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), which move relative to each other
- This motion is what causes earthquakes and makes mountain ranges

Plate Tectonics

- Integrates evidence from many branches of science
- First suggested based on evidence from geology and paleontology
- Fully embraced after evidence from geophysics

Continental Drift

The concept that large-scale horizontal movements of the outer portions of the Earth are responsible for the major topographical features such as mountains and ocean basins.

Proposed by Alfred Wegner in 1912 based on his observation of drifting sheets of ice.

The Rejection and Acceptance of Continental Drift

- Rejected by most geologists.
- New data after WWII led to the "plate tectonic revolution" in 1960's.
- Now embraced by essentially everybody.
- Today's geology textbooks radically different than those 40 years ago.

Geographic Fit of the Continents

One of the first pieces of evidence used to argue for continental drift

Suggested that all continents were once together in a single supercontinent called Pangea

Fig. 2.1

Geology and Paleontology Matches on Opposite Sides of the Atlantic

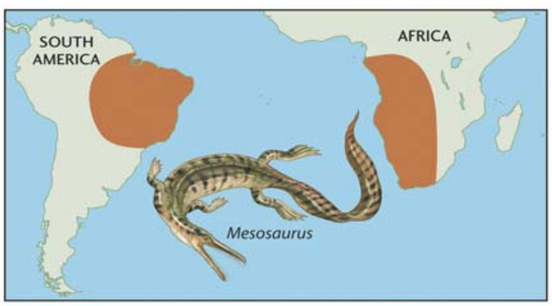


Fig. 2.2

Evidence Came from the Seafloor

- bathymetry
- age of ocean crust
- magnetic data

Fig. 2.3

Tectonics Predicts Location of Earthquakes and Volcanoes

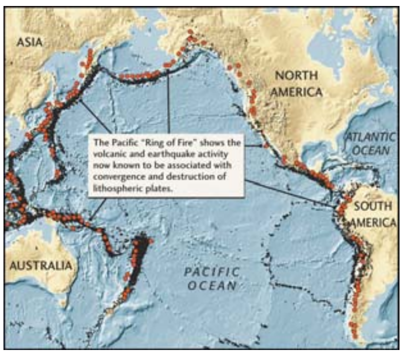


Fig. 2.4

A Mosaic of Plates

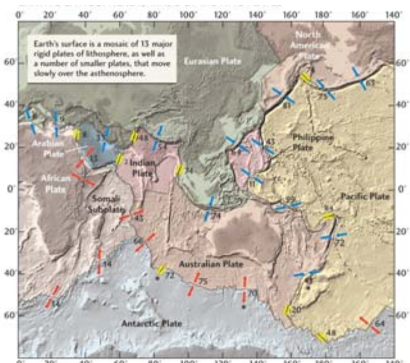


Fig. 2.5

Modern Plate Motions

- geology
- GPS measurements
- magnetic data

mm/year Fig. 2.5

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 top of the asthenosphere

Plates

- Group of rocks all moving in the same direction
- Can have *both* oceanic and continental crust or just one kind.

Three Types of Plate Boundaries

Transform Divergent Convergent

Divergent Plate Boundary

Usually start within continents— grows to become ocean basin

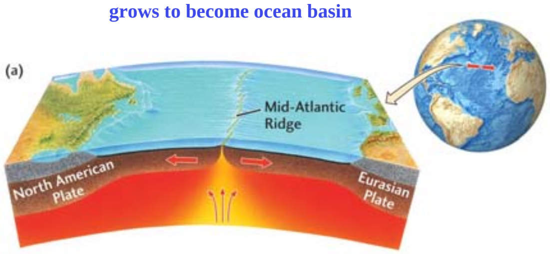


Fig. 2.6

Divergent Plate Boundary

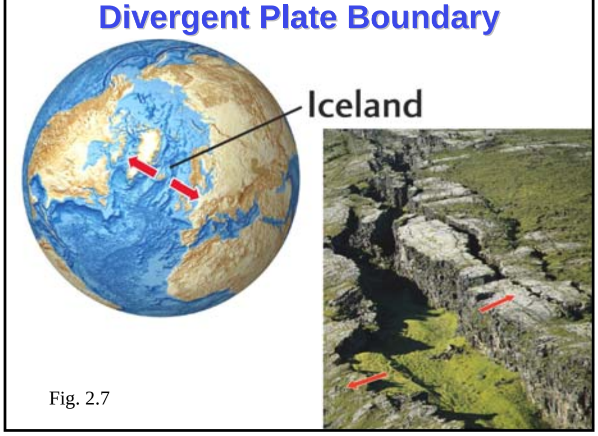


Fig. 2.7

Continental Rifts

- East Africa, Rio Grande rift
- Beginning of ocean formation although it may not get that far

Divergent Plate Boundary

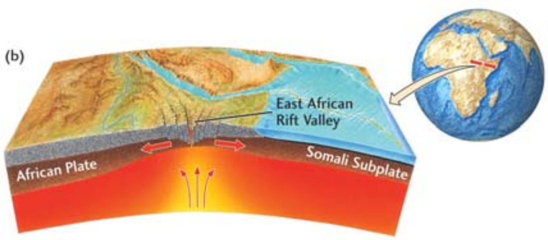


Fig. 2.6

Divergent Plate Boundaries

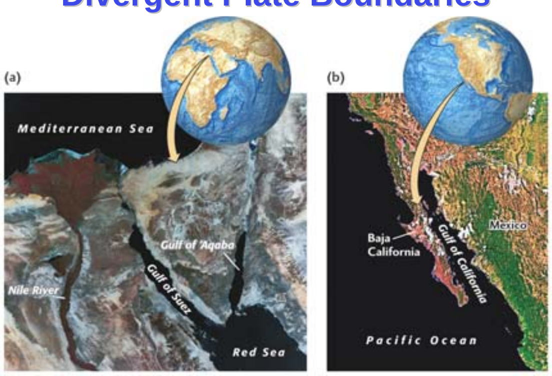


Fig. 2.8

Convergent Boundaries

- **Relative densities are important:**

  continental crust ≈ 2.8 g/cm^3

  oceanic crust ≈ 3.2 g/cm^3

  asthenosphere ≈ 3.3 g/cm^3

Is the Earth Expanding?

- **New crust created at Mid-ocean ridge—old crust destroyed (recycled) at subduction zones**
- **The Earth is maintaining a constant diameter.**

Convergent Boundaries

Three types:

ocean–ocean	***Japan***
ocean–continent	***Andes***
continent–continent	***Himalaya***

Ocean–Ocean

Island arcs:

- Tectonic belts of high seismicity
- High heat flow arc of active volcanoes
- Bordered by a submarine trench

Convergent plate boundary

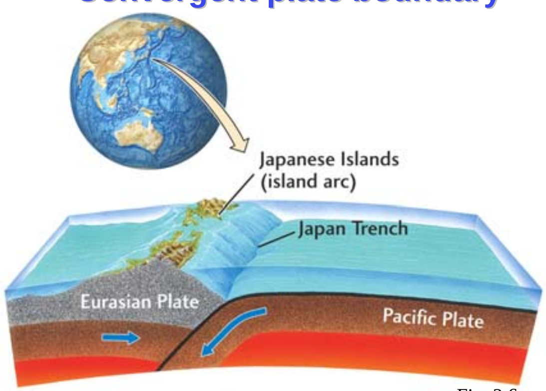


Fig. 2.6

Ocean–Continent

Continental arcs:

- Active volcanoes
- Often accompanied by compression of upper crust

Convergent Plate Boundary

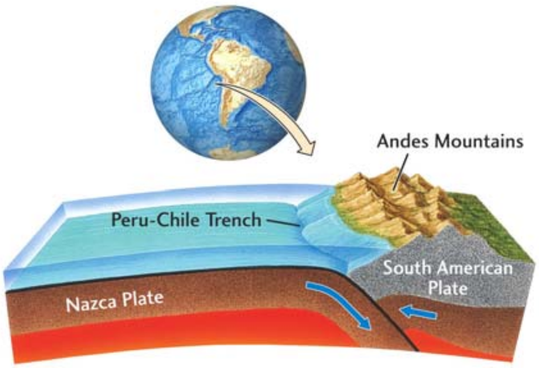


Fig. 2.6

Continent–Continent

- In ocean–continent boundaries, collision convergence is taken up by subduction
- In continent–continent boundaries, convergence is accommodated by deformation of the crust without subduction (both plates are too buoyant to be subducted)

Convergent Boundaries
Continent-Continent Convergence

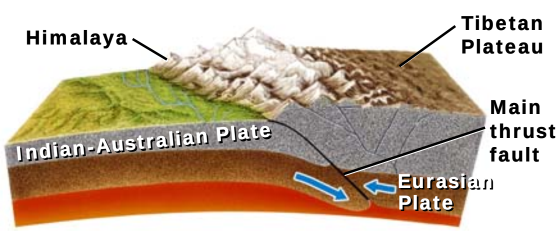


Fig. 2.6

Transform Plate Boundary

Fig. 2.9

Transform-Fault Boundaries

Mid-Ocean Ridge Transform Fault

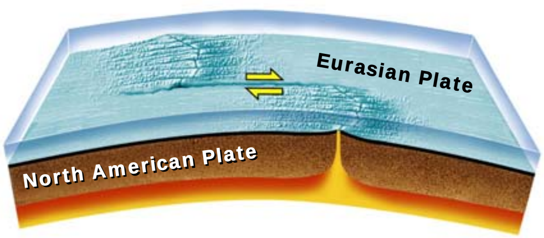


Fig. 2.6

The Seafloor as a Magnetic Tape Recorder

- During and after WWII, it was noticed that the magnetic field near the ocean floor exhibited significant variation.
- Subsequent analysis shows that the changes in the rocks reflect changes in the Earth's magnetic field over time.

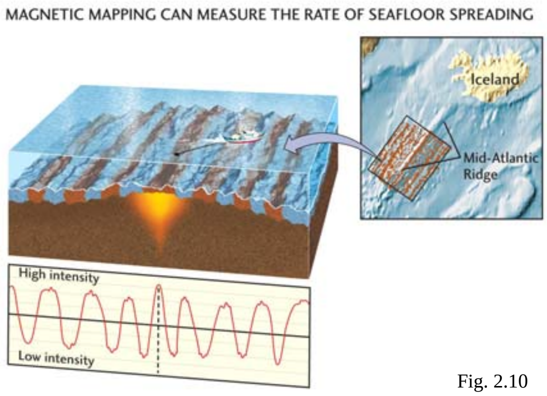


Fig. 2.10

Magnetic Reversals in a Single Volcano

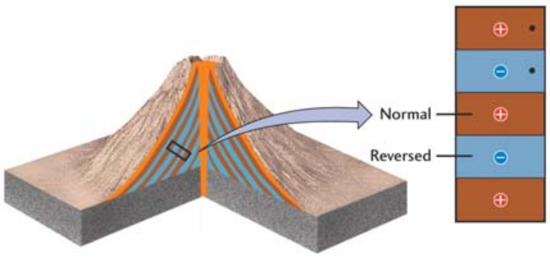


Fig. 2.10

The Magnetic Record

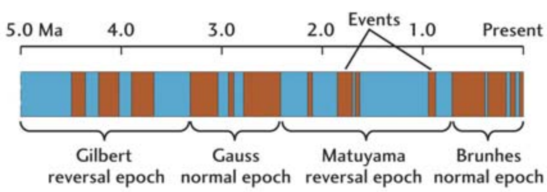


Fig. 2.10

Magnetic Reversals at Mid-ocean Ridges

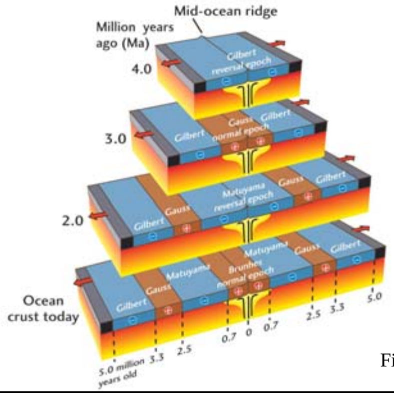


Fig. 2.10

Magnetic Age of the Oceans

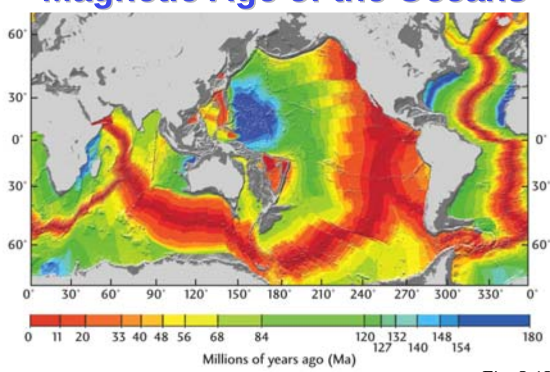


Fig. 2.12

Modern Plate Motions

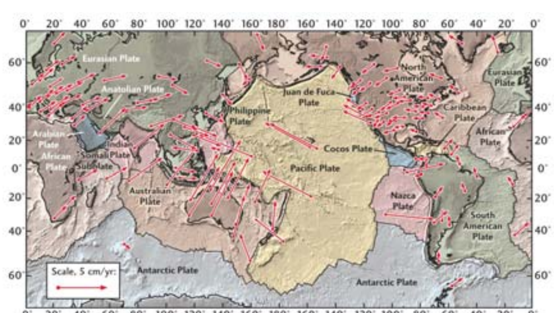


Fig. 2.13

Rates of Plate Motion

Mostly obtained from magnetic anomalies on seafloor.

Fast spreading: 10 cm/year

Slow spreading: 3 cm/year

Middle Ordovician, 458 Ma

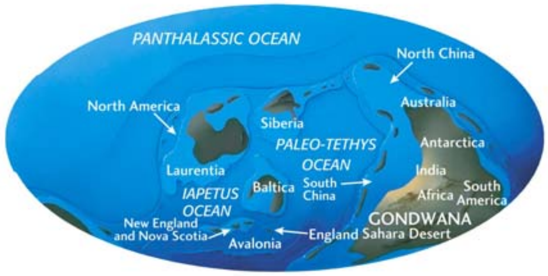


Fig. 2.13

Early Devonian, 390 Ma

Fig. 2.13

Fig. 2.13

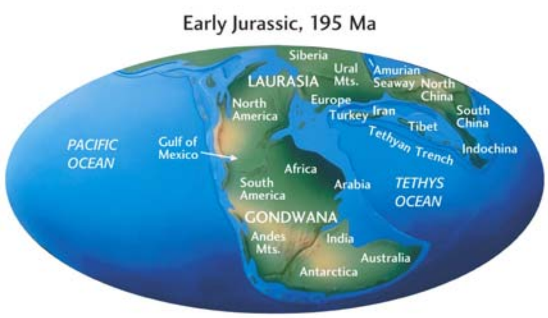


Fig. 2.13

Fig. 2.13

Late Cretaceous, Early Tertiary, 66 Ma

Fig. 2.13

MODERN WORLD

Fig. 2.13

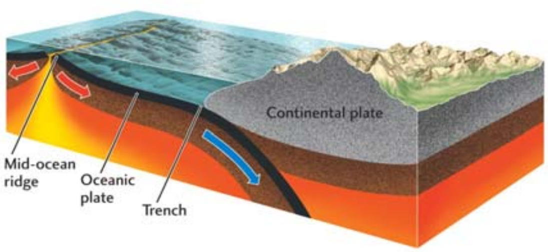
50 million years in the future

Fig. 2.13

Driving Mechanism of Plate Tectonics

- Thought to be convection of the mantle.
- Convection may have overturned asthenosphere 4–6 times.

Ridge Push and Trench Pull



Hot-spot Volcanism

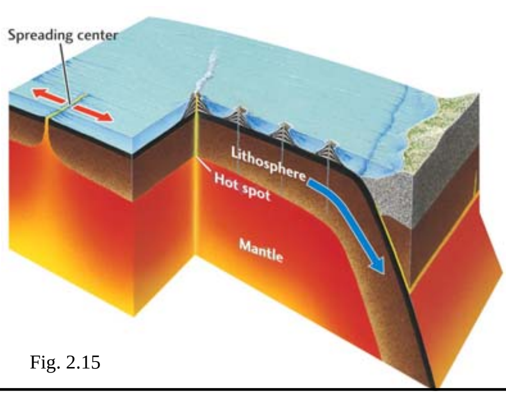


Fig. 2.15