Internal processes: Terra firma?

Reading:
This week: Ch 3
Next week: Ch 4

Plate tectonics: Toward a unifying theory

Plate tectonics: Recognizes that rigid plates are moving across the Earth's surface.

A unifying theory: A single theory that explains a large body of evidence.

Why did it come so late (1960s)?
The idea was around long before substantial evidence
Toward plate tectonics:
A continental jigsaw

1620: Francis Bacon
Africa and South America
fit together

1655: Antonio Snider
Published a sketch

Mid 1800's:
First proposed that
continents did fit
together

Toward plate tectonics:
Glacial striations
Glacial evidence in the tropics!

Also, coal deposits in Antarctica
1912: Alfred Wegener - Continental Drift

**1. Similar fossils:** N America and Europe, S America and Africa

*Glossopteris* and *Mesosaurus*

**2. Similar rock formations across boundaries**

*Conclusion:* There used to be a supercontinent - Pangaea

**Toward plate tectonics:**

Flora and fauna

1928: Arthur Holmes

Proposed that thermal convection in the mantle could be the driving force for plate tectonics.

However, this was a speculative idea. There was no observational evidence supporting mantle convection.
Toward plate tectonics:

Skeptic's

Wegener's ideas were only discussed for a decade and then dropped.

• The coastlines don't match perfectly
• Were the rock formations really the same?

Alternative: land bridges between the continents could explain the fossil record

Environmental Geology – Terra firma?

Toward plate tectonics:

Bathymetry

Environmental Geology – Terra firma?
Toward plate tectonics: Magnetic stripes

Figure 20.3 Magnetic anomaly pattern found in an oceanographic survey over the Reykjanes Ridge, a part of the Mid-Atlantic Ridge southwest of Iceland. The spaces between the colored bands show where the survey ship found negative magnetic anomalies corresponding to rock formations on the seafloor that are reversely magnetized. The bands shown in color indicate where the ship found positive anomalies. The rocks below the colored bands are magnetized in the normal direction, that is, similar to the present-day direction. The almost perfect symmetry of this pattern with respect to the ridge axis puzzled geologists. When the pattern was explained (see Figure 20.1f), it provided strong support for the concept of seafloor spreading.

The Earth’s magnet

Figure 19.11 Left: The magnetic field of a bar magnet is revealed by the alignment of iron filings on paper (from POE: Physics, Ed. by E. L. Leighton, MA: C. E. Merrill, 1964.) Right: Earth’s magnetic field is much like the field that would be produced if a giant bar magnet were placed at the Earth’s center and slightly inclined (11°) from the axis of rotation. Lines of magnetic force produced by such a bar magnet are shown. A compass needle points to the north magnetic pole because it orients in the direction of the local line of force.

...and magnetic rocks
Magnetic volcanoes

Figure 19.14  Lava beds become magnetized in the direction of the Earth’s magnetic field existing at the time the beds solidified and cooled. In this way, they preserve the record of reversals of Earth’s magnetic field. The modern flow at the top shows the direction of the field today. Underlying beds record the directions of ancient fields.

Toward plate tectonics: Seafloor spreading?

Figure 19.10  Pairs of magnetic bands form successively as each new piece of seafloor is intruded, cooled, and becomes magnetized in the normal or reversed direction of the magnetic field existing at that time. As plate separation continues, the newly magnetized crust is pushed out on both sides and gradually moves outward with the separating plates. The pattern of normal (+) and reversed (−) magnetic bands on the seafloor follows the succession of magnetic reversals over time worked out on land (compare with Figure 19.16).
Toward plate tectonics:
Seafloor age

Identifying the plates

Environmental Geology - Terra firma?
Toward plate tectonics:
Subduction at the trenches
Toward plate tectonics:
Identifying the plates

Plate tectonics:
Reconstructing plate motion

The magnetic tape recorder:
Given the oceanic record we can wind back the plates to see how the plates have been moving.
This shows us how Pangaea broke up.
Plate tectonics:
Continental magnetization

Rocks formed 45 million years ago indicate pole position relative to continent at that time (red arrow).

Recently formed rocks "point to" modern pole; older rocks preserve their older magnetic orientation.

By 25 million years ago, when these rocks formed, continent had drifted to here; these rocks show a different relative pole position.

At 15 million years ago, continent was in yet a different spot on the globe.

Plate tectonics:
Plate motion further back in time

Apparent pole, 15 million years ago

MAGNETIC POLE

Polar-wander curve for this continent over last 45 million years

Current position of continent

Apparent pole, 25 million years ago

Apparent relative pole position, 45 million years ago
Plate tectonics:
The formation of Pangaea

When we add the continental plate motion recoded we can extend plate reconstruction back beyond 200Ma
i.e. prior to the break-up of Pangaea

Plate tectonics:
The unifying theory

Plate tectonics: Recognizes that rigid plates are moving across the Earth’s surface.
A unifying theory: A single theory that explains a large body of evidence.

Other examples:
Physics - theory of relativity
Chemistry - nature of a chemical bond
Astrophysics - the Big Bang
Biology - DNA
Geology - plate tectonics
Earth’s interior: Properties of geological materials

How can plates move across the Earth’s surface?

The Earth is not a rigid solid, but a plastic solid.

Earth’s interior: Stress and strain

Earth's interior: Stress-strain diagram

Stress-strain diagram showing the behavior of rocks under stress, including elastic limit, plastic deformation, rupture, brittle behavior, and ductile flow.

Earth's interior: Brittle and ductile rocks

Brittle failure and ductile flow examples.
Earth's interior: An overview

- **Crust**
- **Mantle**
- **Mesosphere**
- **Lithosphere**
- **Asthenoosphere**

**Key Points**

- Temperature and pressure increase with depth.
- Mesosphere: hot but stronger due to high pressure.
- Asthenosphere: hot, weak, plastic.
- Lithosphere: cool, rigid, brittle.

Vertical scale is 10x the horizontal scale. Continental crust thickness greatly exaggerated.