Environmental Geology – Terra firma?

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
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Toward plate tectonics: Flora and fauna

1912: Alfred Wegener – Continental Drift

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

2. Similar rock formations across boundaries
   Conclusion: There used to be a supercontinent - Pangaea

Toward plate tectonics: Skeptics

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

Toward plate tectonics: Mantle convection?

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: Bathymetry
QUESTION

**Toward plate tectonics:**

**Magnetic stripes**

![Image of magnetic anomaly pattern](image)

**Figure 20.5** Magnetic anomaly pattern found in a magnetographic survey over the Mid-Atlantic Ridge axis. Left, The open space between the colored bands shows where the survey ship found negative magnetic anomalies corresponding to rock that was magnetically reversed at the time it cooled. Right, The bands are color-coded to show the age of the rocks that formed at the mid-ocean ridge. The colored bands on this map are reverse magnetic polarity (RP) intervals. The colored bands are continuous across the mid-ocean ridge, which supports the model of the ocean floor spreading. (After Worzel et al., 1967.)

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**The Earth's magnet**

![Image of Earth's magnetic field](image)

**Figure 20.8** Left, The magnetic field of the Earth is caused by the alignment of iron filings on paper. Center, A compass needle pointing north. Right, Earth's magnetic field is such that if a compass needle were placed at the Earth's center and slightly inclined 15° 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 is oriented in the direction of the Earth's field of force.

...and magnetic rocks

**Magnetic volcanoes**

![Image of magnetic field and lava beds](image)

**Figure 21.4** Lava beds become magnetized in the direction of the Earth's magnetic field existing at the time the lava solidified and cooled. In this way, they preserve the record of reversals of Earth's magnetic field. The modern field at the top shows the direction of the field today. Underlying beds record the directions of ancient fields.

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**Toward plate tectonics:**

**Seafloor spreading?**

![Image of seafloor spreading model](image)

**Figure 20.30** Result of superposition seen here successively as each new sheet of seafloor is added, rocks, and becomes magnetized in the normal or reverse direction. We can see this pattern successively as we move farther back in time. As plate separation continues, the newly magnetized crust is pulled out on both sides and gradually moves away from the spreading center. The pattern of normal (N) and reversed (R) magnetic bands on the middle floor shows the sequence of crust that has formed at the center and the age of the seafloor accordingly.

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Toward plate tectonics:
Seafloor age

Toward plate tectonics:
Identifying the plates

Toward plate tectonics:
Subduction at the trenches

Toward plate tectonics:
Subduction at the trenches
Plate tectonics:

**Identifying the plates**

Toward 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:

**Plate motion further back in time**

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.

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

By 25 million years ago, when these rocks formed, continent had drifted to here; these rocks show a different relative pole position.
Plate tectonics: The formation of Pangaea

When we add the continental plate motion recorded 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

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Earth’s interior:
Stress-strain diagram

- Elastic limit
- Plastic deformation
- Rupture

Brittle and ductile rocks

Brittle failure
Ductile flow

Earth’s interior:
An overview

- Oceansic crust
- Continental crust
- Mantle
- Outer core
- Inner core

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