Plate Tectonics and the Dynamic Earth

Plate Tectonics

What is it?

How does it work?

Plate Boundaries – Convergent, Divergent, Transform

Have Questions About Oceanography?

My office hours are:

T: 10:30-11:30 am,

W: 2:15-4:00 pm;

R 10:30-11:30 am, or by appointment

Graphics: 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.

From Seafloor Spreading to Plate Tectonics
If New Seafloor Forms at Mid-Ocean Ridges…

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

But where…

Earthquakes provided the clue

Shallow earthquakes occur along mid-ocean ridges as the ridges spread apart

Earthquakes also occur in other areas, far from mid-ocean ridges

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: (top) See Garrison, 3.15, (bottom) Garrison, Fig. 3.14.

Major Lithospheric Plates

There are about 14 major lithospheric plates

Plates are classified as "continental" or "oceanic", but a single plate can contain both continental and oceanic material

Graphic: (top) Garrison Fig. 3.14, (bottom) Map by J.F. Vigil, courtesy of USGS, Smithsonian Institution and US NRL.

How Does Plate Tectonics Work?

Plates move relative to one another, with continental parts of plates being lighter (more likely to "float") than oceanic parts

Lithosphere is generated where plates pull apart and destroyed where plates come together at subduction zones

Graphic: See Garrison, Fig. 3.13.

Earth's Internal Heat – Driving Plate Motion

Radioactive decay in the crust and upper mantle generates heat, keeping the asthenosphere pliable and the lithosphere in motion

This internal heating sets up convection currents in the mantle

Plates are pushed or pulled in response to mantle convection and gravity

Graphics: Garrison, Fig. 3.12. (animation)

What Does the Theory of Plate Tectonics Explain?

Earthquakes

Mountain ranges

Mid-ocean ridges

Island chains

Volcanoes

Deep ocean trenches

Geothermal areas

The age of the seafloor

Ocean sediments

Fossils and rocks

Graphic: The Hawaiian Islands, as viewed by the MODIS Terra Satellite, courtesy of NASA.

Plate Tectonics Affects Life on Earth Every Day

Eruption of Mount Etna, Italy, Oct-Nov 2002. (top left) Agence France-Presse photo, (bottom left) Associated Press, (right) BBC News.

Plate Tectonics in Action

Tectonic events are common:

- at plate boundaries

e.g., volcanoes in Iceland,

earthquakes in Japan

- where new plates are forming

e.g., volcanoes in East Africa where the African plate is splitting in two

Graphic: Lava fountains from the 1980 eruption of the Krafla volcano, Iceland. Photo by G.E. Sigvaldason. Courtesy of USGS.

Types of Plate Boundaries

Convergent - plates come together (lithosphere destroyed)

Divergent - plates move apart (lithosphere generated)

Transform - plates slide by each other (lithosphere not generated or destroyed)

Graphic: Garrison, Fig. 3.14.

Divergent Plate Boundaries: Birthplaces of Oceans

A rift forms where the lithosphere cracks

Plates separate, magma flows upward and hardens to form new rock

A new ocean basin forms

Examples: East Africa, Red Sea, Atlantic Ocean

Graphic: Garrison Fig. 3.17, (animation)

East Africa - The Next New Ocean?

Left: Seismic activity in Africa, courtesy of Incorporated Research Institutions for Seismology.

Top: Lava flows through the streets of Goma, Jan 20, 2002. Associated Press.

Mid-Ocean Ridges and Sea Floor Spreading

Newly formed rocks at divergent plate boundaries are hotter and less dense than surrounding material

These seafloor rocks "sit" up higher than surrounding areas, forming long mountain chains known as mid-ocean ridges

Graphics: (left) Age of the seafloor, courtesy of NOAA (red=young, blue=old). (right) Topography along the East Pacific Rise, showing the higher elevations of the mid-ocean ridge (red) and the lower elevations (blue) of the surrounding terrain.

Motion Along Convergent Plate Boundaries

At convergent boundaries the motion depends on the densities of the colliding plates

Continental crust **less dense**

Young oceanic crust

Old oceanic crust **more dense**

Graphic: The Himalayas, PBS/NOVA.

Subduction Zones: Convergence of Oceanic and Continental Plates

The oceanic plate subducts below the less dense continental plate

Descent of the oceanic plate causes earthquakes

The subducting plate melts into the asthenosphere fueling volcanic activity

Example: West coast of South America

Graphic: Garrison, Fig. 3.21. (animation)

Island Arcs: Convergence of Oceanic Plates

Island arcs form by volcanic activity caused by the subduction of one oceanic plate under another

Example: Islands of Japan

Graphic: Garrison, Fig. 3.23.

Mountain Building: Convergence of Continental Plates

Neither plate is dense enough to subduct

Mountain ranges form where the plates crumple together

Example: Himalayas

Graphic: Garrison, Fig. 3.24. (animation)

Motion Along Transform Plate Boundaries

Plates slide by each other at transform plate boundaries

This motion is also referred to as "shear" or "translation"

Graphic: Garrison, Fig. 3.16.

Faults at Transform Plate Boundaries

Sliding motion causes elastic or brittle deformation

Brittle deformation causes earthquakes

Ex: San Andreas Fault, California

Graphics: (left) See Garrison, Fig. 3.25, (right) Aerial view of San Andreas fault, R.E. Wallace, photographer, courtesy of USGS.

Motion at Plate Boundaries - Summary

<u>Divergent</u> boundaries

Rifting (splitting of a continental plate)

Creation of new oceans (divergence of two oceanic plates)

<u>Convergent</u> boundaries

a) Subduction

Formation of continental volcanoes (convergence of an oceanic and a continental plate)

Island arc formation (convergence of two oceanic plates)

b) No subduction:

Formation of a non-volcanic continental mountain ranges (convergence of two continental plates)

<u>Transform</u> boundaries

Plates slide by each other, sometimes producing intense seismic activity

Preview of Next Lecture

Plate Tectonics and Ancient Oceans

Graphic: CNN, Jan 23, 2003. Photo by the Associated Press.