How Important is Attending Class?

Based on data from previous oceanography classes. (Poor attendance is defined as missing 2 or more classes prior to midterm 1)

Earthquakes and the Structure of the Earth

Earthquakes

What are they?

What do they tell us?

Earth's Internal Structure

Graphic: A fence offset 8.5 feet by the 1906 San Francisco earthquake. Photo by G.K. Gilbert, courtesy of USGS.

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Strange but True…

Deep in the ocean, there are fish that glow

An octopus doesn't have bones and it can fit (almost) anywhere

As you go deeper in the ocean, the fish become more transparent

Some fish don't have eyes

Deep down, it can be below 32^{o}F and not be frozen

Some fish are toxic due to high levels of mercury

There are furry white lobsters

There are animals in the ocean that can switch from male to female as needed

More people have visited the moon than the Marianas Trench

A dead jellyfish can still sting you

Graphics: Gulper eel courtesy of Norfanz, a blind "Yeti Crab" (Kiwa Hirsute) from the South Pacific, AP photo.

Earth's Interior

The Earth is layered, with each layer having different chemical and physical properties

Scientists have learned about Earth's structure by analyzing earthquakes

Graphic: Garrison, Fig. 3.1.

What Are Earthquakes?

Earthquakes are sudden motions of the Earth's crust due to waves caused by faulting or volcanic activity

Two types of seismic waves we'll discuss:

"P waves"

"S waves"

Graphic: (top) Earthquake damage following the Good Friday Earthquake, Alaska, March 1964. Photo courtesy of NOAA, (bottom) See Garrison Fig. 3.5

Seismic Waves: "P" and "S"

"P" (primary) - compression

"S" (secondary) - shear

These and other seismic waves can cause the ground to move more than 10 meters during a large earthquake

Graphic: See Garrison, Fig. 3.3.

How Are Earthquakes Measured?

<u>Seismographs</u> measure displacement of the ground at a particular location

A world-wide <u>seismograph network</u> measures:

- intensity (energy released)

- surface of earthquake location (epicenter)

- depth of earthquake location (hypocenter)

Graphic: (top) Mass and spring seismograph, graphic courtesy of IRIS Education outreach series flier no. 7, (bottom) P and S wave signatures recorded by a seismograph, courtesy of USGS.

Ranking Earthquakes by Ground Motion: Richter Scale

Determining an Earthquake's Location

The delay between the arrival of P and S waves indicates distance to the epicenter

<u>Near epicenter:</u>

S waves received soon after P waves

<u>Far from epicenter:</u>

S waves received much later than P waves

Graphic: Courtesy of IRIS One-Pager Educational Resource No. 6.

Triangulation

If three or more monitoring sites measure the distance to the epicenter, the location of the epicenter can be determined by triangulation

Graphic: Courtesy of IRIS One-Pager Educational Resource No. 6.

Recent Earthquakes

As of Tuesday Sept 1, 9:00 pm

P and S Waves for a Typical (Large) Earthquake

P and S wave spacing increases in time with distance from epicenter

Seismograms Alaska (1540 km)

Washington (5830 km)

Graphics courtesy of IRIS Seismic Monitor

What do P and S Waves Reveal?

P waves travel through solid and liquid parts of the Earth

S waves travel only through solid parts of the Earth

Measuring P and S waves indicates which parts of the Earth are solid and which are liquid

Graphic: P and S wave propagation, courtesy of USGS.

Seismic Waves in a Homogeneous Earth

If the Earth were completely solid and of uniform density...

P and S waves would travel through the Earth along straight lines. Their speed would not change as they travelled

P and S waves from a particular earthquake would be detected everywhere on Earth

Graphic: Garrison, Fig. 3.4a.

Seismic Waves in a Density-Stratified Earth

If the Earth were completely solid, but more dense in the center...

P and S waves would bend and change speed as they travelled through the Earth

P and S waves from a particular earthquake would be detected everywhere on Earth

Graphic: Garrison, Fig. 3.4b.

P and S Wave Motion, solid Earth

"S" Waves in a Layered Earth

S waves:

- only travel through solids

- cannot travel through the liquid outer core

- cannot reach the inner core

The Earth's core absorbs S waves and produces a large shadow zone where S waves are not detected at the surface

Graphic: See Garrison, Fig. 3.4d.

"P" Waves in a Layered Earth

P waves:

- travel through solids and liquids

- bend as they travel through the Earth

This bending creates a small shadow zone where P waves are not detected at the surface

Graphic: Garrison, Fig. 3.4c (animation)

P and S Waves, Earth with liquid outer core

Seismic Waves - Summary

I. Two types of seismic waves:

- P waves (Primary compressional waves)

pass through solids and liquids

- S waves (shear waves)

only pass through solids

II. Density stratification bends P and S waves as they travel creating shadow zones where waves are not detected

III. A global network of seismographs

- detects of the arrival times of P and S waves

- determines the locations of shadow zones

- reveals internal structure of the Earth

Density - The Concept

<u>Density</u> = relative heaviness of a substance (mass per unit volume)

$\rho = m/v$

Examples: water = 1 g/cm^3

granite rocks = 2.7 g/cm^3

Heavier materials have higher densities

Wave speeds change as they move through materials of different density

Graphic: Deploying an anchor for oceanographic instruments off Antarctica. M.Van Woert, photographer, courtesy of NOAA.

Density Stratification

Layering of materials by density (more dense materials below less dense materials)

Example 1: Icebergs float because ice is less dense than water

Example 2: Rocks sink because they are more dense than water

Graphics: (top) Icebergs near Antarctica, M.Van Woert, photographer. (bottom) Artificial reefs created from concrete pipes, J.P.McVey, photographer. Both courtesy of NOAA.

The Layered Earth

Analysis of seismic waves shows that the <u>Earth is layered</u>

Layers can be classified by:

- chemical properties

- physical properties

Graphic: Garrison, Fig. 3.6.

Chemical Properties of Earth's Layers

Continental crust

mostly granite (2.7g/cm^3)

Oceanic crust

mostly basalt (2.9 g/cm^3)

Mantle

silicon, oxygen, iron, magnesium (~4.5 g/cm^3)'

Core

mostly iron (~13 g/cm^3)

Graphic: Garrison, Fig. 3.6, inset.

Physical Properties of Earth's Layers

Lithosphere

crust and upper mantle

cool and rigid

Asthenosphere

hot, partially melted, slowly flowing part of upper mantle

Lower mantle

hot, but not melted

flows very, very slowly

Core

liquid outer core

solid inner core

Graphic: Garrison, Fig. 3.6, inset.

Can Earthquakes Help Explain the Dynamic Earth?

Earthquakes are not randomly distributed

Observations like this paved the way for a revolution in geology ... the theory of plate tectonics

Graphic: Garrison, Fig. 3.14.

Preview of Next Lecture

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

Graphic: Topography of land and sea.

If you have not turned one in,

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