Plate Tectonics: summary in haiku form

Alfred Wegener
gave us Continental Drift.
Fifty years later…

Chapter Overview

- Much evidence supports plate tectonics theory.
- The plate tectonics model describes features and processes on Earth.
- Plate tectonic science has applications to Earth Science studies.
- Configuration of land and oceans has changed in the past and will continue to change into the future.

Plate Tectonics

- *Alfred Wegener* first proposed in 1912
- Called it "*Continental Drift*"

Evidence for Continental Drift

- Wegener proposed Pangaea – one large continent existed 200 million years ago
- Panthalassa – one large ocean
  - Included the Tethys Sea
- Noted puzzle-like fit of modern continents

Present-day Configuration

200 million years ago

Evidence for Continental Drift

- Puzzle-like fit corroborated in 1960s
- Sir Edward Bullard used computer models to fit continents.

Evidence for Continental Drift

- Matching sequences of rocks and mountain chains
- Similar rock types, ages, and structures on different continents

Present Day

About 300 million years ago

Evidence for Continental Drift

- Glacial ages and other climate evidence
- Evidence of glaciation in now tropical regions
- Direction of glacial flow and rock scouring
- Plant and animal fossils indicate different climate than today.

Evidence for Continental Drift

- Distribution of organisms
  - Same fossils found on continents that today are widely separated
  - Modern organisms with similar ancestries

Objections to Early Continental Drift Model

- 1915 – Wegener published *The Origins of Continents and Oceans*
  - Suggested continents plow through ocean basins
- Met with hostile criticism and open ridicule
- Tidal gravitational attractions too small to move continents
- Proposed mechanism defies laws of physics

Evidence for Plate Tectonics

- New evidence from World War II
  - Sea floor studies with sonar
  - New technology enabled study of Earth's magnetic field

17 **Evidence for Plate Tectonics**
- Earth's magnetic field and paleomagnetism
- Earth has magnetic polarity
- North and South polarities
- Magnetic polarity recorded in igneous rocks
  - Magnetite in basalt

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18 **Evidence for Plate Tectonics**
- Paleomagnetism – study of Earth's ancient magnetic field
  - Interprets where rocks first formed
  - Magnetic dip

19 **Earth's Magnetic North Pole**

20 **Evidence for Plate Tectonics**
- *Apparent* polar wandering
- Location of North Pole changed over time
- Magnetic dip data

21 **Magnetic Polarity Reversals**
- Earth's magnetic polarity reverses periodically
- Recorded in ancient igneous rocks
- 176 reversals in past 76 million years
- Unpredictable pattern

22 **Paleomagnetism and the Ocean Floor**
- 1955 – deep water rock mapping
- Magnetic anomalies – regular pattern of north-south magnetism "stripes"
- Stripes were symmetrical about long underwater mountain range
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23 **Sea Floor Spreading**
- Harry Hess
  - World War II submarine captain and geologist
- Depth recordings show sea floor features
- *History of Ocean Basins*
  - Seafloor spreading
  - Mantle convection cells as driving mechanism

24 **Plate Tectonic Processes**

25 **Sea-Floor Spreading and Plate Boundaries**

26 **Sea Floor Spreading**
- Mid-ocean ridge – spreading center
- Subduction zones – oceanic trench site of crust destruction
- Subduction can generate deep ocean trenches.

27 **Sea Floor Spreading Evidence**
- Frederick Vine and Drummond Matthews (1963)
- Analysis of igneous rock stripes around mid-ocean ridge
- Sea floor stripes record Earth's magnetic polarity

28 **Age of Ocean Floor**
- Late 1960s deep-sea drilling
- Radiometric dating of ocean rocks
- Symmetric pattern of age distribution about mid-ocean ridges

- Oldest ocean floor only 180 million years old

29 **Age of Ocean Floor**

30 **JOIDES Resolution**

31 **Heat Flow**

- Heat flow – heat from Earth's interior released to surface
- Very high at mid-ocean ridges
- Low at subduction zones
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32 **Earthquakes as Evidence**

- Most large earthquakes occur at subduction zones.
- Earthquake activity mirrors tectonic plate boundaries.

33 **Global Plate Boundaries**

34 **Plate Tectonics Theory**

- Lithosphere – tectonic plates that float on ductile asthenosphere
- Large-scale geologic features occur at plate boundaries.
- Two major tectonic forces
  - Slab pull
  - Slab suction

35 **Types of plate boundaries**

36 **Examples of Plate Boundaries**

37 **Divergent Boundary Features**

- Plates move apart
- Mid-ocean ridge
  - Rift valley
- New ocean floor created
- Shallow focus earthquakes
  - Intensity measured with seismic moment magnitude
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38 **Divergent Plate Boundary**

39

40 **Formation of a Rift Valley**

41 **Types of Spreading Centers**

- Oceanic rise
  - Fast-spreading
  - Gentle slopes
  - East Pacific
- Oceanic ridge
  - Slow-spreading
  - Steep slopes
  - Mid-Atlantic
- Ultra-slow
  - Deep rift valley
  - Widely scattered volcanoes
  - Arctic and southwest India

42 **Fast vs. Slow:**

43 **Convergent Boundary Features**

- Plates move toward each other
- Oceanic crust destroyed
  - Ocean trench
  - Volcanic arc
- Deep focus earthquakes

- Great forces involved
- Mineral structure changes associated

44 **Three types of convergent plate boundaries:**

45 **Types of Convergent Boundaries**

- Oceanic-Continental Convergence
  - Ocean plate is subducted
  - Continental arcs generated
  - Explosive andesitic volcanic eruptions

46 **Types of Convergent Boundaries**

- Oceanic-Oceanic Convergence
  - Denser plate is subducted
  - Deep trenches generated
  - Volcanic island arcs generated
  -

47 **Types of Convergent Boundaries**

- Continental-Continental Convergence
  - No subduction
  - Tall mountains uplifted
- Himalayas from India-Asia collision

48 **Converging Margins: India-Asia Collision**

49 **Transform Boundary Features**

- Offsets oriented perpendicular to mid-ocean ridge
  - Segments of plates slide past each other
- Offsets permit mid-ocean ridge to move apart at different rates
- Shallow but strong earthquakes

50 **Transform Boundary Features**

- Oceanic Transform Fault – ocean floor only
- Continental Transform Fault – cuts across continent
  - San Andreas Fault
- Transform faults occur between mid-ocean ridge segments.

51 **Transform Faults**

52 ***Transform fault boundary***

53 **Applications of Plate Tectonics**

- Mantle Plumes and Hotspots
  - Intraplate features
    - Volcanic islands within a plate
    - Island chains
- Record ancient plate motions
  - Nematath – hotspot track

54 **Global Hotspot Locations**

55 **Hawaiian Is. – Emperor Seamount Nematath**

56 **Plate Tectonics and Intraplate Features**

- Seamounts
  - Rounded tops
- Tablemounts or guyots
  - Flattened tops
- Subsidence of flanks of mid-ocean ridge

- Wave erosion may flatten seamount.
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57 **Coral Reef Development**
- Fringing reefs – develop along margin of landmass
- Barrier reefs – separated from landmass by lagoon
- Atolls – reefs continue to grow after volcanoes are submerged

58 **Great Barrier Reef**
records plate movement

59 **Detecting Plate Motion with Satellites**

60 **Paleogeography**
- Paleogeography – study of ancient continents
- Continental accretion
  - Continental material added to edges of continents through plate motion
- Pangaea – 540 million to 300 million years ago
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61 **Breakup of Pangaea**
- 180 million years ago – Pangaea separated
  - N. and S. America rifted from Europe and Africa
  - Atlantic Ocean forms
- 120 million years ago – S. America and Africa clearly separated
- 45 million years ago – India starts
  Asia collision
  - Australia moving north from Antarctica

62 **Pangaea Breakup**

63 **Future Predictions**
- Assume same direction and rate of plate motions as now
  - Atlantic will enlarge, Pacific will shrink
  - New sea from East Africa rift valleys
  - Further Himalaya uplift
  - Separation of North and South America
  - Part of California in Alaska
  -

64 **World Map 50 million Years in Future**

65 **Wilson Cycle**
- John Tuzo Wilson
- Plate tectonics model shows life cycle of ocean basins
  - Formation
  - Growth
  - Destruction

66 **Wilson Cycle**

67 **End of Chapter 2 -**
Plate Tectonics and the Ocean Floor