

## Plate Tectonics: Big Ideas

- Our understanding of Earth is continuously refined.
- Earth's systems are dynamic; they continually react to changing influences from geological, hydrological, physical, chemical, and biological processes.
- Over Earth's vast history, both gradual and catastrophic processes have produced enormous changes

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## 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

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## Plate Tectonics

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

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## 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.*

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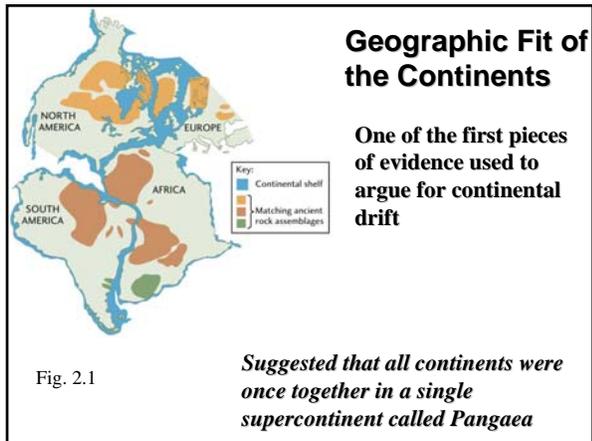
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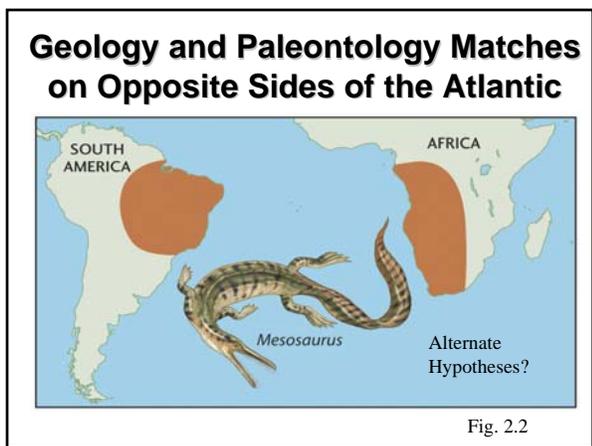
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## The Rejection and Acceptance of Continental Drift

- Rejected by most geologists.
  - Mechanism
  - Rates
- 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.

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## Evidence Came from the Seafloor



- bathymetry
- age of ocean crust
- magnetic data

Fig. 2.3

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## Tectonics Predicts Location of Earthquakes and Volcanoes

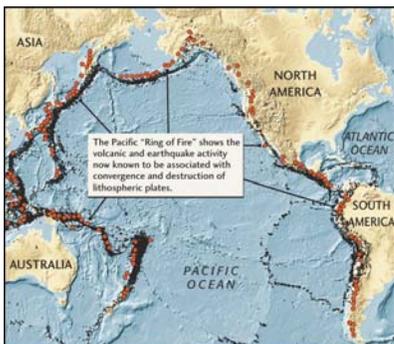


Fig. 2.4

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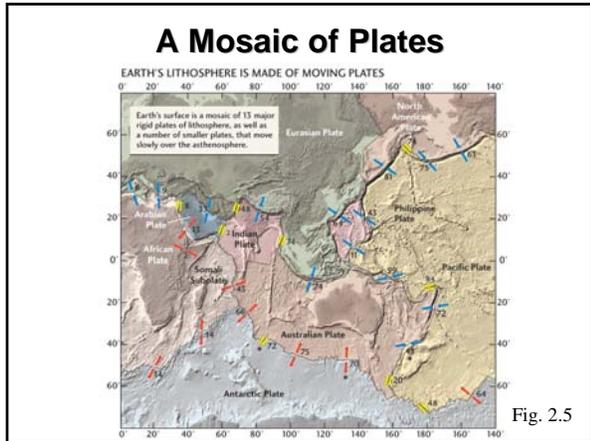
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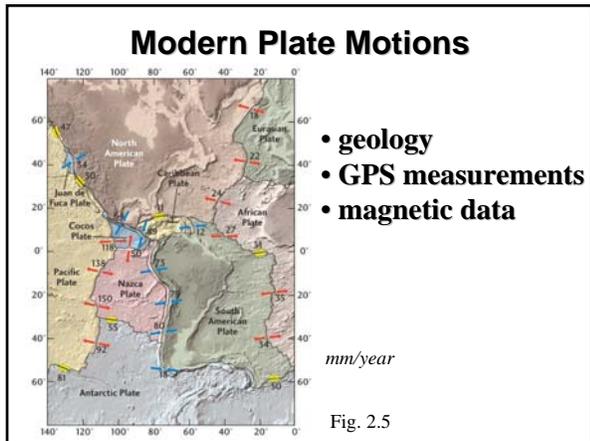
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### Plate Tectonics

- 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

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## Plates

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

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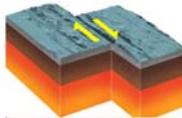
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## Three Types of Plate Boundaries

Transform

Divergent

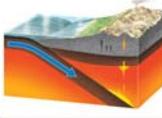
Convergent



At transform-fault boundaries, plates slide horizontally past each other.



At divergent boundaries, plates move apart and create new lithosphere.



At convergent boundaries, plates collide and one is pulled into the mantle and recycled.

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## Divergent Plate Boundary

Usually start within continents—  
grows to become ocean basin

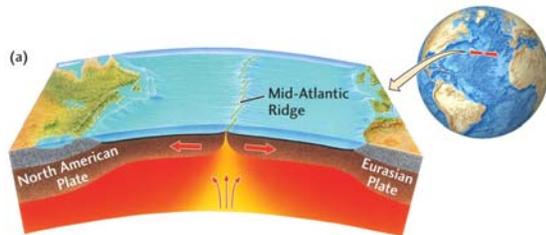


Fig. 2.6

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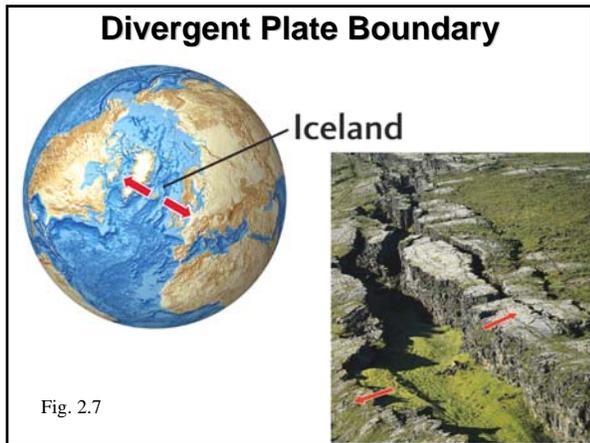
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### Continental Rifts

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

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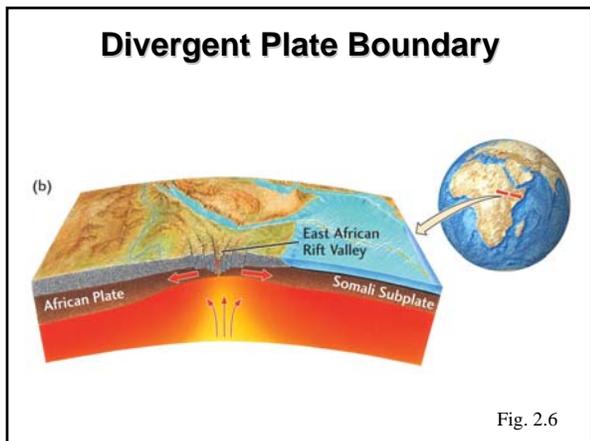
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## Divergent Plate Boundaries

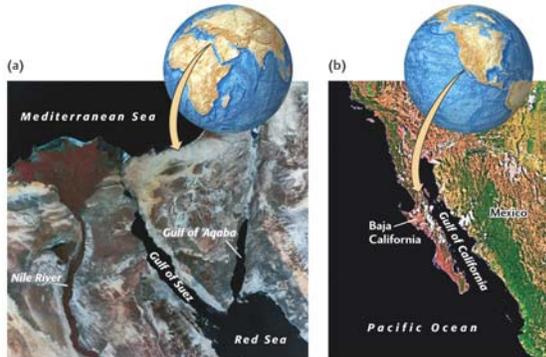


Fig. 2.8

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## Convergent Boundaries

- Relative densities are important:
  - continental crust  $\approx 2.8 \text{ g/cm}^3$
  - oceanic crust  $\approx 3.2 \text{ g/cm}^3$
  - asthenosphere  $\approx 3.3 \text{ g/cm}^3$



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## 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.

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## Convergent Boundaries

Three types:

ocean–ocean	<i>Japan</i>
ocean–continent	<i>Andes</i>
continent–continent	<i>Himalaya</i>

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## Ocean–Ocean

Island arcs:

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

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## Convergent plate boundary

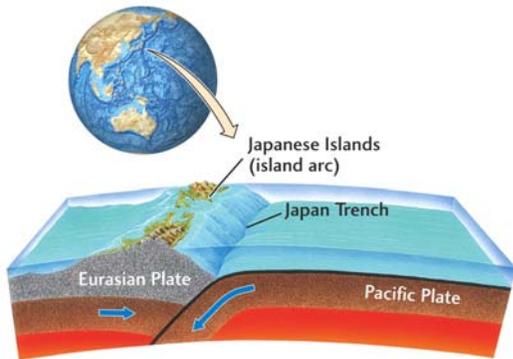


Fig. 2.6

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## Ocean–Continent

Continental arcs:

- Active volcanoes
- Often accompanied by compression of upper crust

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## Convergent Plate Boundary



Fig. 2.6

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## 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)

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**Convergent Boundaries**  
Continent-Continent Convergence

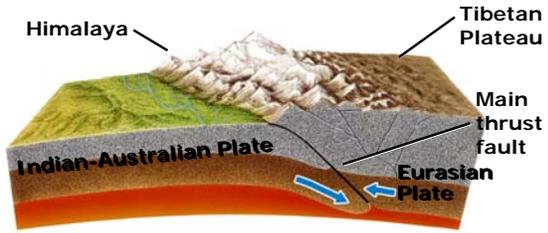


Fig. 2.6

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**Transform Plate Boundary**



Fig. 2.9

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**Transform-Fault Boundaries**  
Mid-Ocean Ridge Transform Fault

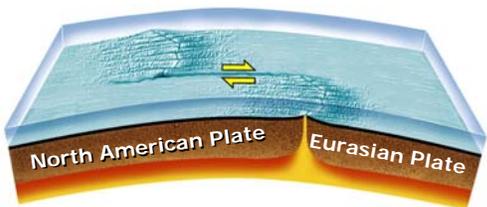


Fig. 2.6

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## 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.

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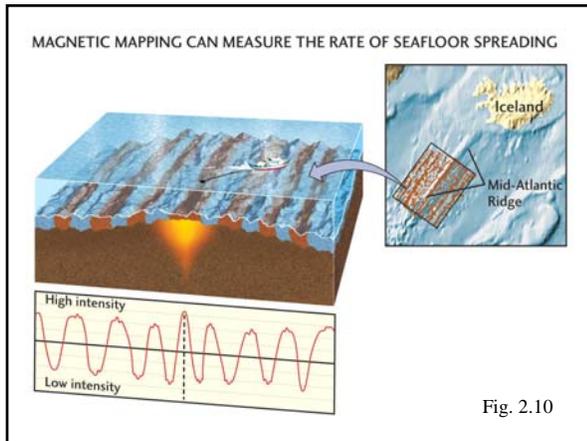
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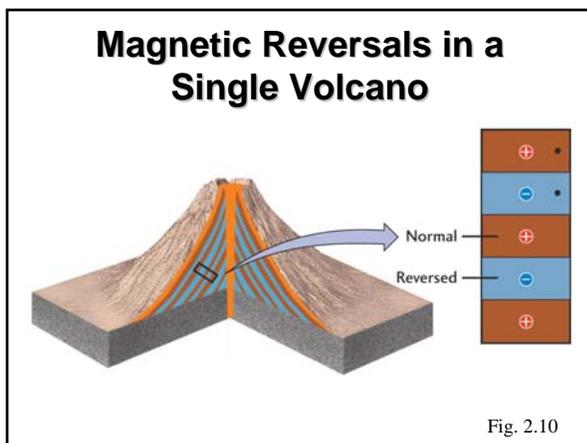
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## The Magnetic Record

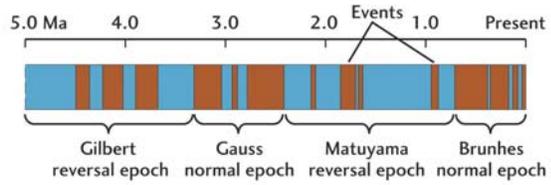


Fig. 2.10

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## Magnetic Reversals at Mid-ocean Ridges

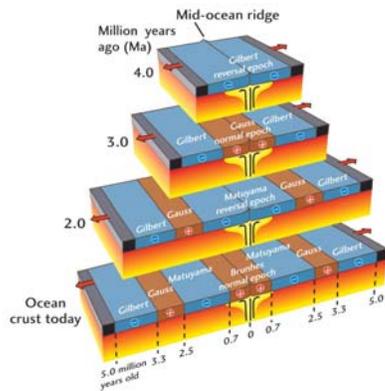


Fig. 2.10

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## Magnetic Age of the Oceans

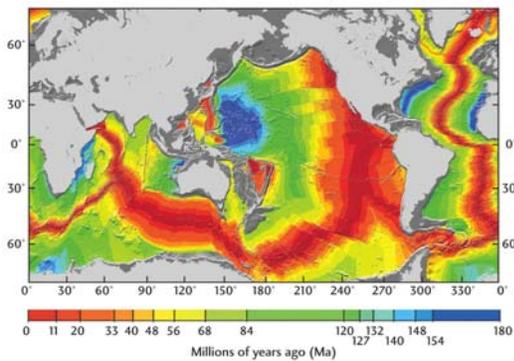


Fig. 2.12

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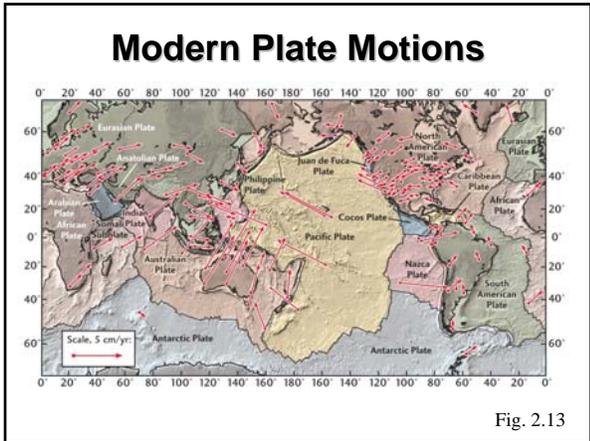
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### Rates of Plate Motion

Mostly obtained from magnetic anomalies on seafloor.

Fast spreading: 10 cm/year

Slow spreading: 3 cm/year

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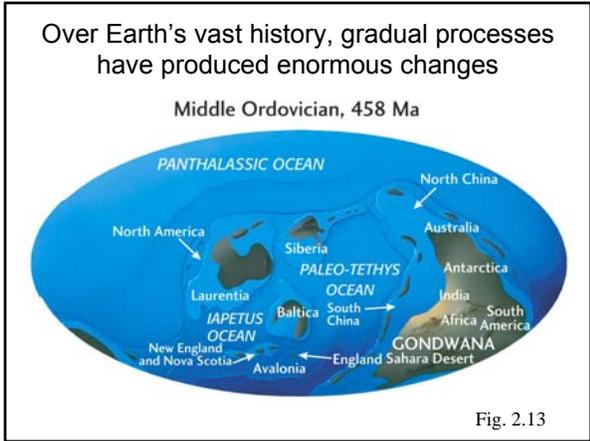
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Over Earth's vast history, gradual processes have produced enormous changes

Early Devonian, 390 Ma



Fig. 2.13

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Over Earth's vast history, gradual processes have produced enormous changes

PANGAEA  
Early Triassic, 237 Ma



Fig. 2.13

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Over Earth's vast history, gradual processes have produced enormous changes

Early Jurassic, 195 Ma



Fig. 2.13

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Over Earth's vast history, gradual processes have produced enormous changes

Late Jurassic, 152 Ma



Fig. 2.13

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Over Earth's vast history, gradual processes have produced enormous changes

Late Cretaceous, Early Tertiary, 66 Ma



Fig. 2.13

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Over Earth's vast history, gradual processes have produced enormous changes

MODERN WORLD



Fig. 2.13

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Over Earth's vast history, gradual processes have produced enormous changes

50 million years in the future



Fig. 2.13

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### Driving Mechanism of Plate Tectonics

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

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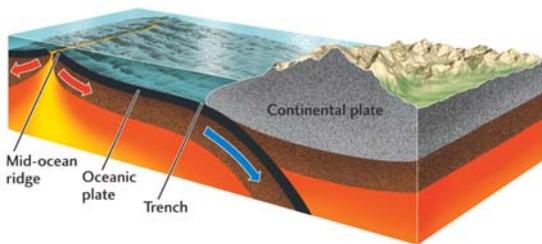
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### Ridge Push and Trench Pull



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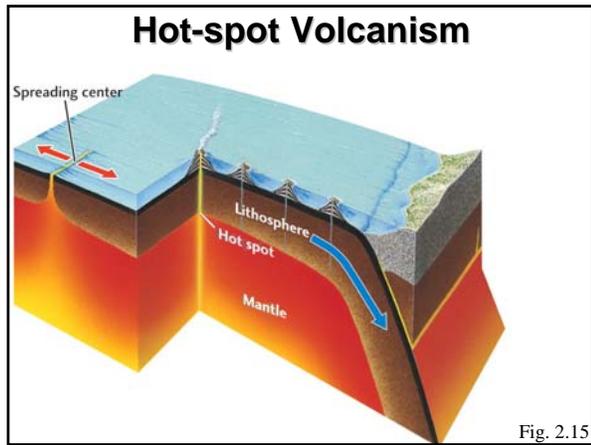
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