Seafloor Magnetism, Seafloor Spreading: Developing the Theory of Plate Tectonics

Graphics: (top) Earth topography, (bottom) Garrison, Fig. 3.14.

Earthquakes and the Dynamic Earth

The Earth is not entirely solid

Earthquakes are not randomly distributed

Observations like these paved the way for <u>a revolution in geology… the theory of plate tectonics</u>

Graphic: Garrison, Fig. 3.14.

What is a Scientific "Theory"?

Popular usage – a hunch or guess which may be unproven or lack credibility

Keep in mind that the popular definition of a theory is not what we mean scientifically

Scientific usage - an explanation of related observations which have been <u>verified multiple times by many groups of scientists</u> and is generally considered "true" by scientific experts

A theory:
- can be enhanced to incorporate new findings
- makes testable predictions

Examples: atomic theory, gravitational theory, cell theory, evolutionary theory, plate tectonic theory

Graphic: A theory in the making? Scientific research aboard an oceanographic vessel. Courtesy Dr. J.Ortiz, KSU Dept. Geology.

Distribution of Land and Ocean Today

Northern hemisphere: 61% of surface is ocean, 39% is land

Southern hemisphere: 81% of surface is ocean, 19% is land

North polar area - covered by ocean (Arctic Ocean)

South polar area - covered by land (Antarctica)

Graphic: See Garrison, Fig. 1.2.

Latitude and Longitude

<u>Latitude</u> **<u>Longitude</u>**

Latitude and longitude uniquely specify the the location of each place on Earth

North-South **East-West**

Range: 90°N to 90°S **Range: 0°E-360°E**

or 180°W-180°E

North Pole=90°N	**0°=Greenwich**	**Kent, Ohio=41.15°N**
South Pole=90°S	**England**	**278.64°E**

Graphic: see Garrison, Box 1.1

Buoyancy and Isostatic Equilibrium

Floating objects displace a volume of fluid which is equal to their mass due to <u>buoyancy</u>

Example:

Empty ships sit higher in the water than loaded ships

In geology, balancing lighter material in heavier fluid matrix is known as <u>isostatic equilibrium</u>

Graphic: Garrison, Fig. 3.7.

The Roots of Mountain Ranges

Large mountain ranges have deep <u>roots</u> due to the physical properties of Earth's layers

As mountains erode their roots become shallower

This process is known as <u>isostatic adjustment</u> and is similar to buoyancy in fluids

Graphic: Garrison, Fig. 3.8.

Isostacy and the Shape of the Seas

Continental crust sits higher on Earth's surface than ocean crust because it is lighter (less dense)

The change in elevation from continental to oceanic crust is due to isostacy

Graphic: (top) Garrison, Fig. 3.6, inset, (bottom) Continental shelf and slope off Los Angeles, California, courtesy of the USGS Pacific Sea-Floor Mapping Project.

Evidence for a Past "Supercontinent"

Geometric “fit” of continents

Fossilized animal and plant remains

Types of rocks and their locations

Graphic: Configuration of rejoined continents based on geological evidence. Courtesy of USGS.

Continental Drift

Hypothesis: Continents were once joined to form a single land mass which drifted apart

Proposed Mechanism: continents plowed through ocean crust…

But…

- no "wakes" were found in the seafloor behind continents

- geologists didn't yet believe that parts of the mantle could flow

Graphic: Garrison, Fig. 3.10.

A Piece of the Puzzle - Measuring Ocean Depths

Bathymetry (ocean depth) can be measured using:

- weighted lines

- sound (acoustics)

- Earth-orbiting satellites (new!)

<u>Acoustic bathymetry:</u>

- a sound pulse is sent to the seafloor

- measure time needed for the echo to be received

- this time is related to the distance to the seafloor

Graphic: After Garrison, Fig. 4.2b.

A Piece of the Puzzle – Seafloor Bathymetry

- Seafloor bathymetry was more complex than imagined

- Discovery of mid-ocean ridges was particularly unexpected

Blue/Purple=deep Green/yellow/red=shallower

Graphic: Garrison Fig.4.32.

Mid-Ocean Ridges and Abyssal Plains – There are Huge

Mountains Under the Sea!

Mid-ocean Ridge

Abyssal Plains

Graphic: (top) Garrison, Fig. 4.22, (bottom) Garrison, Fig. 4.21.

Another Piece of the Puzzle – Paleomagnetism

Rotation of the Earth and its metal core creates a global magnetic field

The polarity of this field switches through time ("magnetic reversals")

Graphic: Garrison, Fig. 3.26b.

Magnets and Rocks

When rocks solidify from molten magma, magnetic particles in the rocks align with the orientation of the Earth's magnetic field

Scientists can "tell time" by comparing patterns of magnetic reversals preserved in rocks from different places

Graphic: Garrison, Fig. 3.27.

There are Magnetic Stripes on the Bottom of the Sea!

Observations of the seafloor showed:

- There is a symmetrical "striped" magnetic pattern on either side of the mid-ocean ridges

- Rocks are youngest at the tops of mid-ocean ridges and are older on either side

Graphic: Garrison, Fig. 3.28.

A Piece of the Puzzle - The Age of the Seafloor

- The seafloor is not all the same age

- The seafloor is much younger than the continents

Red=young Blue=old

Graphic: Age of the seafloor, courtesy of NOAA. See Garrison Fig. 3.29.

Sediment Thickness

Sediment = material that accumulates on the bottom of the ocean

It takes a long time to build up a thick layer of sediments

Sediment is thin at the tops of mid-ocean ridges and thick on the abyssal plains

Graphic: Seafloor sediment thickness. Courtesy of NOAA. Light blue=thin, Darker blue to red= thick.

From Observations to the Seafloor Spreading Hypothesis - Putting Together the Puzzle

The Seafloor Spreading Hypothesis

The formation of new seafloor occurs at "spreading centers" along mid-ocean ridges

Over time, these newly formed rocks are carried away from the spreading center

Hypothesis explains: age of seafloor, magnetic "stripes", the existence of midocean ridges, etc

Seafloor spreading animation

Paleomagnetism animation

Seafloor Spreading and Paleomagnetism

How many times has the Earth's magnetic field changed direction?

Approximately what percentage of the time has the magnetic field been "normal"? Reversed?

What might control how high the midocean ridge becomes?

But If New Seafloor Forms at Mid-Ocean Ridges…

Some of the Earth's crust must be destroyed elsewhere,

But where???

Earthquakes provided the clue

Graphic: Garrison Fig. 3.14.

Plate Tectonics: A New View of the Earth

Earth's surface is divided into rigid plates

Earth dynamics depends on plate motion – as plates move, new lithosphere forms and old lithosphere is destroyed

Graphic: Garrison, Figs. 3.14 and 3.15.

Preview of Next Lecture
Plate Tectonics: Story of a Dynamic Earth

Graphic: The convergence of the Nazca and South American Plates has deformed and pushed up marine limestone strata to form towering peaks of the Andes, as seen here in the Pachapaqui mining area in Peru. George Ericksen, photographer. Courtesy of USGS.