



1  **Plate Tectonics**

Earth, 9th edition – Chapter 2

2  **Plate Tectonics: summary in haiku form**


Alfred Wegener
gave us Continental Drift.
Fifty years later...

3  **Key Concepts**


- Wegener's hypothesis of "continental drift" and the breakup of a former supercontinent (Pangaea).
- Paleomagnetism and Hess' hypothesis of "seafloor spreading."
- Supporting evidence for the plate tectonics model – effective confirmation of Wegener and Hess.
- Fundamental components of the plate tectonics model.

4  **Key Concepts (continued)**


- Components and processes of divergent plate margins.
- Components and processes of convergent plate margins.
- Components and processes of transform plate margins.
- Driving mechanisms for plate tectonics: Mantle convection models.

5  **Continental Drift –
an idea before its time**


- Alfred Wegener
 - First proposed his continental drift hypothesis in 1915
 - Published *The Origin of Continents and Oceans*
 - *some ideas in the publication were:*
 1. A "supercontinent" named Pangaea
 2. southern section: named Gondwana or Gondwanaland
 3. northern section: Laurasia
 4. the supercontinent broke in pieces about 200 million years ago

6  **Pangaea approximately 200 million years ago**

7  **Pangaea Breakup**

8  **Continental Drift –
an idea before its time**

- Continental drift hypothesis
 - Continents "drifted" to present positions
- Evidence used in support of continental drift hypothesis:
 - Fit of the continents
 - Fossil evidence
 - Rock type and structural similarities
 - Paleoclimatic evidence

9  **Evidence for Continental Drift**





















- Continental fit
 - Continental crust matches oceanic crust at the continental slope

10  **Fossil evidence**

- The same fossils are found in both South America and Africa
- Fresh water fish cannot migrate through oceans
- Swamp evidence is found in Antarctica

11  **Fossil evidence**

- The same fossils are found in both South America and Africa
- Fresh water fish cannot migrate through oceans

- Swamp evidence is found in Antarctica
- 12  **Similarity of Rock Sequences and Mountain Ranges**
 - If you close the continents of North America, Greenland, the UK, and Northern Europe, you find one continuous mountain range
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- 17  **Paleoclimatic evidence**
 - Glaciers tend to move from land to sea, but in the rock record they appear to move from sea to land
- 18  **Paleoclimatic evidence**
 - If all the Gondwanaland continents are fitted together, then the glaciers moved from the continents to the sea
- 19  **The great debate**
 - Objections to the continental drift hypothesis
 - Inability to provide a mechanism capable of moving continents across the globe
 - Wegener suggested that continents broke through the ocean crust, much like ice breakers cut through ice
- 20  **The great debate**
 - Continental drift and the scientific method
 - Wegner’s hypothesis was correct in principle, but contained incorrect details
 - For any scientific viewpoint to gain wide acceptance, supporting evidence from all realms of science must be found
 - A few scientists considered Wegner’s ideas plausible and continued the search
- 21  **Continental drift and paleomagnetism**
 - Initial impetus for the renewed interest in continental drift came from rock magnetism
 - Magnetized minerals in rocks
 - Show the direction to Earth’s magnetic poles
 - Provide a means of determining their latitude of origin
- 22  **Figure 2.8**
- 23  **Figure 2.9**
- 24  **Figure 2.10**
- 25  **Continental drift and paleomagnetism**
 - Polar wandering
 - The apparent movement of the magnetic poles illustrated in magnetized rocks indicates that the continents have moved
 - Shows that Europe was much closer to the equator when coal-producing swamps existed
- 26  **Continental drift and paleomagnetism**
 - Polar wandering
 - Polar wandering curves for North America and Europe have similar paths but are separated by about 24° of longitude
 - Different paths can be reconciled if the continents are placed next to one another
- 27  **Apparent polar-wandering paths for Eurasia and North America**
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- 30  **The scientific revolution begins**
 - During the 1950’s and 1960’s technological strides permitted extensive mapping of the ocean floor
 - Seafloor spreading hypothesis was proposed by Harry Hess in the early 1960’s
- 31  **The scientific revolution begins**
 - Geomagnetic reversals

- Earth's magnetic field periodically reverses polarity
 - the north magnetic pole becomes the south magnetic pole, and vice versa
- Dates when the polarity of Earth's magnetism changed were determined from lava flows

32 **The scientific revolution begins**

- Geomagnetic reversals
 - Geomagnetic reversals are recorded in the ocean crust
 - In 1963 Fred Vine and D. Matthews tied the discovery of magnetic stripes in the ocean crust near ridge crests to Hess' concept of seafloor spreading

33 **Paleomagnetic reversals recorded by basalt at mid-ocean ridges**

34 **Figure 2.15**

35 **Figure 2.13**

36 **Figure 2.14**

37 **Figure 2.16**

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39 **Figure 2.16B**

40 **Seafloor Spreading and Magnetization**

41 **The scientific revolution begins**

- Geomagnetic reversals
 - *Paleomagnetism* (evidence of past magnetism recorded in the rocks) was the most convincing evidence set forth to support the concept of seafloor spreading

42 **Plate tectonics: The new paradigm**

- Much more encompassing theory than continental drift
- The composite of a variety of ideas that explain the observed motion of Earth's lithosphere through the mechanisms of subduction and seafloor spreading

43 **Plate tectonics: The new paradigm**

- Earth's major plates
 - Associated with Earth's strong, rigid outer layer
 - Known as the *lithosphere*
 - Consists of uppermost mantle and overlying crust
 - Overlies a weaker region in the mantle called the *asthenosphere*

44 **Plate tectonics: The new paradigm**

- Earth's major plates
 - Seven major lithospheric plates
 - Plates are in motion and continually changing in shape and size
 - Largest plate is the Pacific plate
 - Several plates include an entire continent plus a large area of seafloor

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47 **Plate Boundary Features**












48 **Plate tectonics: The new paradigm**

- Earth's major plates
 - Plates move relative to each other at a very slow but continuous rate
 - Average about 5 centimeters (2 inches) per year
 - Cooler, denser slabs of oceanic lithosphere descend into the mantle

49 **Plate Motions**

50 **Plate tectonics: The new paradigm**

- Plate boundaries
 - All major interactions among individual plates occur along their boundaries
 - Types of plate boundaries
 - *Divergent* plate boundaries
 - (constructive margins)
 - *Convergent* plate boundaries

- (destructive margins)
 - *Transform* fault boundaries
 - (conservative margins)
- 51  **Plate tectonics: The new paradigm**
- Plate boundaries
 - Each plate is bounded by a combination of the three types of boundaries
 - New plate boundaries can be created in response to changes in the forces acting on these rigid slabs
- 52  **Divergent plate boundaries**
- Most are located along the crests of oceanic ridges and can be thought of as constructive plate margins
 - Oceanic ridges and seafloor spreading
 - Along well-developed divergent plate boundaries, the seafloor is elevated forming *oceanic ridges*
- 53  **Divergent plate boundaries**
- Oceanic ridges and seafloor spreading
 - Seafloor spreading occurs along the oceanic ridge system
 - Spreading rates and ridge topography
 - Ridge systems exhibit topographic differences
 - Topographic differences are controlled by spreading rates
- 54  **Divergent plate boundaries are located mainly along oceanic ridges**
- 55  **Divergent Boundary Formation**
- 56  **Divergent plate boundaries**
- Spreading rates and ridge topography
 - Topographic differences are controlled by spreading rates
 - Slow spreading rates (1-5 centimeters per year)
 - a prominent rift valley develops along the ridge crest that is wide (30 to 50 km) and deep (1500-3000 meters)
 - Intermediate spreading rates (5-9 centimeters per year)
 - rift valleys that develop are shallow with subdued topography
- 57  **Divergent plate boundaries**
- Spreading rates and ridge topography
 - Topographic differences are controlled by spreading rates
 - At spreading rates greater than 9 centimeters per year no median rift valley develops and these areas are usually narrow and extensively faulted
 - Continental rifts
 - Split landmasses into two or more smaller segments
- 58  **Divergent plate boundaries**
- Continental rifts
 - Examples include the East African rift valleys and the Rhine Valley in northern Europe
 - Produced by extensional forces acting on the lithospheric plates
 - Not all rift valleys develop into full-fledged spreading centers
- 59  **The East African rift:
a divergent boundary on land**
- 60  **Convergent plate boundaries**
- Older portions of oceanic plates are returned to the mantle in these destructive plate margins
 - Surface expression of the descending plate is an *ocean trench*
 - Called *subduction zones*
 - Average angle at which oceanic lithosphere descends into the mantle is about 45°
- 61  **Convergent plate boundaries**
- Although all have the same basic characteristics, they are highly variable features

- Types of convergent boundaries:
 - *Oceanic-continental convergence*
 - Denser oceanic slab sinks into the asthenosphere


62  **Convergent plate boundaries**

- Types of convergent boundaries
 - *Oceanic-continental convergence*
 - As the plate descends, partial melting of mantle rock generates magmas having a basaltic or andesitic composition
 - Mountains produced in part by volcanic activity associated with subduction of oceanic lithosphere are called *continental volcanic arcs* (Andes and Cascades)

63  **An oceanic - continental convergent plate boundary**

64  **Convergent plate boundaries**

- Types of convergent boundaries
 - *Oceanic-oceanic convergence*
 - When two oceanic slabs converge, one descends beneath the other
 - Often forms volcanoes on the ocean floor
 - If the volcanoes emerge as islands, a *volcanic island arc* is formed (Japan, Aleutian islands, Tonga islands)

65  **An oceanic - oceanic convergent plate boundary**

66  **Convergent plate boundaries**

- Types of convergent boundaries
 - *Continental - continental convergence*
 - Continued subduction can bring two continents together
 - Less dense, buoyant continental lithosphere does not subduct
 - Result is a collision between two continental blocks
 - Process produces mountains
 - (Himalayas, Alps, Appalachians)

67  **continental - continental convergent plate boundary**

68  ***Collision of India and Asia produced the Himalayas***

69  **Convergent Margins: India-Asia Collision II**

70  **Transform fault boundaries**

- The third type of plate boundary
- Plates slide past one another and no new lithosphere is created or destroyed
- *Transform faults*
 - Most join two segments of a mid-ocean ridge as parts of prominent linear breaks in the oceanic crust known as *fracture zones*

71  **Transform fault boundaries**

- Transform faults
 - A few cut through continental crust
 - San Andreas fault
 - Alpine fault (New Zealand)

72  ***Transform fault boundary***

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76  **Transform Faults**

77  **Testing the plate tectonics model**

- Plate tectonics and earthquakes
 - Plate tectonics model accounts for the global distribution of earthquakes
 - Absence of deep-focus earthquakes along the oceanic ridge is consistent with plate tectonics theory
 - Deep-focus earthquakes are closely associated with subduction zones


- The pattern of earthquakes along a trench provides a method for tracking the plate's descent

78  **Deep-focus earthquakes occur along convergent boundaries**


79  **Earthquake foci in the vicinity of the Japan trench**

80  **Testing the plate tectonics model**

- Evidence from ocean drilling
 - Some of the most convincing evidence confirming seafloor spreading has come from drilling directly into ocean-floor sediment
 - Age of deepest sediments
 - Thickness of ocean-floor sediments verifies seafloor spreading


81  **Age of ocean floor**

82  **Seafloor Spreading and Plate Boundaries**

83  **Motion at Plate Boundaries**


84  **Testing the plate tectonics model**

- Hot spots
 - Caused by rising plumes of mantle material
 - Volcanoes can form over them (Hawaiian Island chain)
 - Most mantle plumes are long-lived structures and at least some originate at great depth, perhaps at the mantle-core boundary


85  **The Hawaiian Islands have formed over a stationary hot spot**

86  **The driving mechanism**

- No one driving mechanism accounts for all major facets of plate tectonics
- Most researchers agree that convective flow in the rocky 2,900 kilometer-thick mantle is the basic driving force of plate tectonics
- Several mechanisms generate forces that contribute to plate motion
 - Slab-pull
 - Ridge-push

87  **The driving mechanism**

- Models of plate-mantle convection
 - Any model describing mantle convection must explain why basalts that erupt along the oceanic ridge
 - Models:
 - Layering at 660 kilometers
 - Whole-mantle convection
 - Deep-layer model

88  **Importance of plate tectonics**

- Theory provides a unified explanation of Earth's major surface processes
- Within the framework of plate tectonics, geologists have found explanations for the geologic distributions of earthquakes, volcanoes, and mountains
- Plate tectonics also provides explanations for past distributions of plants and animals

89 