Lithospheric Plates

The Earth's rocky outer crust solidified billions of years ago, soon after the Earth formed. This crust is not a solid shell.

It is broken up into huge, thick plates that drift atop the soft, underlying mantle.

A number of rigid, but moving, pieces of the Earth’s surface.

Also called lithospheric plates
Alfred Wegener: German Meteorologist

On January 6, 1912 Wegener presented his Continental Drift theory/hypothesis after analyzing either side of the Atlantic Ocean for rock type, geological structures and fossils. However, it wasn't considered to be sufficient evidence by the scientific community.
In Wegener’s hypothesis he gave a name to the single landmass and it’s ocean.

- **Pangaea:** (means “All Land”)
  - The single landmass that formed between 250 and 300 million years ago.

- **Panthalassa:** (means “All Seas”)
  - The name given to the vast ocean that surrounded Pangaea.
The Similar Fossils Found

Fossil remains of *Cynognathus*, a Triassic land reptile approximately 3 m long.

Fossil remains of the freshwater reptile *Mesosaurus*.

Fossil evidence of the Triassic land reptile *Lystrosaurus*.

Fossils of the fern *Glossopteris*, found in all of the southern continents, show that they were once joined.
The Similar Rock Structures Found

Similar layers of rock were formed in Antarctica, Australia, South America, Africa, and India before Pangea broke apart. Glossopteris fossils were found in the rocks on each continent.
Continental Drift

Wegener’s evidence for Continental Drift
Evidence of Continental Drift:

1.) Coastline Similarities

2.) Fossils of Plants & Reptiles were similar

3.) Geologic Patterns of Rocks & Mountain Chains

Why then was his theory rejected by leading scientists?

Because it did not sufficiently explain the forces causing Continental Drift—Wegener died in 1930 still trying to discover what made the continents move.
Wegener, poor and unable to support his family tries one last time...

In 1930 Wegener leaves for Greenland to find evidence for his hypothesis.

He is never seen again

This is last the photo taken of him before his death.

His theory is hotly debated for the next 30 years
The Evidence is Discovered:

- **1947**, Scientists on the survey ship Atlantis begin mapping the ocean floor and found that the ocean floor was not flat like they thought.

In the **1950’s** a great mountain range on the ocean floor was discovered that virtually encircled the Earth. (*Global mid-ocean ridge*) It zigzags between the continents 65,000 km long with an average height of 4,500 m.
The Evidence is Discovered:
Seafloor Spreading, 1961

**Seafloor spreading:** states that new ocean crust is formed at ocean ridges and destroyed at deep-sea trenches.

- Magma is forced toward the crust along an ocean ridge and fills the gap that is created.
Seafloor Spreading

- When the magma hardens, a small amount of new ocean floor is added to Earth’s surface.

- Each cycle of spreading and the intrusion of magma results in the formation of another small section of ocean floor, which slowly moves away from the ridge.
The Missing Link

– Seafloor spreading was the missing link needed by Wegener to complete his model of continental drift.

– Continents are not pushing through ocean crust, as Wegener proposed; they ride with ocean crust as it slowly moves away from ocean ridges.
Scientists then used echo soundings hoping they would be able to build up a picture of the ocean floor.

Sonar uses sound waves to measure water depth by measuring the time it takes for sound waves to travel from the device and back to a receiver.
Ocean floor features:

- Trenches
- Sea mounts
- Mountain chains
- Fracture zones
The Evidence is Discovered:

The Geomagnetic Time Scale

- In 1963 scientists towed magnetometers behind ships to measure the magnetic field of the ocean floor... they soon revealed an interesting pattern.
  
  • In places where the magnetic readings of the ocean floor matched Earth’s present field, a stronger-than-normal reading (+) was recorded.
  
  • In places where the magnetic data were reversed in relation to Earth’s present magnetic field, a lower-than-normal reading (−) was recorded.

A magnetic reversal is a change in Earth’s magnetic field.
Paleomagnetism

The Geomagnetic Time Scale

Paleomagnetism is the study of Earth’s magnetic record.

Rocks containing iron-bearing minerals provide a record of Earth’s magnetic field.

- Basalt, because it is rich in iron-bearing minerals, provides an accurate record of ancient magnetism.
Paleomagnetism
The Geomagnetic Time Scale
Magnetic Symmetry

- The positive and negative areas of the seafloor form a series of stripes that were parallel to ocean ridges.
- From this match, scientists were able to determine the age of the ocean floor from a magnetic recording and create geologic time maps of the ocean floor.
Paleomagnetism
The Geomagnetic Time Scale
Final Conclusion:

- The Seafloor is spreading apart at these mid-ocean ridges pushing the continents with them.
- The ocean floor rock is younger than the continental rock.
- The earth’s magnetic poles switch sides and polarity of the rock can determine the time frame in which the rock was formed.
http://www.ucmp.berkeley.edu/geology/anim1.html
-Pop Quiz-
Continental Drift

Questions?

1.) What type of evidence supports Wegener’s Hypothesis of Continental Drift?

2.) Describe the process of how seafloor spreading occurs.

3.) What observation first led to Wegner’s hypothesis of continental drift?

Answers!

Similar Fossil, Geological, Mid-ocean ridges, Paleomagnetic bands.

Magma pushes up through the Mid-Ocean ridges, cools and forces the oceanic crust to separate.

The similarity of coastlines between continents on either side of the Atlantic Ocean.
DIRECTIONS:

1. Label the land masses on each sheet. Color the fossil areas to match the legend below.

2. Cut out each of the continents along the edge of the continental shelf (the outermost dark line). Alfred Wegener's evidence for continental drift is shown on the cut-outs. Wegener used this evidence to reconstruct the positions of the continents relative to each other in the distant past.

3. Try to logically piece the continents together so that they form a giant supercontinent.

4. When you are satisfied with the ‘fit' of the continents, discuss the evidence with your partners and decide if the evidence is compelling or not. Explain your decision and reasoning on the evidence.
Plate Tectonics Emerges:

1968, The Theory of Plate Tectonics:
- The Lithosphere is made up of plates that float on the Asthenosphere and the plates move by convection currents.

Let's take a closer look at both the Lithosphere and the Asthenosphere.
The Lithosphere is made up of 3 parts

1.) **Oceanic Crust:** contains Very Dense ocean floor material

2.) **Continental Crust:** contains Less Dense continental material

3.) **Rigid Upper Mantle:** the thins outer shell of the earth that supports both oceanic and continental crusts

**Asthenosphere:**

The layer of solid plastic type rock under the Lithosphere that slowly flows (like putty) when under pressure.
The interior of Planet Earth

- Crust: 0-100 km thick
- Asthenosphere
- Mantle
- Lithosphere (crust and uppermost solid mantle)
- Core: 2,900 km
- Inner core: 5,100 km
- Liquid
- Solid
- Not to scale

To scale: 6,378 km
-30 moving plates have been identified to date. Some move away from each other, some collide with each other, and some grind past each other.
The Major Plate Boundaries
The 3 types of Plate Boundaries:

1.) **DIVERGENT Boundary:** Created when two plates spread from each other.

   Mid-Ocean Ridges & Rift Valleys:
   (The Atlantic Ocean and The Red Sea)

2.) **CONVERGENT Boundary:** Created when two plates collide with each other.

   Volcanoes and Mountain Ranges form this way

   * **Subduction Zones:** The region along a boundary when oceanic plates moves under a continental plate.

   * **Ocean Trench:** A deep trench that forms along subduction zones.

3.) **TRANSFORM FAULT Boundary:** Created when two plates grind past each other.

   (San Andreas Fault: California)
Divergent plate boundaries
New basaltic magma rises to the surface along the ridge forming new oceanic crust
The formation of the Atlantic ocean

(a) Doming and fracturing

(b) Rift underlain by volcanic rock

(c) Linear sea with mid-ocean ridge and transform fault

(d) Fully formed ocean
ICELAND Lies in the Middle of a Divergent Boundary Zone
Convergent plate boundaries
3 Types of Convergent plate boundaries

Oceanic-Oceanic
E.g. Japan, New Zealand

Oceanic-Continental
E.g. Andes, Sierra Nevada's

Continental-Continental
E.g. Himalayas
Oceanic-Oceanic convergence
Trench
Island arc
Piled up sedimentary rock
Japan is an example of an Island Arc system.
Oceanic - Continental convergence
Subduction Zone:
Oceanic & Continental Convergent Boundary Zone

This is how the Volcanic Cascade Mts. were formed in the North West.
Juan de Fuca Ridge

The boundary between the Pacific and Juan de Fuca Plates is marked by a broad submarine mountain chain about 500 kilometers long (300 miles), known as the Juan de Fuca Ridge. Young volcanoes, lava flows, and hot springs were discovered in a broad valley less than 8 kilometers wide (5 miles) along the crest of the ridge in the 1970’s. The ocean floor is spreading apart and forming new ocean crust along this valley or “rift” as hot magma from the Earth’s interior is injected into the ridge and erupted at its top.

Cascade Range

In the Pacific Northwest, the Juan de Fuca Plate plunges beneath the North American Plate. As the denser plate of oceanic crust is forced deep into the Earth’s interior beneath the continental plate, a process known as "subduction", it encounters high temperatures and pressures that partially melt solid rock. Some of this newly formed magma rises toward the Earth’s surface to erupt, forming a chain of volcanoes above the subduction zone.

Mount Rainier is the highest peak in the Cascade Range, which runs through southwestern Canada and the northwestern United States. The dormant, glacier-capped volcano rises to a height of 14,410 ft in western Washington. The mountain’s slopes support 25 named glaciers, the thickest of which is the Carbon Glacier, at 705 ft.
The bathyscaph, designed by Belgian scientist Auguste Piccard (1884-1962), was not suspended from a surface vessel but rather attached to a free-floating tank. (The tank was filled with petroleum liquid, which is lighter than water and hence buoyant.) Piccard's first bathyscaph, the FNRS-2, was referred to as the "submarine balloon" because its heavy-metal ballast, attached by electromagnets, allowed it to sink to a desired depth when engaged and rise to the surface when released. It had greater maneuverability than the bathysphere, though it did not fare well in tests. Piccard and his son Jacques later designed and built a new bathyscaph, the Trieste. In 1953, they descended in it to a depth of 10,330 feet in the Mediterranean. The Piccards sold the Trieste to the U.S. Navy in 1958. On January 23, 1960, the Trieste set a new world record of 35,800 feet when it touched bottom in the Marianas Trench near Guam.

The History of the Bathyscaph
Finding the Deepest place on Earth!

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Continental-Continental convergence
The sub-continent of India has collided with the Eurasian continent to form the Himalayas.
Old ocean sediments

Himalayan Mountains

Uplifted Tibetan plateau

Continent 1

Continent 2
The Himalayan Mountain Range
Convergent Boundary Zone

Himalayan Mountain Range - Highest Mountain Range in the World - includes 8 of the 10 highest Mt.
Transform plate boundaries
Transform Fault - San Andreas Fault in CA.
North American plate

Pacific plate
Can you name the Boundary???
Volcanoes and Plate boundaries

[Map showing global distribution of volcanoes and plate boundaries]

Oceanic volcanoes vs. Continental volcanoes:
- Subduction zone
- Hot spot
- Rift

Diagram illustrating volcanic activity at subduction zones and hotspots.
Cause of Plate Movement:

Convection Current:
-Much like hot air rising and cool air sinking. The molten rock or the asthenosphere rises and sinks forcing the plates to move.
Convection Current Theory:
Overview of Plate Tectonics

- **ISLAND ARC PLATE SUBDUCTION**
  - Mafic to intermediate intrusives (plutonism)
  - Mafic to intermediate extrusives (volcanism)
  - Island arc subduction zone
  - Island arc volcano

- **PLATE DIVERGENCE**
  - Basaltic extrusives
  - Basaltic intrusives
  - Mid-ocean ridge

- **HOT-SPOT VOLCANISM**
  - Basaltic extrusives
  - Basaltic intrusives
  - Hot-spot volcano

- **CONTINENTAL PLATE SUBDUCTION**
  - Mafic to felsic intrusives
  - Mafic to felsic extrusives
  - Subduction zone
  - Continental margin volcano

Diagram details:
- Partial melting of upper mantle
- Rising magma
- Mantle plume (hot spot)
- Oceanic crust
- Mantle
- Oceanic lithosphere
Overview of Plate Tectonics
Overview of Plate Tectonics
http://www.ucmp.berkeley.edu/geology/tecall1_4.mov

http://www.ucmp.berkeley.edu/geology/anim3.html
Are the Plates Still Moving?

Let's take a look as to what the Future may hold.
Future World + 250 Ma

- Ancient Landmass
- Modern Landmass
- Subduction Zone (triangles point in the direction of subduction)
- Sea Floor Spreading Ridge