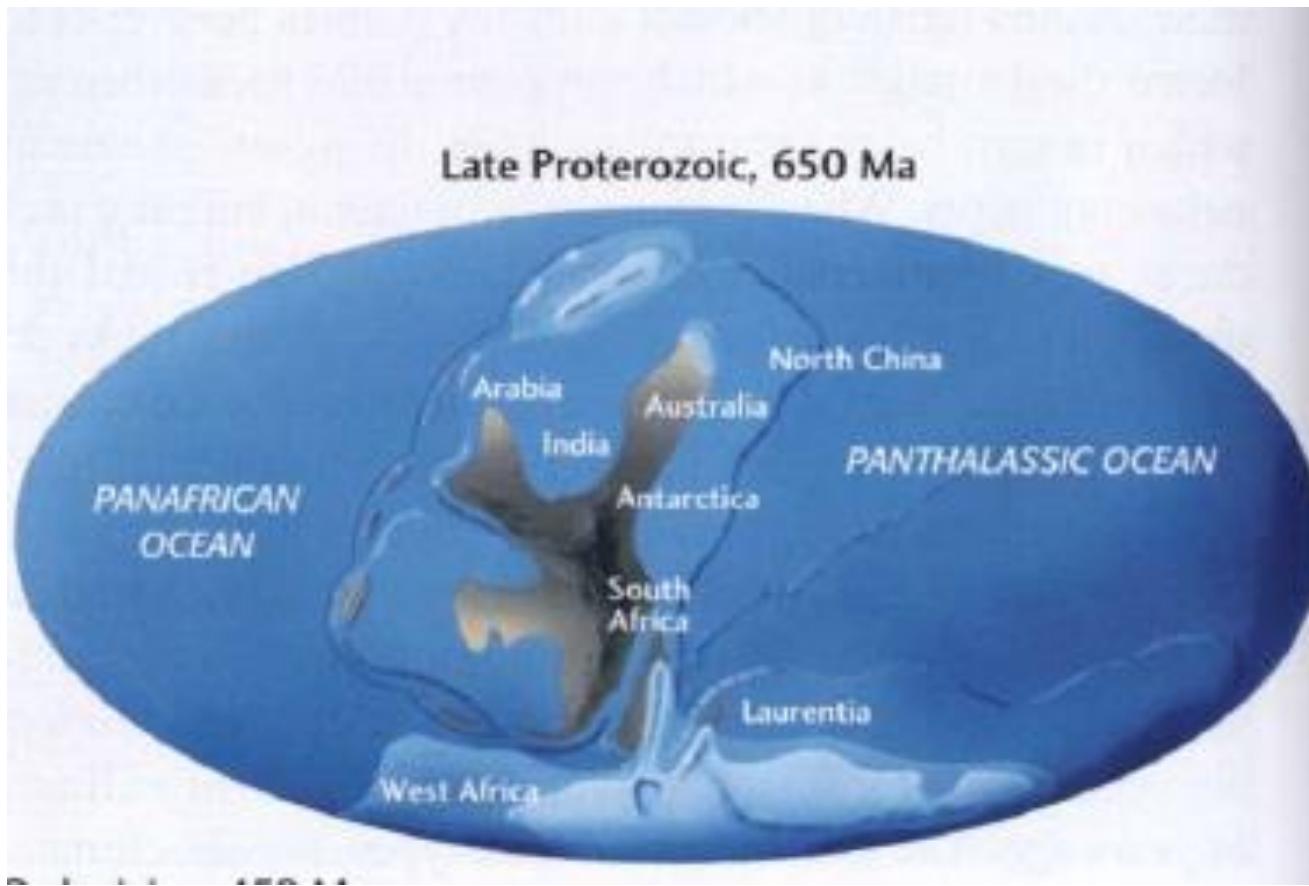
Reconstructing history of plate movements

- Sea floor isochron
- Transform fault boundaries
- Evidences also derived from rock types, fossils, mountain belts etc

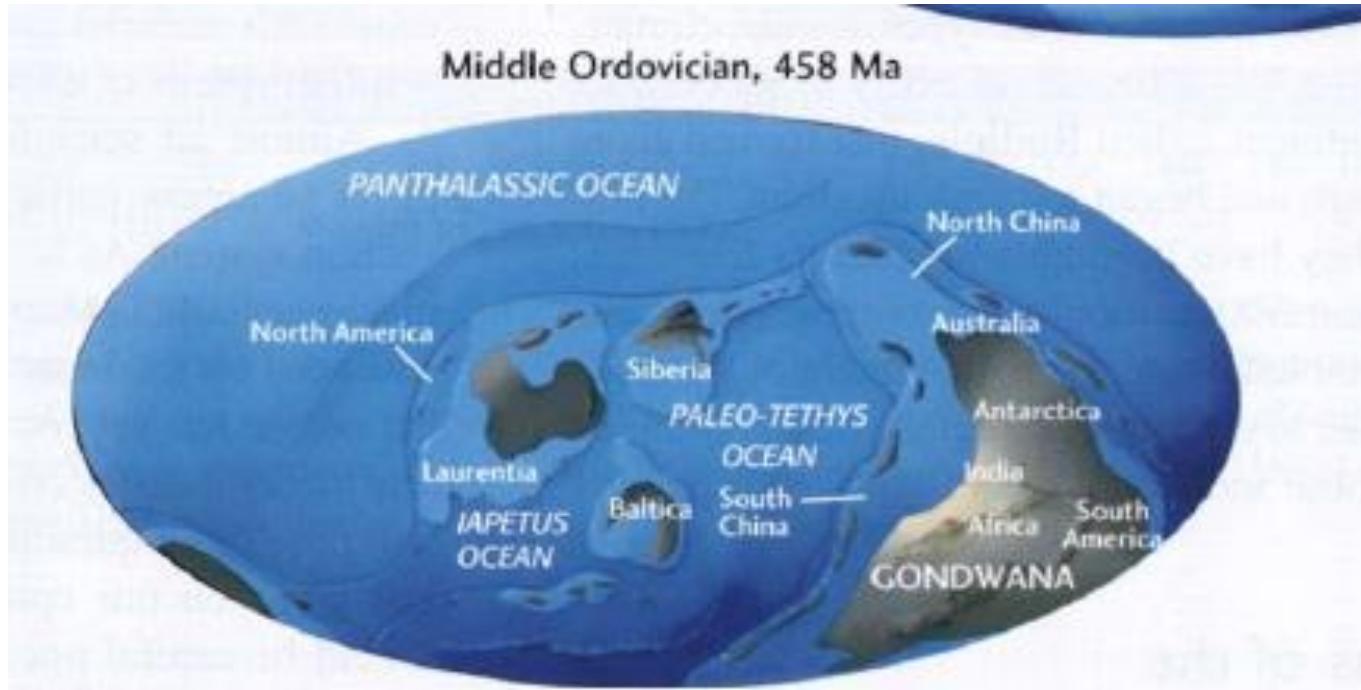
Assembly of Pangaea



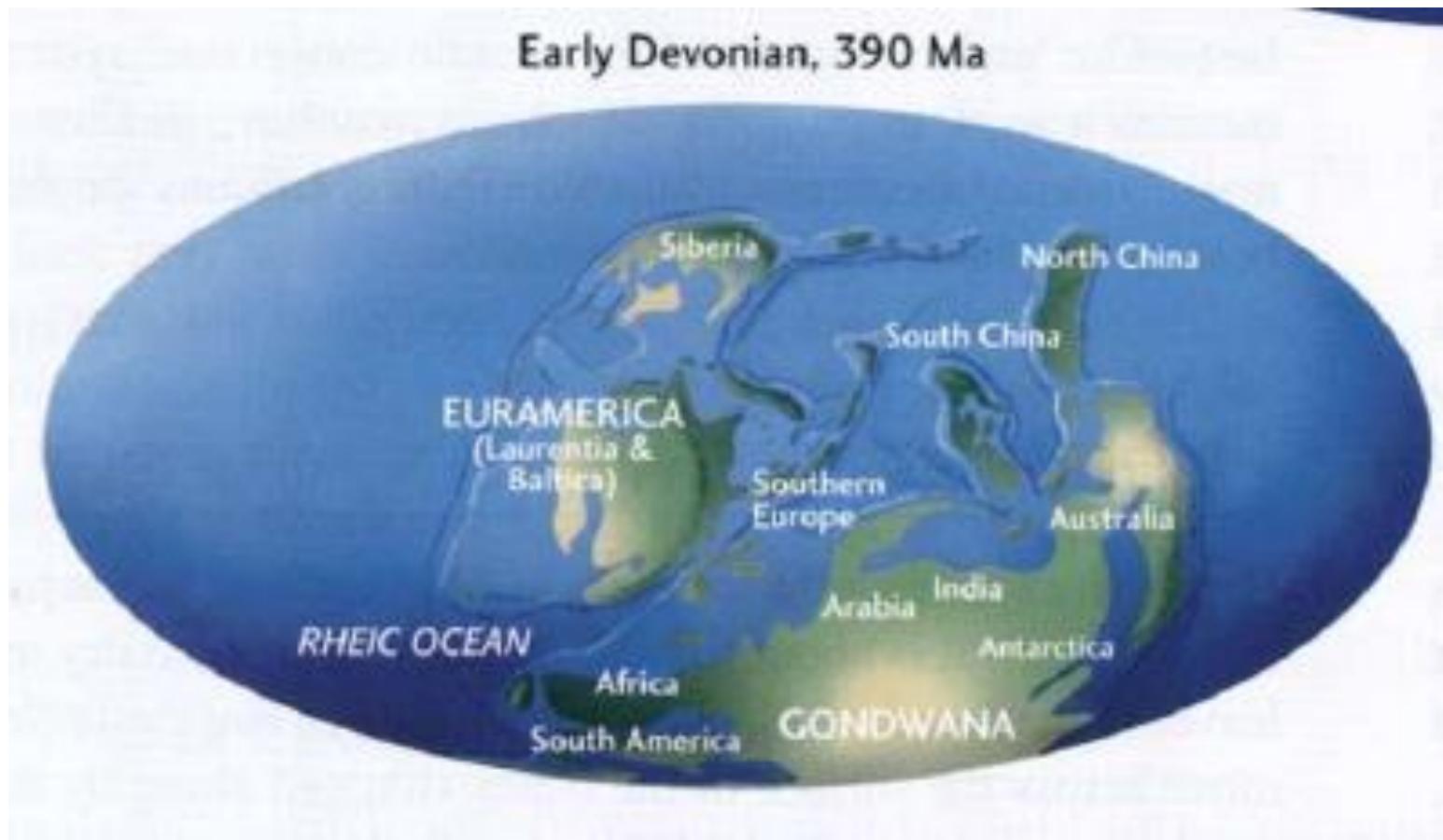
Assembly of Pangaea



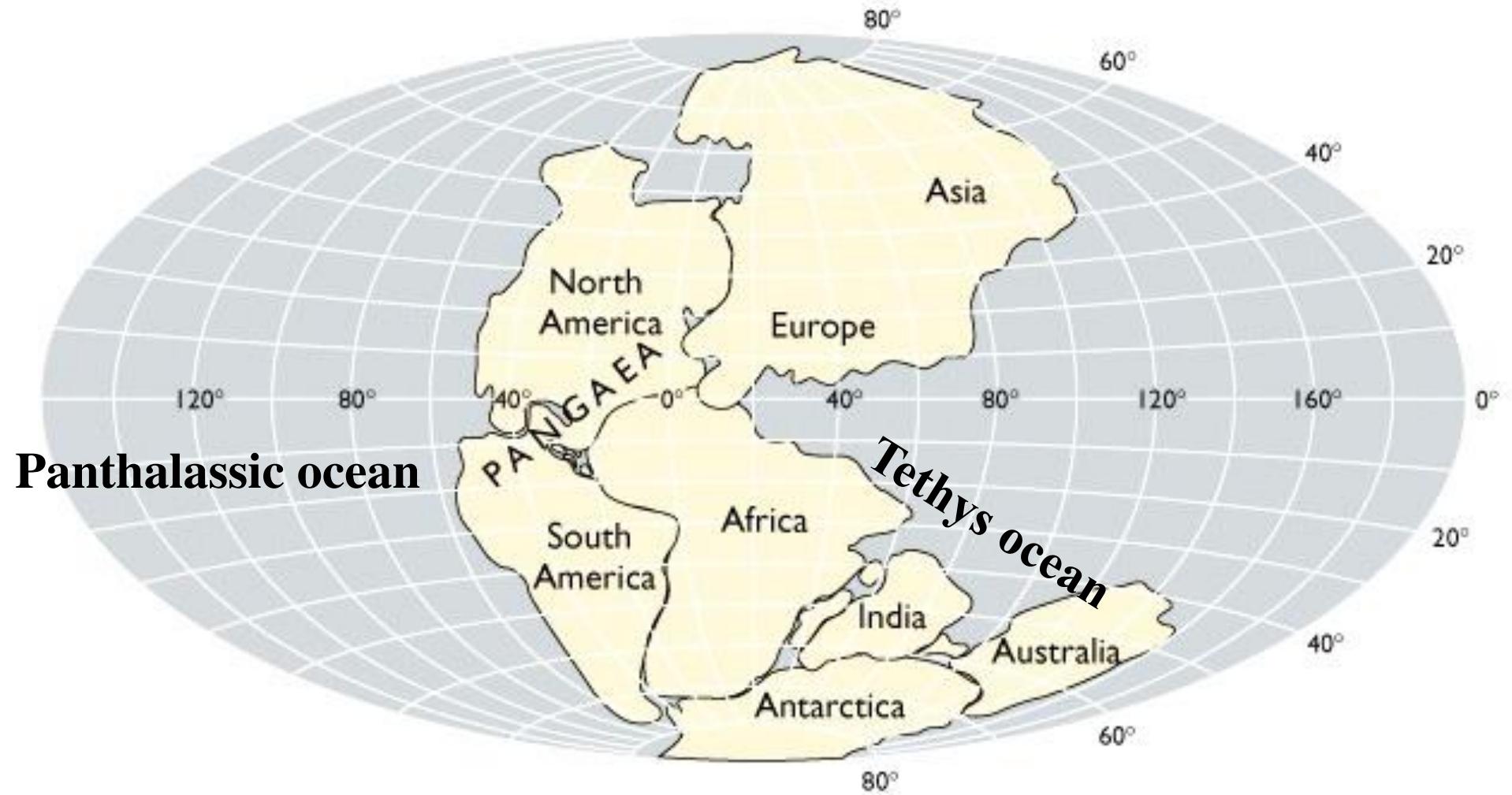
Assembly of Pangaea



Assembly of Pangaea

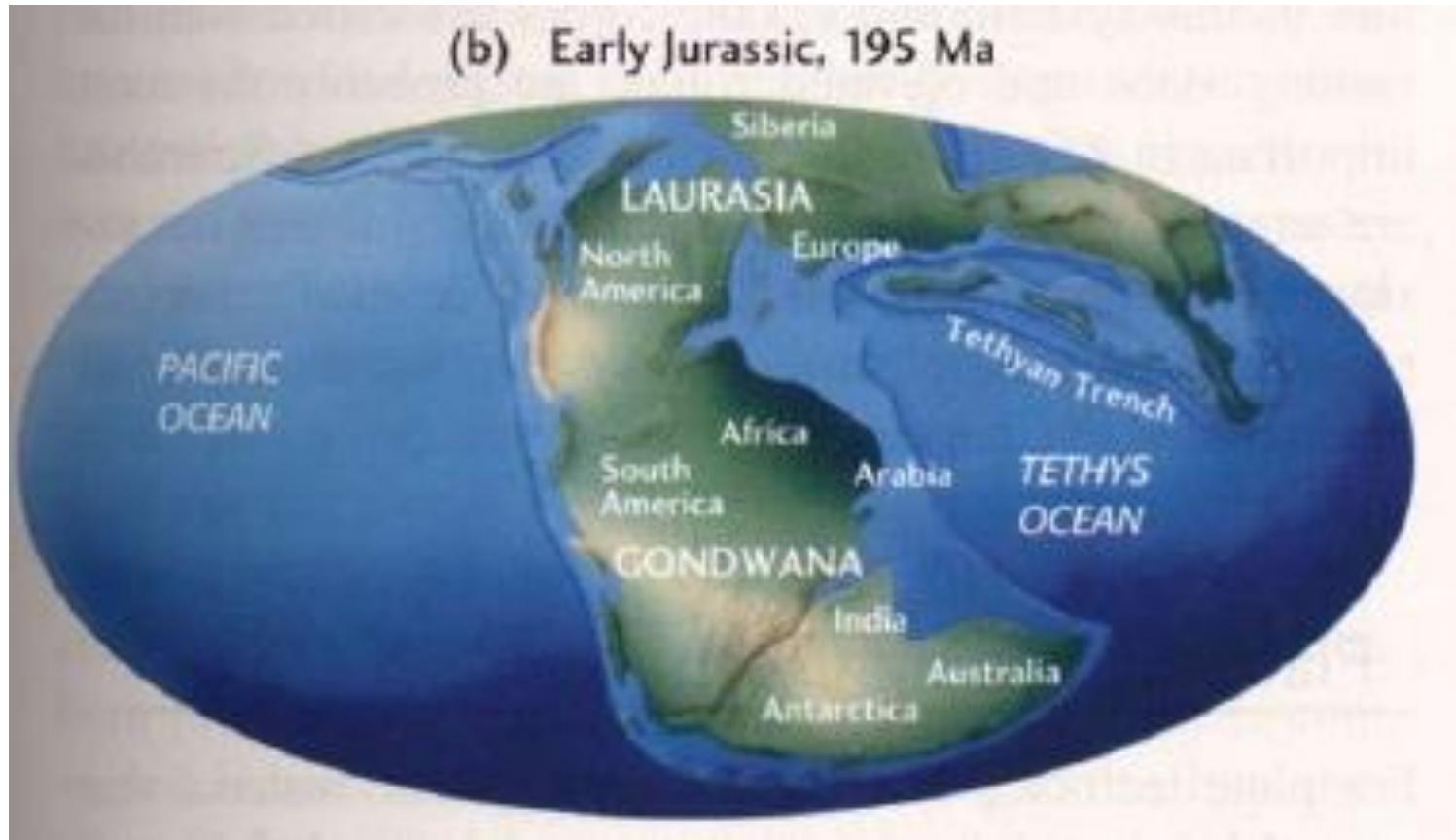


THE SUPERCONTINENT OF PANGAEA (237 MILLION YEARS AGO)



Break up of Pangaea

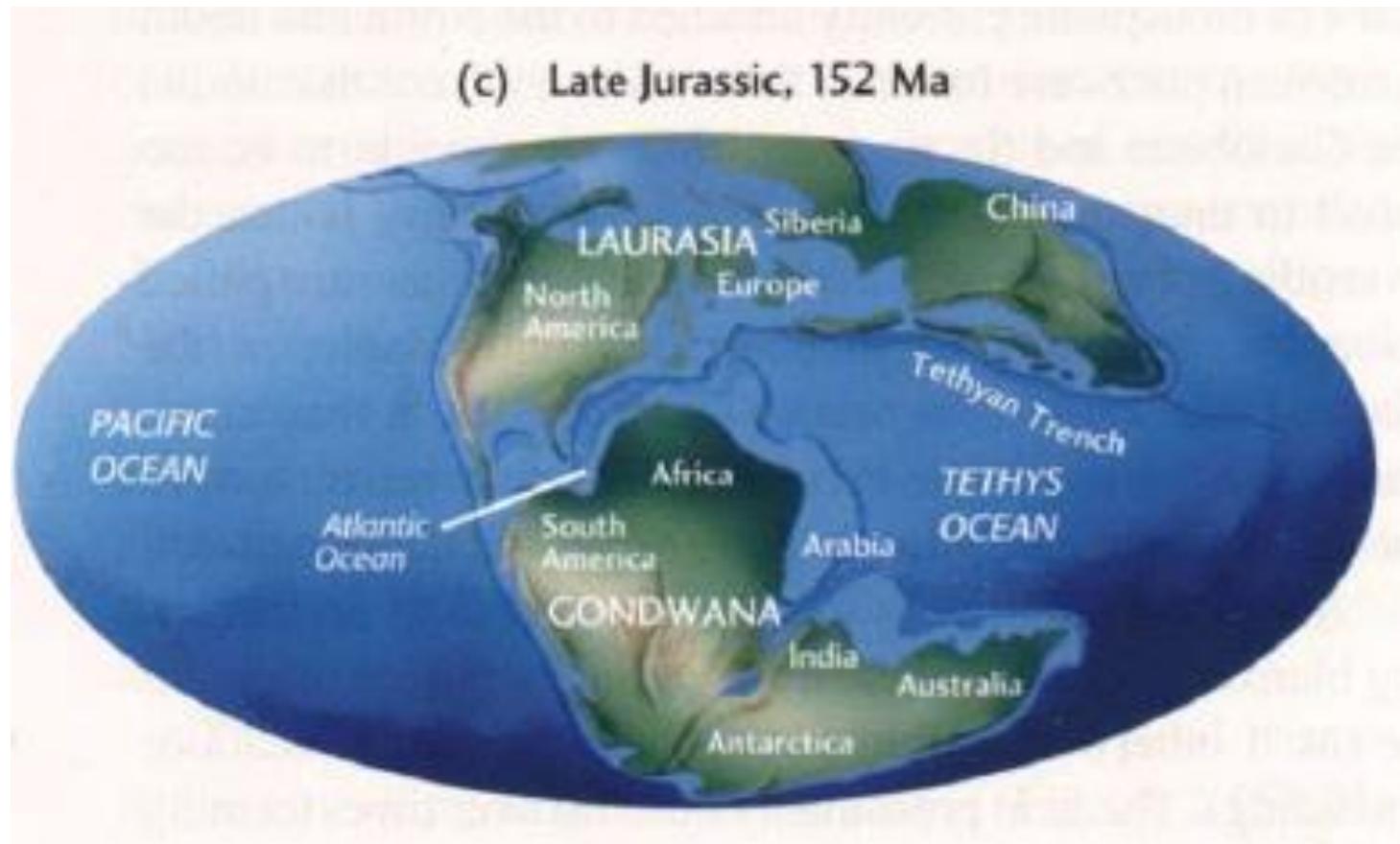
Evidence-rift system-volcanic rocks from Nova Scotia and North Carolina



Break up of Pangaea

Early stage of break up- Atlantic ocean opened up and Tethys sea contracted

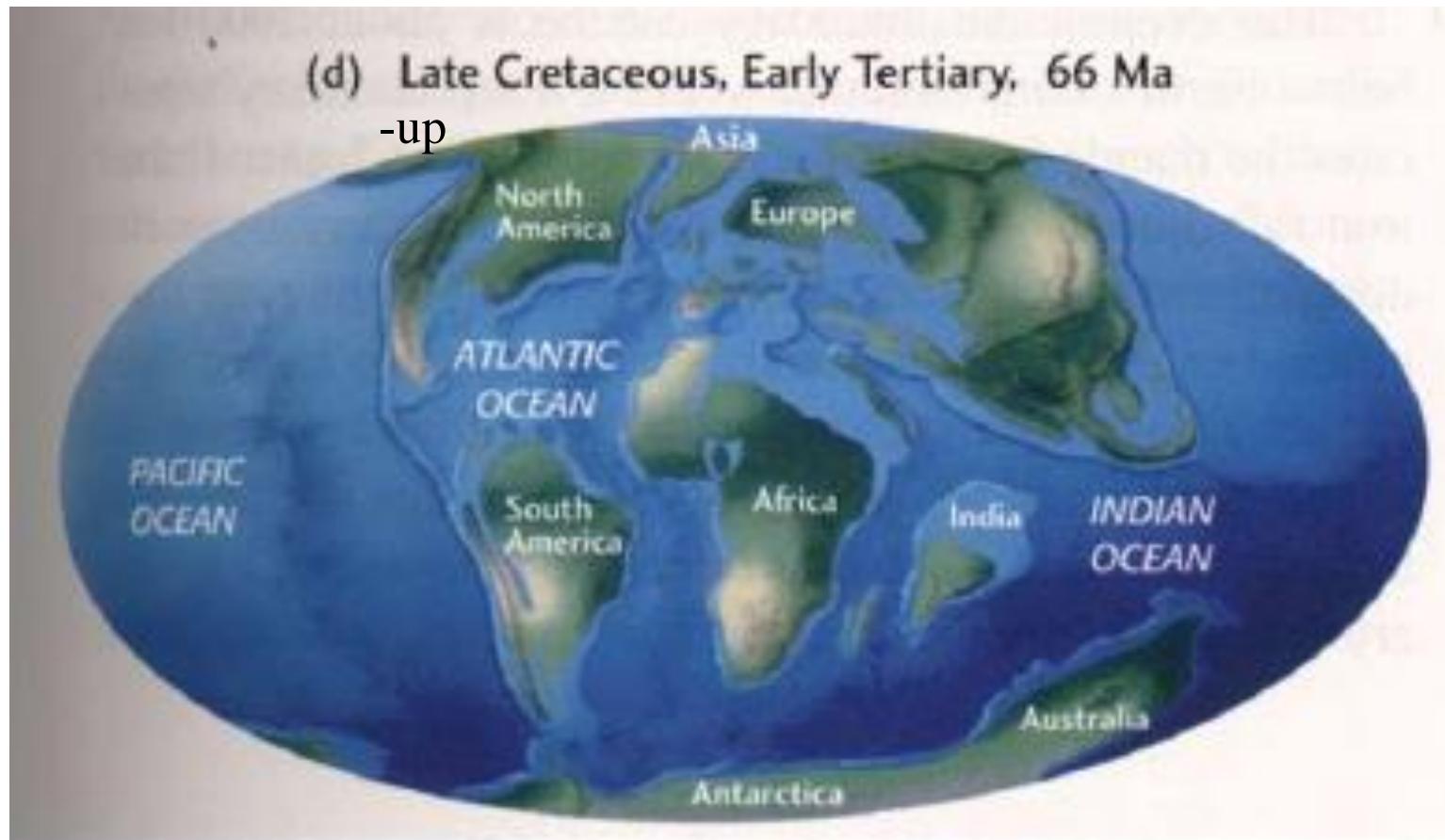
-Southern continents and northern continent split up



Break up of Pangaea

Early stage of break up- Atlantic ocean opened and widened

- Tethys ocean was closing to form Mediterranean
- India was well going northward



The present day and future world

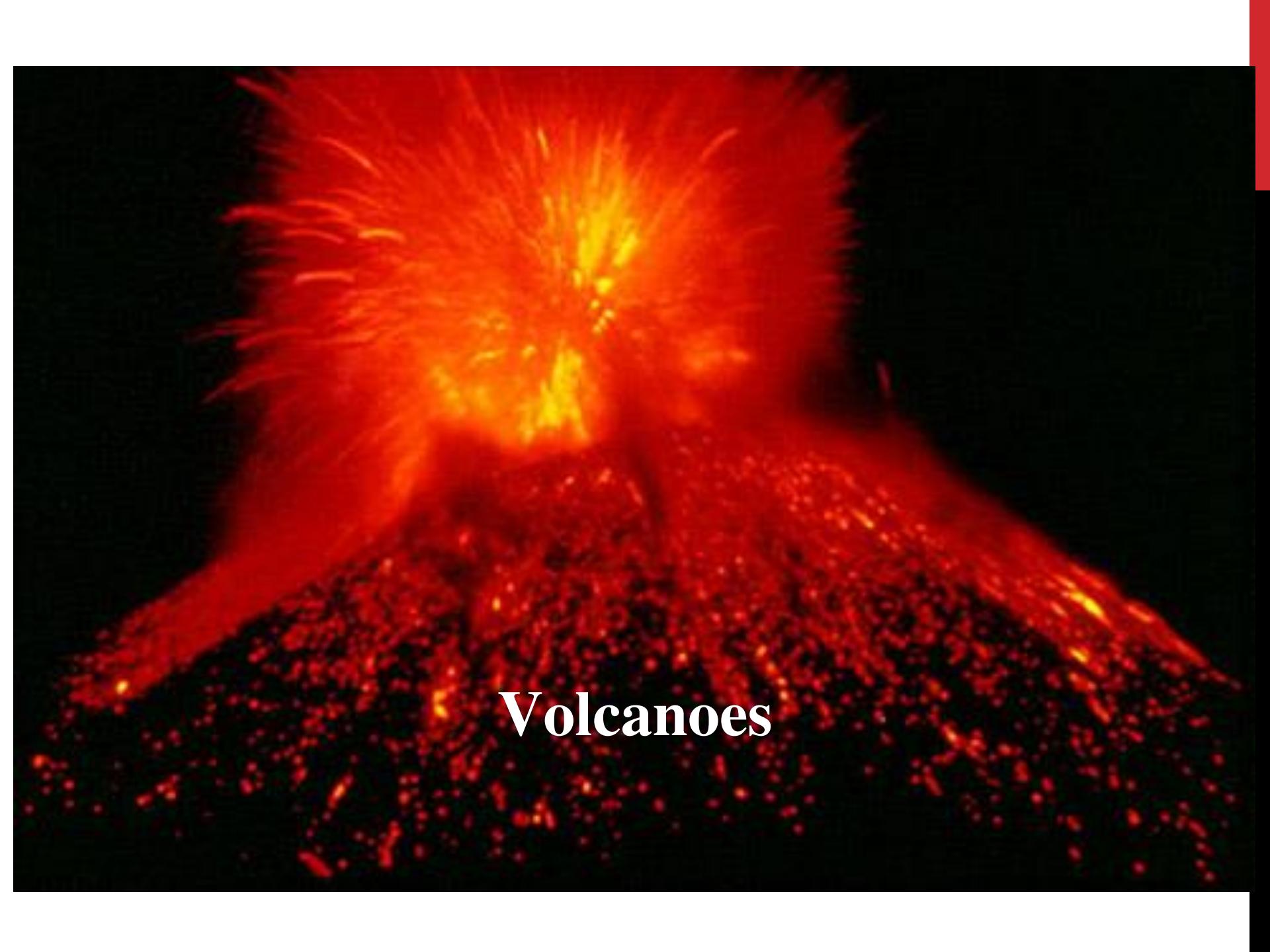
(e) PRESENT-DAY WORLD



7 The modern world has been produced over the past 65 million years. India collided with Asia, ending its trip across the ocean, and is still pushing northward into Asia. Australia has separated from Antarctica.

(f) 50 million years in the future



A photograph of a volcano erupting at night. The volcano's peak is a intense orange and yellow, with a large plume of smoke and ash rising into the dark sky. The base of the volcano is covered in lava and rock. The word "Volcanoes" is overlaid in white text.

Volcanoes

Eruption at Pompeii

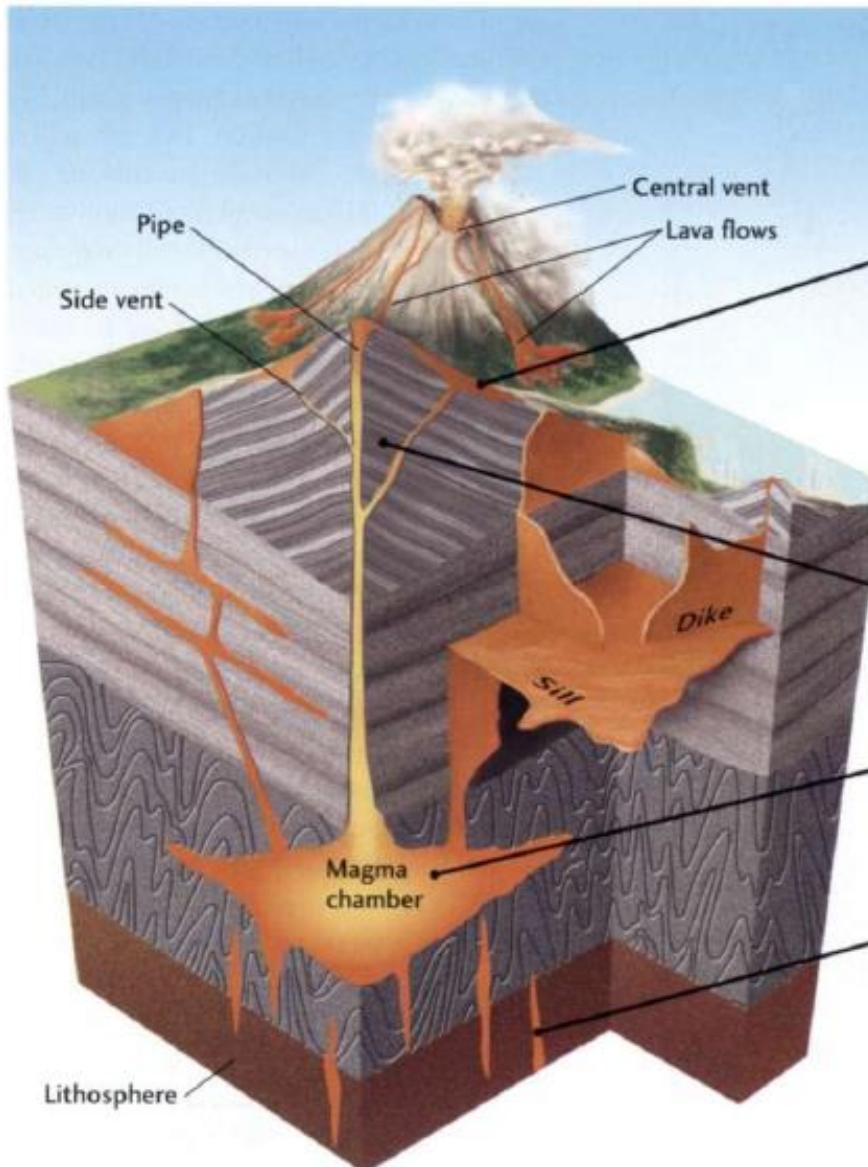


MAY 1990 ERUPTION OF KILAUEA, HAWAII



James Cachero/Sygma

Plumbing System of a Volcano



Lava accumulates on the surface to form volcano

Lava erupts through a Central and side vents

Rise through the lithosphere

Originates from the Asthenosphere

Types of Lavas

- Basaltic Lavas
- Andesitic Lavas
- Rhyolitic Lavas

Basaltic Lavas

- Mid oceanic ridges
- Mafic in composition
- Higher temperature
- Rarely explosive



A central vent eruption from Kilauea, Hawaii produces fast flowing Basaltic lavas

Type of Basaltic Lavas



Pillow Lava



Andesitic Lavas

- Intermediate SiO₂
- Flow relatively slow
- Temperature lower
- Subduction settings
- Phreatic explosions



Mount St Helens, a andesitic volcano in south-western Washington state

Phreatic explosions



Rhyolitic Lavas

- High silica (~68%)
- Temperature lower (600-800)
- Thick bulbous deposits
- Gases are easily trapped within rhyolitic lavas



Viscous rhyolite lava flow. Wilson Butte dome, Long Valley, California

Textures of Volcanic rocks

Obsidian

Vesicular

Obsidian



Silica rich rapidly cooled lavas form obsidian

Vesicular Basalt



Pumice floating in water

Pyroclastic deposits



Explosive eruption at Arenal Volcano,
Costa Rica

Volcanic ejecta

Pyroclastic flows

Pyroclastic deposits

- **Volcanic ash – less than 2mm in diameter**
- **Volcanic Bombs- large fragments**



Volcanic ash



Volcanic Bombs

Pyroclastic deposits



(a)

Tuff



(b)

Volcanic breccia

Pyroclastic flow



Pyroclastic flow plunged down the slopes of Mount Unzen, Japan

Eruptive styles and landforms

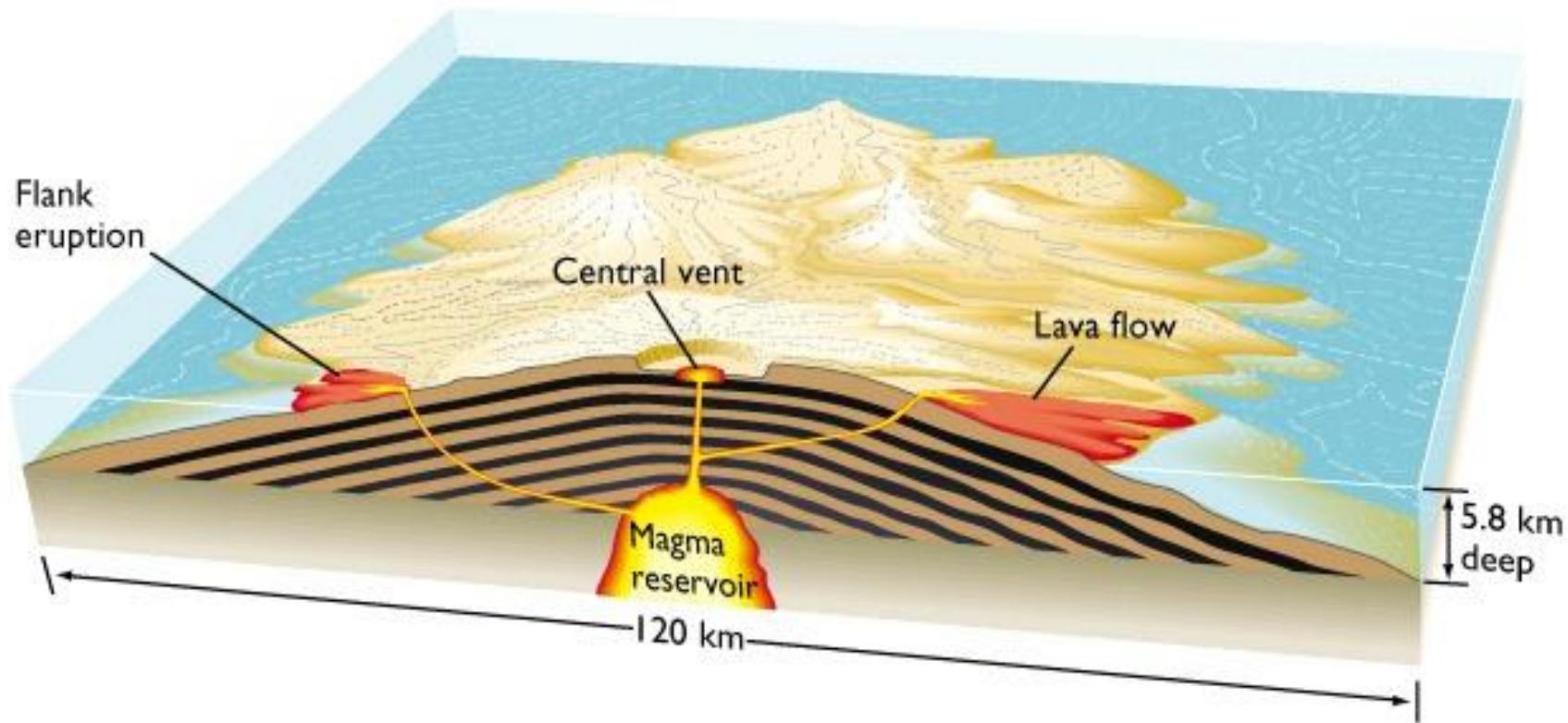
- **Composition of magma**
 - gas content
 - chemical composition
- **Type of material erupted (lava versus pyroclasts)**
- **Environmental condition in which it erupts
(submarine vs. continental)**

Central Eruptions

Shield Volcanoes

- **Low-viscosity lava flows (Mafic)**
- **Gently sloping flanks — between 2 and 10 degrees**

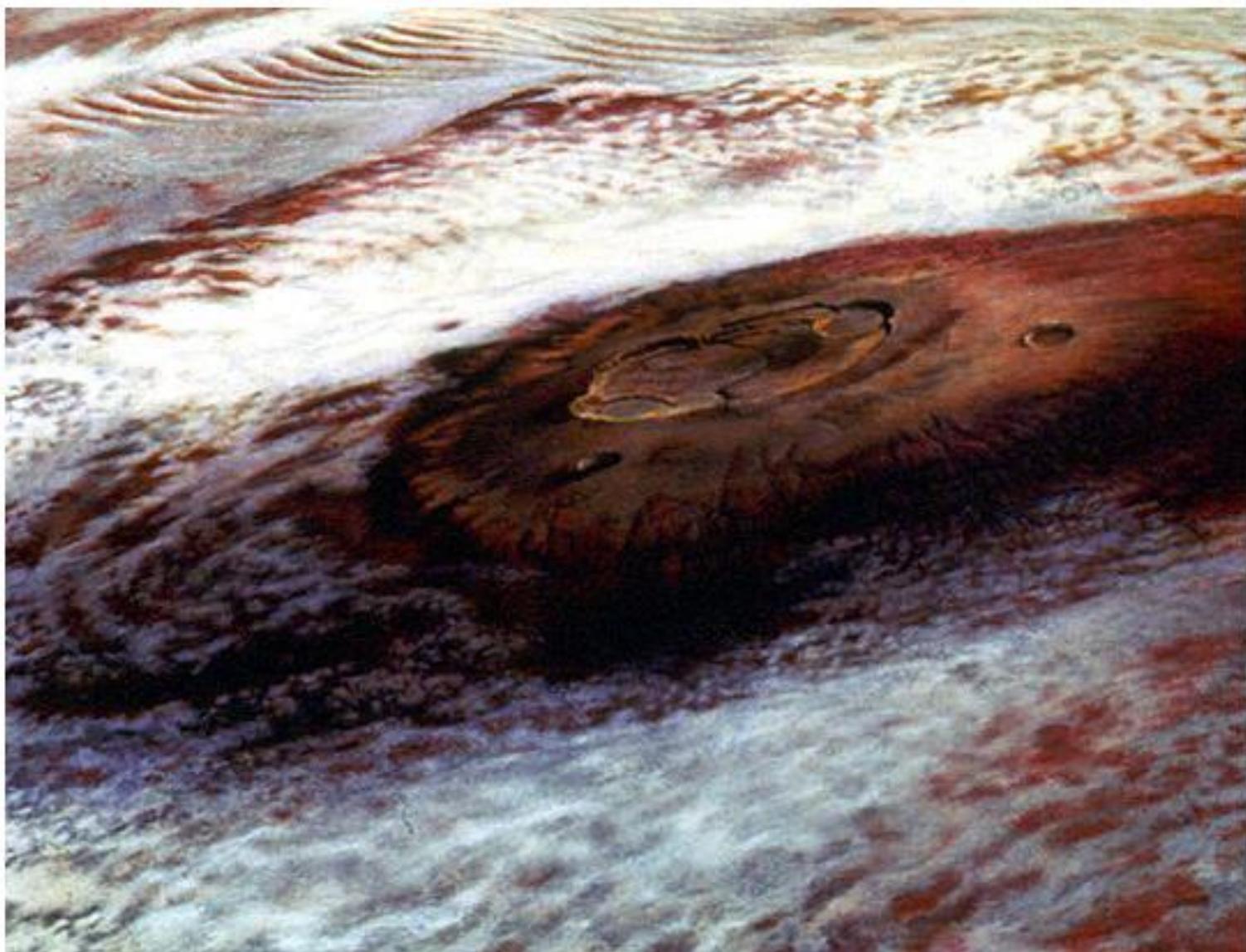
Shield Volcanoes



Shield Volcanoes



Olympus Mons Shield Volcano

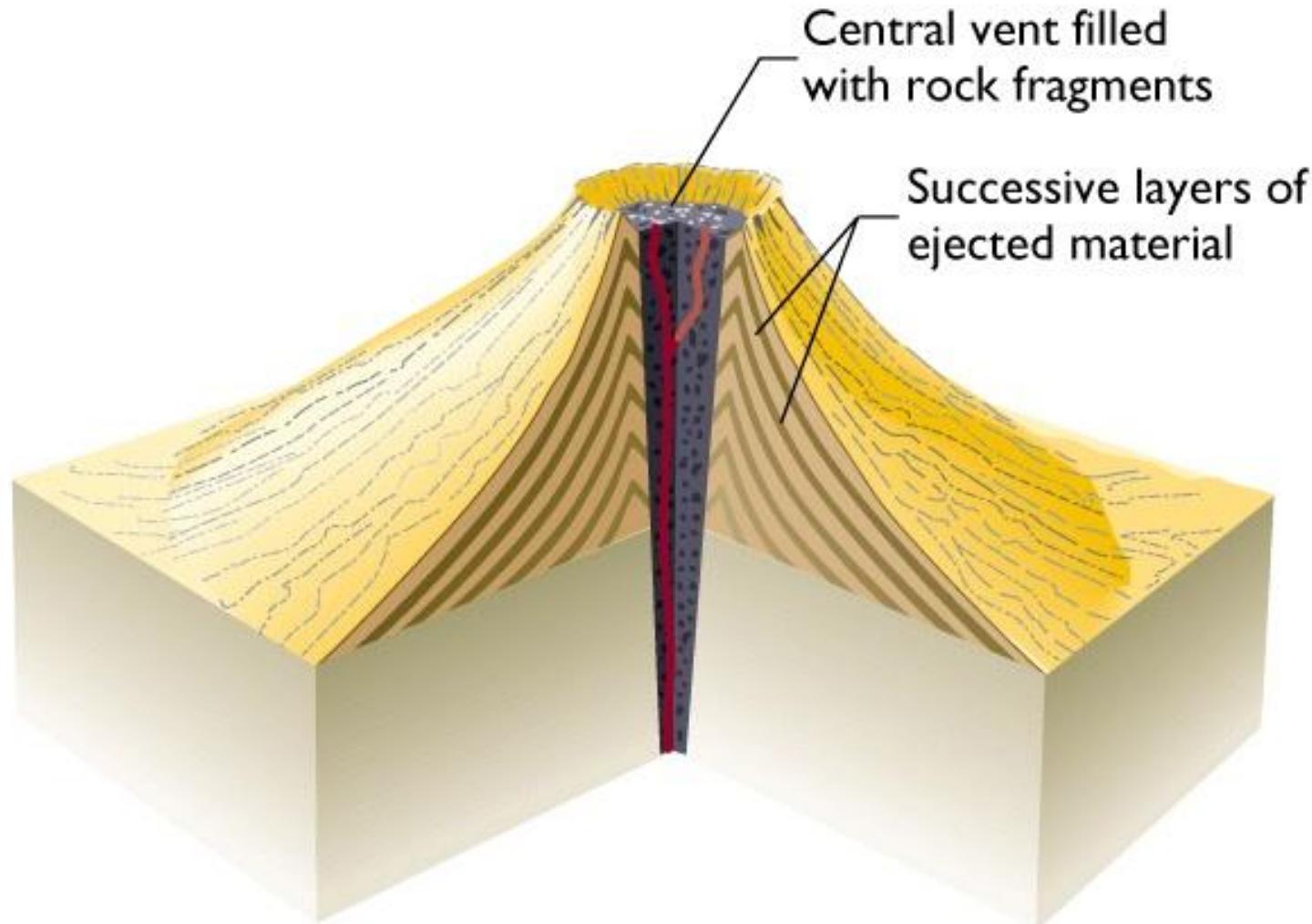


Central Eruptions

Cinder Cones

- **Formed of pyroclastics only**
- **Steep sides — ~30 degrees**
- **Short duration of activity**
- **Larger fragments near to vent form steep slopes**

Cinder Cones



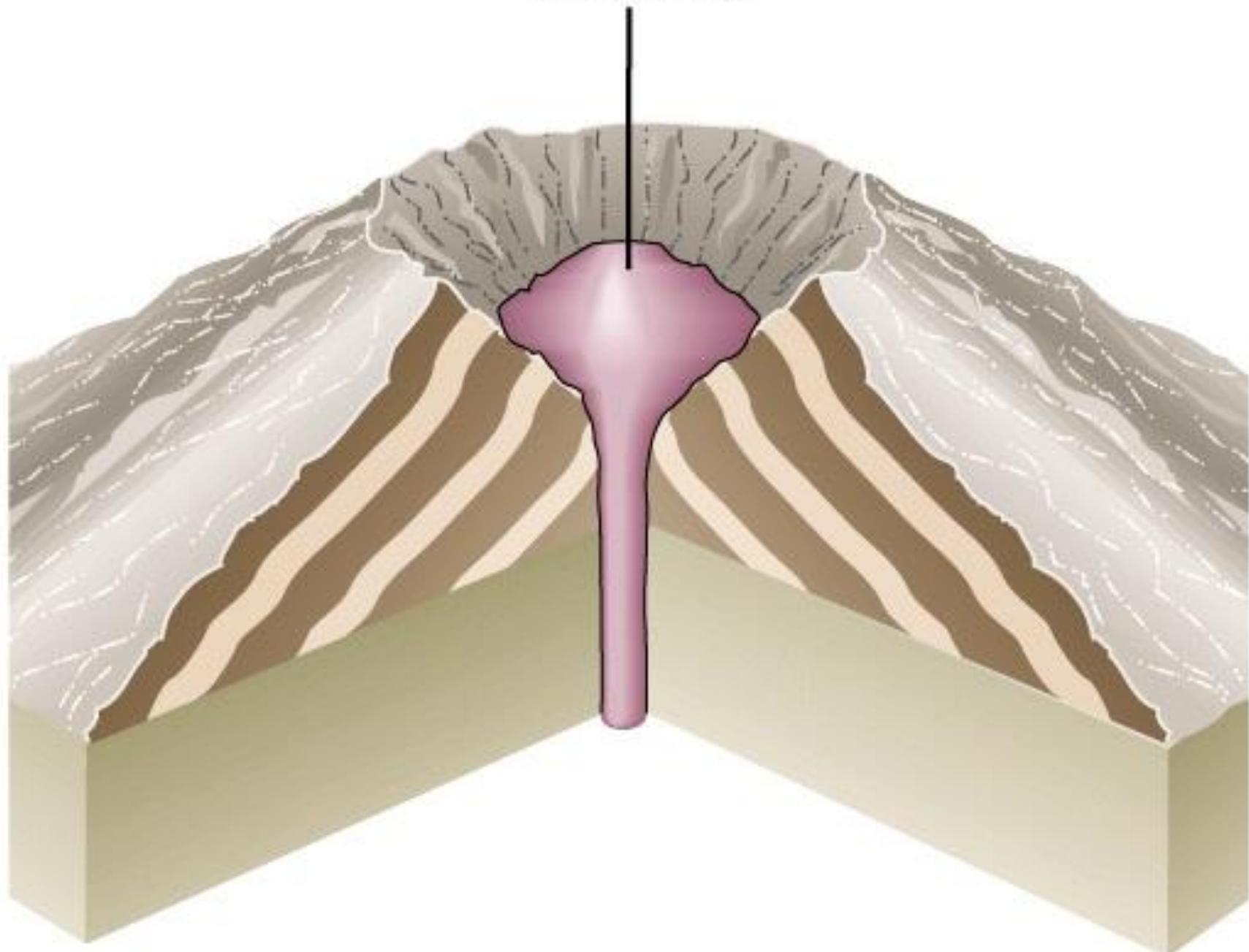


**Cerro Negro Cinder
Cone near Managua
Nicaragua in 1968**

Volcanic domes

- **Forms above a volcanic vent, a bulbous step sided mass of rock**
- **Viscous lava — usually silica-rich (or cooler magma)**
- **Associated with violent eruptions**

Lava dome





Lava
Dome

Lyn Topinka/USGS

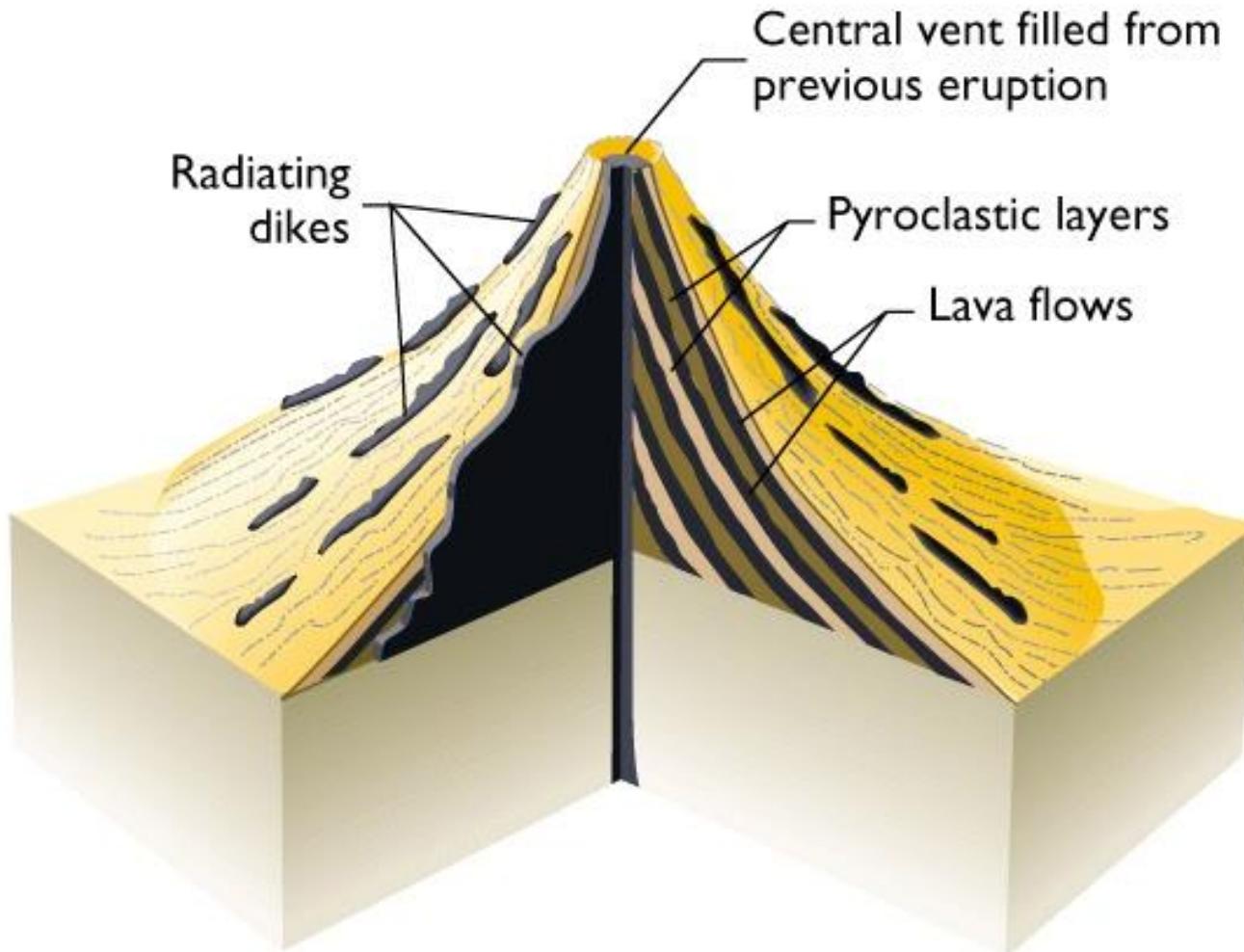
INYO OBSIDIAN DOMES-CALIFORNIA



Composite/strato Volcano

- **Alternating pyroclastic layers and lava flows**
- **Slopes intermediate in steepness**
- **Intermittent eruptions over long time span**
- **Mostly Andesite**
- **Distribution**
 - Circum-Pacific Belt (“Ring of Fire”)
 - Mediterranean Belt

Composite Volcano



MT FUJIYAMA, JAPAN



Fig. 5.15

Crater

- Bowl shape pit found at the summit of volcanic mountains



Xico volcanic crater, Mexico city

Calderas

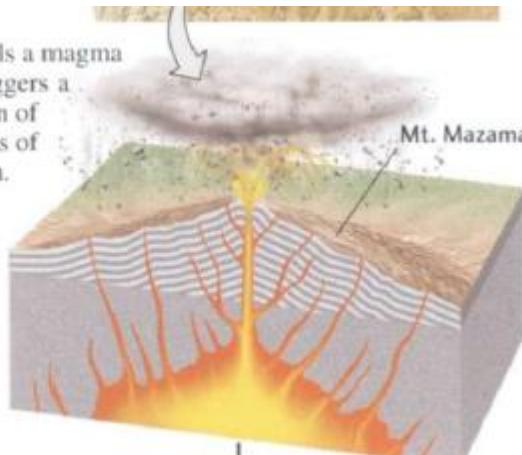
- Depression at top of volcano produced during an eruption
- Great volume of magma are discharged rapidly from a large magma chamber, the chamber can no longer support it

Calderas

Volcanic eruption

STAGE 1

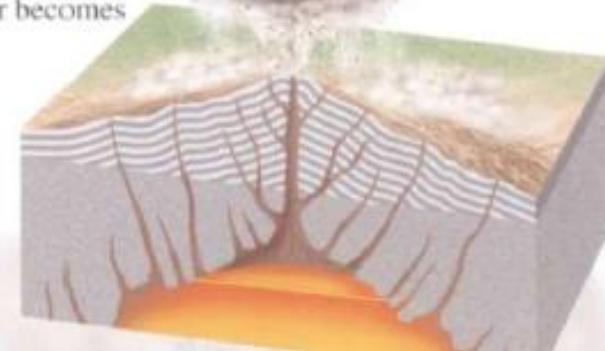
Fresh magma fills a magma chamber and triggers a volcanic eruption of lava and columns of incandescent ash.



Magma chamber gets depleted

STAGE 2

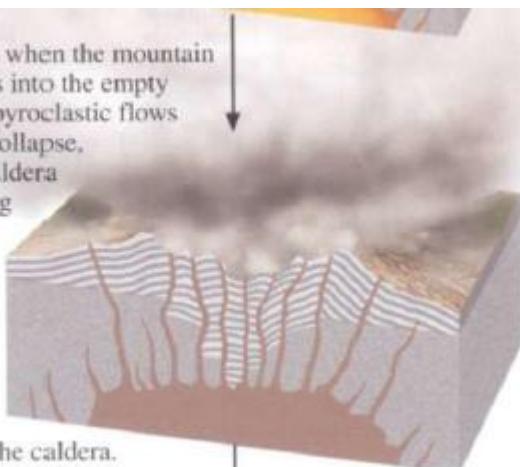
Eruption of lava and pyroclastic flows continue, and the magma chamber becomes partly depleted.



Collapse of mountain summit into empty chamber

STAGE 3

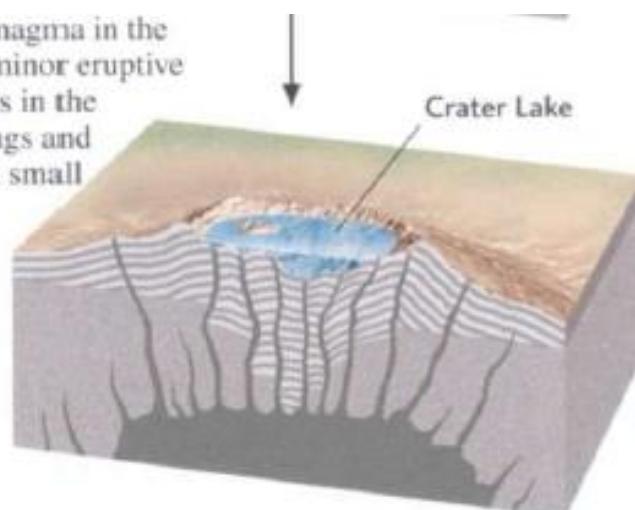
A caldera results when the mountain summit collapses into the empty chamber. Large pyroclastic flows accompany the collapse, blanketing the caldera and a surrounding area of hundreds of square kilometers.



STAGE 4

A lake forms in the caldera.

Final magma in the caldera, minor eruptive activity continues in the springs and vents. A small lake



Mt Fujiyama, Japan

Before May, 1980



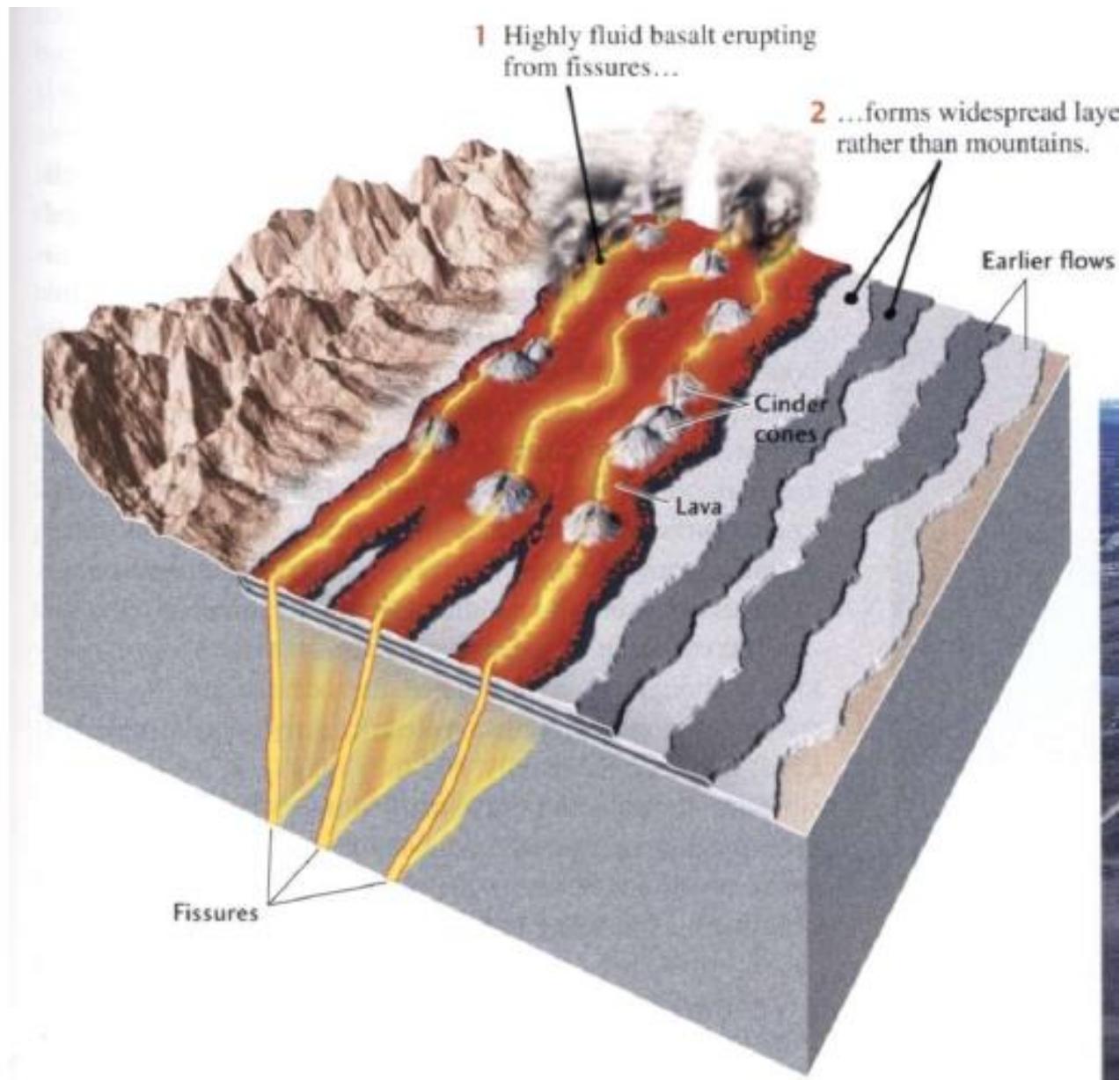
© Muench/Photo Researchers

After May, 1980



David Weintraub/Photo Researchers

Fissure type eruption



Fissure type eruption

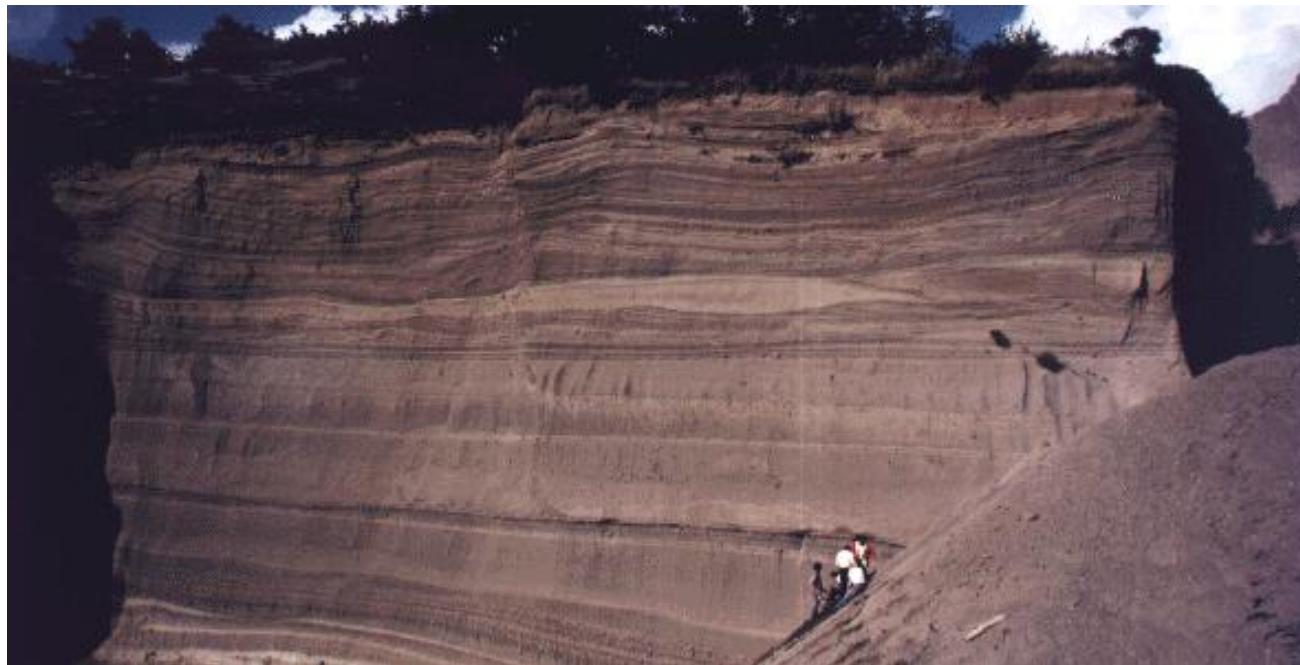
Flood basalts



Deccan basalts

Fissure type eruption

Ash flow deposits



Quarry within pyroclastic deposits of Laacher See volcano, Germany

Materials ejected from Volcanoes

Volatile material

- Steam (H_2O)
- Carbon dioxide (CO_2)
- Hydrogen sulfide (H_2S)
- Many other constituents (N, Ar, He etc)

Sulfur-encrusted fumerole: Galapagos Islands

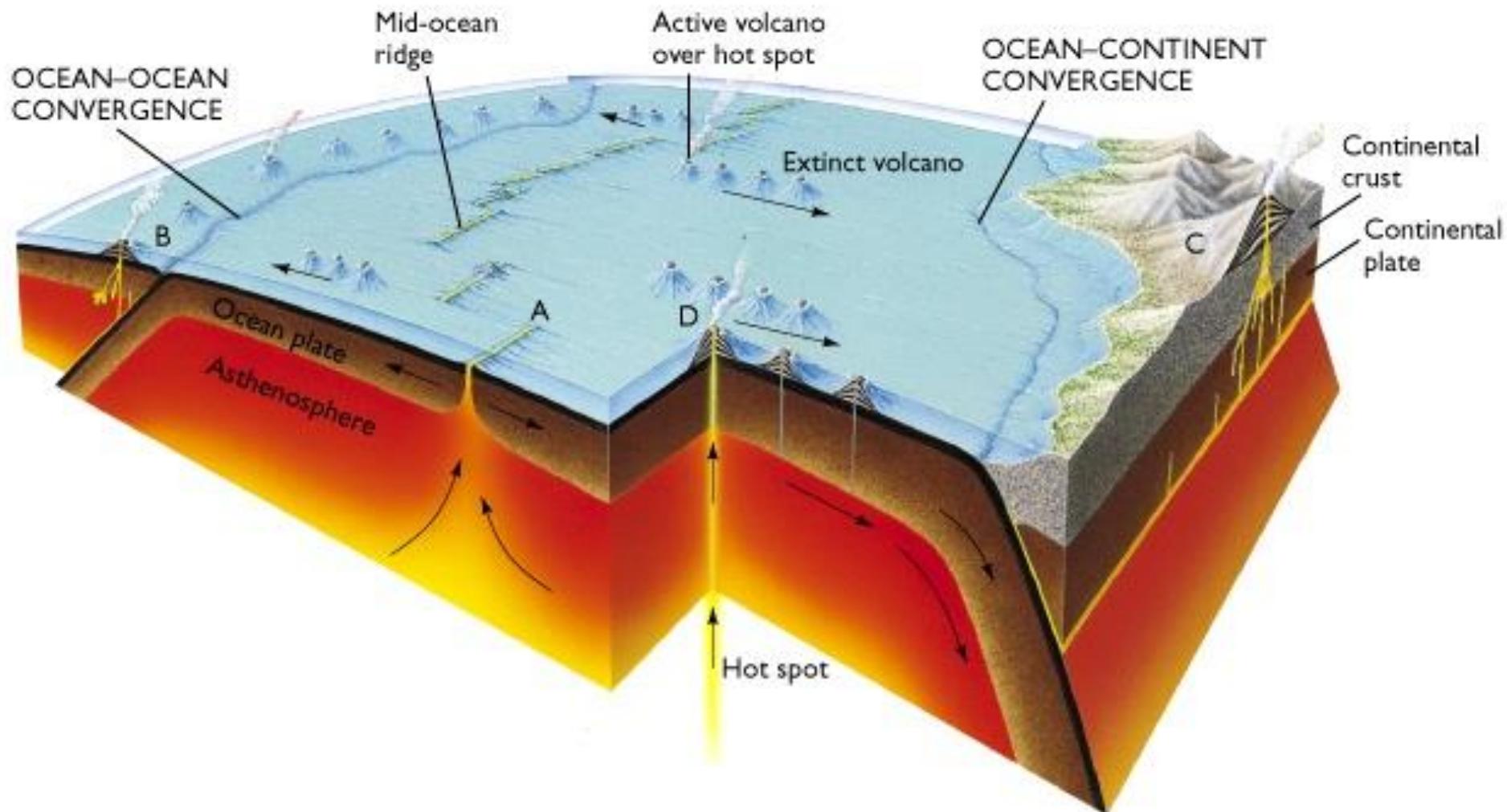


ek/Photo Researchers

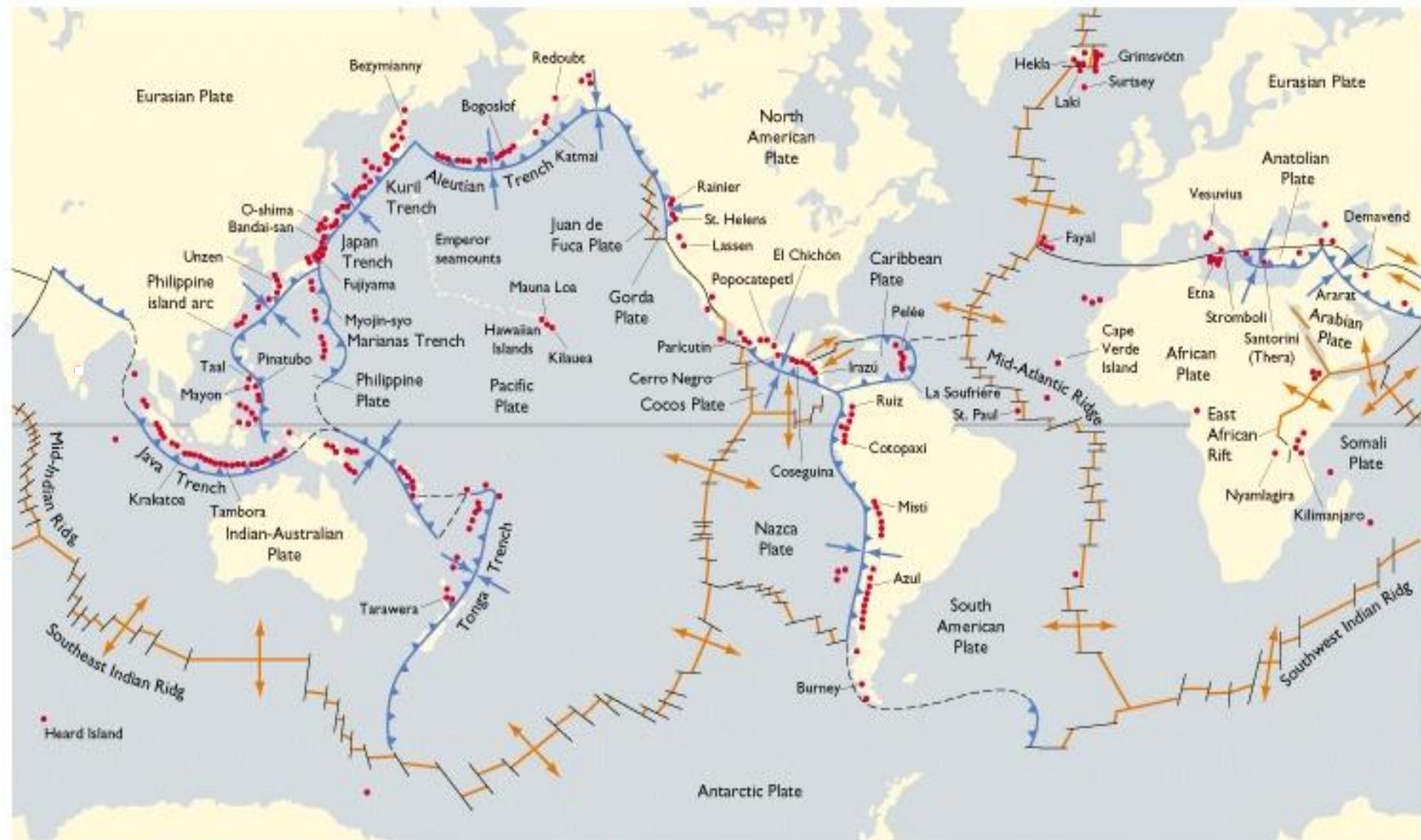
The tectonic setting of Volcanoes

- Convergent plate boundaries
- Divergent plate boundaries
- Within plate “hotspots”

The Volcanism associated with plate tectonics

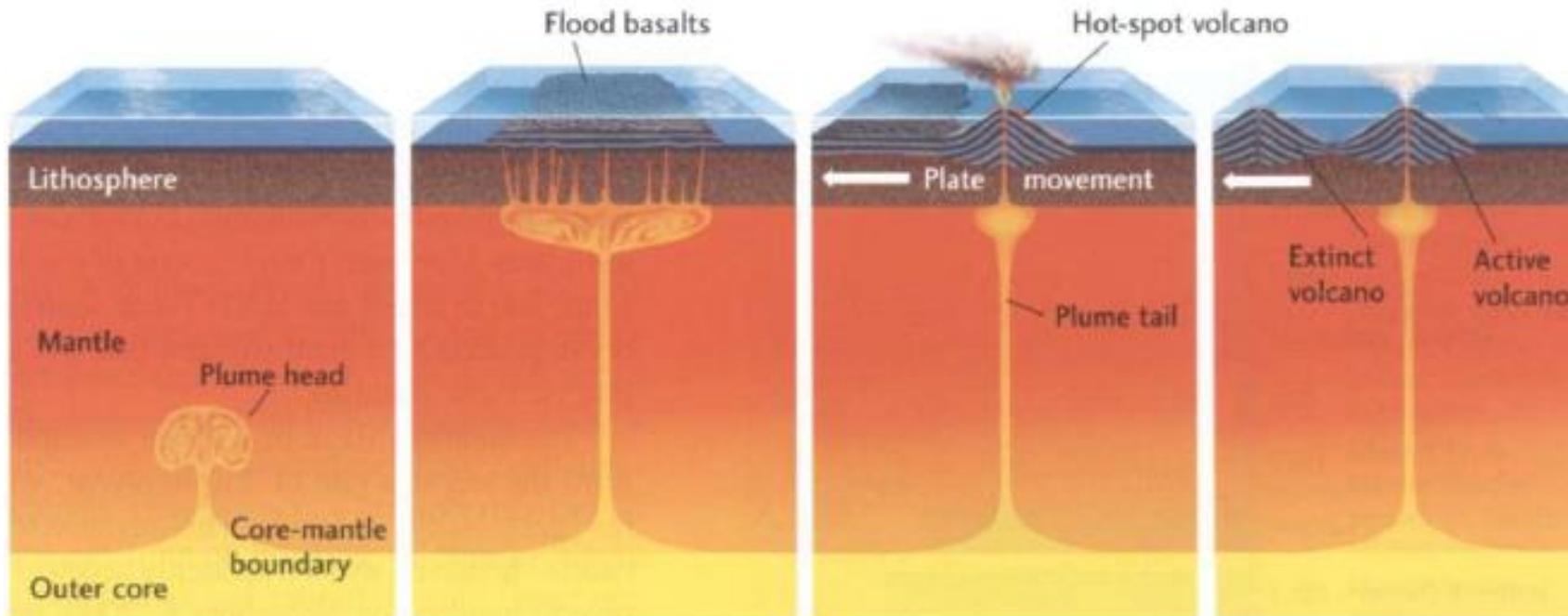


The world's active Volcanoes



Hotspots/Mantle plumes

- Arises in the core mantle boundary
- Large turbulent blob of hot materials- ‘plume head’
 - At top of the mantle the plume head generates large amount of magma



Speculative model for the formation of Hot spots