1 ***Plate Tectonics***

***A Scientific Revolution Unfolds***

2 **Plate Tectonics: summary in haiku form**
Alfred Wegener
gave us Continental Drift.
Fifty years later…

3 **From Continental Drift to Plate Tectonics**
- Prior to the late 1960s, many geologists believed that the positions of the continents and ocean basins were fixed
- Continental drift, a hypothesis designed to explain continental movement, was first proposed in the twentieth century, but initially rejected by North American geologists

4 **Continental Drift: An Idea Before Its Time**
- Alfred Wegener
  - First proposed continental drift hypothesis in 1915
  - Published *The Origin of Continents and Oceans*
- Continental drift hypothesis
  - A supercontinent, consisting of all of Earth's landmasses, once existed
  - This supercontinent was called Pangaea and began breaking apart about 200 million years ago

5 **Reconstructions of Pangaea**

6 **Pangaea Breakup**

7 **Continental Drift: An Idea Before Its Time**
- Evidence used in support of continental drift hypothesis:
  - The Continental Jigsaw puzzle

8 **Continental Drift: An Idea Before Its Time**
- Evidence used in support of continental drift hypothesis:
  - Fossil evidence—identical fossil organisms are found on continents now separated by vast oceans

9 **Continental Drift: An Idea Before Its Time**
- Evidence used in support of continental drift hypothesis:
  - Rock types and geologic features

10 **Continental Drift: An Idea Before Its Time**
- Evidence used in support of continental drift hypothesis:
  - Ancient climates

11 **The Great Debate**
- Objections to the continental drift hypothesis:
  - Wegener incorrectly suggested that the gravitational forces of the Moon and Sun were capable of moving the continents
  - Wegener also incorrectly suggested that continents broke through the ocean crust
  - There was strong opposition to this hypothesis from all areas of the scientific community
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12
- Following World War II, oceanographers learned much about the seafloor
  - The oceanic ridge system winds through all of the major oceans

  - There is no oceanic crust older than 180 million years old
  - Sediment accumulation in the deep oceans was relatively minor
- These developments led to the theory of plate tectonics

13

- Rigid Lithosphere Overlies Weak Asthenosphere
  - The lithosphere is Earth's strong, outer layer
  - The asthenosphere is a hotter, weaker region of the mantle under the lithosphere
  - Because of the differences in physical properties, the lithosphere is effectively detached from the asthenosphere

14

- Earth's Major Plates
  - The lithosphere is broken into approximately two dozen smaller sections called lithospheric plates
  - These plates are in constant motion

15

- Plate Boundaries
  - Most interactions among individual plates occur along their boundaries
  - Types of plate boundaries:
    - Divergent plate boundaries (constructive margins)—plates move apart
    - Convergent plate boundaries (destructive margins)—plates move together
    - Transform plate boundaries (conservative margins)—plates grind past each other without the production or destruction of lithosphere (also called a transform fault)

16 **Divergent Plate Boundaries**

- New ocean floor is generated as two plates move apart
- Most divergent plate boundaries are located along the crests of oceanic ridges
- Oceanic ridges and seafloor spreading
  - Along well-developed divergent plate boundaries, the seafloor is elevated, forming oceanic ridges
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17 **Divergent Plate Boundaries**

- Oceanic Ridges and Seafloor Spreading
  - Along the crest of the ridge is a canyon-like feature called a rift valley
  - Seafloor spreading is the mechanism that operates along the ridge to create new ocean floor
- Spreading Rates
  - The average spreading rate is 5 cm/year
  - The Mid-Atlantic Ridge has a spreading rate of 2 cm/year
  - The East Pacific Rise has a spreading rate of 15 cm/year

18 **Divergent Plate Boundaries**

19 **Divergent Plate Boundaries**

- Continental Rifting
  - Occurs when a divergent plate boundary occurs within a continent
  - A landmass will split into two or more smaller segments
  - A continental rift, an elongated depression, will develop within the region of the divergence
  - Examples include:
    - East African Rift

20 **Divergent Boundary Formation**

21

22 **Seafloor Spreading and Magnetization**

23 **Convergent Plate Boundaries**

- Two plates move toward each other at these destructive plate margins, where the older

portions of oceanic plates are returned to the mantle
- The leading edge of one plate is bent downward, as it slides beneath the other at subduction zones
- Deep-ocean trenches are the surface manifestations produced at subduction zones
- Examples include:
  - Peru-Chili Trench
  - Mariana Trench
  - Tonga Trench
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24 **Convergent Plate Boundaries**

- Types of Convergent Boundaries:
  - Oceanic–continental convergence
    - The denser oceanic slab sinks beneath the continental block into the asthenosphere
    - At a depth of 100 kilometers, partial melting occurs when water from the subducting plate mixes with the hot rocks of the asthenosphere, generating magma
    - The resulting volcanic mountain chain is called a continental volcanic arc
      - Examples include:
        - The Andes
        - The Cascade Range
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25 **Oceanic–Continental Convergence**

26 **Convergent Plate Boundaries**

- Types of Convergent Boundaries:
  - Oceanic–oceanic convergence
    - When two oceanic slabs converge, one descends beneath the other
    - As with oceanic–continental convergence, partial melting initiates volcanic activity
    - If the volcanoes emerge as islands, a volcanic island arc is formed
      - Examples include:
        - The Aleutian Islands
        - The Mariana Islands

27 **Oceanic–Oceanic Convergence**

28 **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
    - The resulting collision produces mountains
      - Examples include:
        - The Himalayas
        - The Alps
        - The Appalachians

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29 **Continental–Continental Convergence**

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

31 **Transform Plate Boundaries**

- Plates slide past one another and no lithosphere is created or destroyed
- Most join two segments of an oceanic ridge system along breaks in the oceanic crust known

as fracture zones
- Transform faults can also move ridge crests toward subduction zones
- A few transform faults cut through continental crust
  - Examples include:
    - The San Andreas Fault
    - The Alpine Fault of New Zealand
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32 **Transform Fault Boundaries**
33 **Transform Faults**
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35
36
37 ***Transform fault boundary***
38 **Testing the Plate Tectonics Model**

- Evidence from Ocean Drilling
  - Some of the most convincing evidence has come from drilling directly into ocean-floor sediment
    - Age of the deepest sediments: The oldest sediments are furthest from the spreading center
    - The thickness of ocean-floor sediments verifies seafloor spreading: Sediments are almost absent on the ridge crest and thickest furthest from the spreading center
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39 **Evidence from Ocean Drilling**
40 **JOIDES Resolution**
41 **Testing the Plate Tectonics Model**

- Hot Spots and Mantle Plumes
  - A mantle plume is a cylindrically shaped upwelling of hot rock
  - The surface expression of a mantle plume is a hot spot, which is an area of volcanism
  - As a plate moves over a hot spot, a chain of volcanoes, known as a hot-spot track, is built
  - The age of each volcano indicates how much time has passes since the volcano was over the mantle plume
  - Examples include:
    - Hawaiian Island chain
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42 **Hot Spots and Hot Spot Tracks**
43 **Testing the Plate Tectonics Model**

- Paleomagnetism
  - Basaltic rocks contain magnetite, an iron-rich mineral affected by Earth's magnetic field
  - When the basalt cools below the Curie point, the magnetite aligns toward the position of the north pole
  - The magnetite is then "frozen" in position and indicates the position of the north pole at the time of rock solidification. This is referred to as paleomagnetism
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44 **Testing the Plate Tectonics Model**

- Apparent Polar Wandering
  - The apparent movement of the magnetic poles indicates that the continents have moved

– It also indicates North America and Europe were joined in the Mesozoic

45 **Apparent Polar Wandering Paths**

46 **Testing the Plate Tectonics Model**

- Magnetic Reversals and Seafloor Spreading
  - During a magnetic reversal, Earth's magnetic field periodically reverses polarity—the north pole becomes the south pole, and vice versa
    - Rocks that exhibit the same magnetism as the present magnetic field exhibit normal polarity
    - Rocks that exhibit the opposite magnetism exhibit reverse polarity
  - The magnetic time scale shows the sequence of shifts in the polarity of Earth's magnetic field, determined from lava flows
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47 **Ocean Floor as a Magnetic Recorder**

48 **How Is Plate Motion Measured?**

- Geologic Evidence for Plate Motion
  - By knowing the age of the seafloor and the distance from the spreading center, an average rate of plate motion can be calculated
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49 **How Is Plate Motion Measured?**

- Measuring Plate Motion from Space
  - Accomplished by using the Global Positioning System to measure various points on Earth's surface
  - GPS data are collected over various points repeatedly for many years to establish plate motion
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50 **Plate Motions**

51 **How Does Plate Motion Affect Plate Boundaries?**

- The total surface of Earth does not change, despite movement along plate boundaries
- Plates can grow or shrink depending on the plate boundaries surrounding each plate
  - Examples include:
    - The African plate is bounded by divergent boundaries and is growing
    - The Pacific plate is bounded by convergent boundaries and is shrinking

52 **What Drives Plate Motions?**

- Researchers agree that convective flow in the mantle is the basic driving force of plate tectonics
- Forces That Drive Plate Motion:
  - The subduction of cold oceanic lithosphere is a slab-pull force
  - Elevated lithosphere on an oceanic ridge will slide down due to gravity, called the ridge-force
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53 **Forces Driving Plate Motions**

54 **What Drives Plate Motions?**

- Models of Plate–Mantle Convection
  - Convection in the mantle, where warm, buoyant rocks rise and cool, dense rocks sink, is the underlying driving force of plate tectonics
  - The slab-pull and ridge-push forces of plate tectonics are part of the same system as mantle convection
  - Convective flow in the mantle is a major force for transporting heat away from the interior of Earth

55 **Plate Boundary Features**
56 **Age of ocean floor**
57 **Seafloor Spreading and Plate Boundaries**
58 **Motion at Plate Boundaries**
59