OCN 201 Laboratory #2: Structures of the Earth and Physiography of the Oceans

Introduction:

This laboratory supports material covered in OCN 201 lectures describing the internal structure of the earth and the physiography of the ocean basins.

A large part of today’s laboratory will involve studying various fundamental physical principles that have been used by geophysicists to elucidate the internal structure (layers) of the Earth as well as to understand how its outer layers function and interact. Some of these topics include the generation and propagation of seismic waves, density, isostasy, how the composition of rocks affects their physical properties, etc.

The laboratory begins with the performance of simple exercises that illustrate how seismic wave propagation can be used to elucidate the structure of the Earth. Hopefully, they will also help you understand the underlying physical concepts (i.e., types of seismic waves and their properties) better. During the exercises, you will be asked to make observations and attempt to explain them in the context of the appropriate geophysical techniques used by earth scientists.

The second exercise focuses on the principle of isostasy and how it helped further our understanding of the structure of the outer layers (lithosphere, crust, asthenosphere) of the Earth. The principle of isostasy, as you will see, is really one of buoyancy.

The third exercise deals with density and is related to isostasy. You will study several solutions of different densities and try to predict how the density of these solutions is related to their composition. Think about how the concept of buoyancy is applied, in this exercise, to determine density.

The composition and structure of rocks vary as a function of conditions that exist in the environment in which they form. Thus, we should expect rocks formed under different conditions or in different areas to also display variations in their physical properties. In the fourth exercise you will observe several samples of rocks and be asked to predict some of their physical properties.

The last portion of the laboratory is concerned with the world’s ocean and its major physical (physiographic) features. This exercise largely involves locating and identifying various features in the ocean on the maps provided for you. It is designed to familiarize you with major features of the ocean, their location, and their distribution. The exercise also builds on the skills (i.e. plotting a course, latitude, longitude, etc.) that you learned in the previous laboratory. Additionally you will be challenged to explain the existence of some of these features, although the principles of their formation may not have been covered in class yet.

Key words: P-waves, S-waves, Density, Isostasy, Buoyancy, Continental shelf, Mid-Ocean ridge, Trench, Island Chain, Island Arc, Back-arc basin, Seamount, Abyssal Plain.
Part 1: Seismology

For this portion of today's lab please read and follow the directions given in the handout (Exercise 17: Earthquakes) taken from the text "Laboratory Manual in Physical Geology" (p. 174-178), 2nd edition published by AGI/NAGT. This exercise takes advantage of the differences in the propagating velocities of P-waves and S-waves generated by earthquakes. The arrival time differences of these waves can be used to determine the focal point (epicenter) of an earthquake.

Part 2: Principles of Isostasy

The rigid outer shell of the Earth, the lithosphere, floats on a softer, semi-fluid, plastic layer known as the asthenosphere, analogous to how wood floats on water. Much like a Fig Newton®, the Earth's outer shell has layers that behave by breaking or stretching. The rigid lithosphere is cracked and broken like the shell of a hard-boiled egg. These broken pieces of the outer shell move around the asthenosphere as the interior of the Earth moves due to convection. Convection results from heating deep in the Earth's core. These moving pieces of lithosphere are known as tectonic plates, the upper-most part of which comprises the Earth's crust. Two types of crust exist: continental and oceanic. Continental crust has a lower density and is “granitic” in composition while oceanic crust has a greater density and is “basaltic” in composition.

Isostasy is the process by which the lithospheric plates, floating on the asthenosphere, adjust vertically to achieve equilibrium. Because oceanic crust has a higher density than continental crust, it adjusts lower in the asthenosphere. The oceanic crust is thinner than the continental crust and thus has less mass to compensate for through buoyant displacement of the mantle. Continental crust is thicker and has a lower density than oceanic crust. Thus, it floats higher and has a lower “root”. This phenomenon is easily explained using a model of a block in a liquid.

Open the web page:
http://atlas.geo.cornell.edu/education/student/topography/isostasy.html

This model allows you to conduct your own isotopic experiments by adjusting the block height and density, and the liquid density. The block root is the height of the block that is submerged in the liquid. Block height and block root are represented by the buoyancy equation:

\[ \text{buoyancy} = \frac{\text{block height}}{\text{block root}} \]
1. The block density can be adjusted using the up and down arrows. Describe what happens if you increase the block density, and leave the other parameters unchanged.

2. What is the maximum block density that will still allow the block to be buoyant (include units)?

3. Imagine the block is representing a mountain range on the Earth’s crust, which is sitting in the asthenosphere. How would the buoyancy change as the mountain weathers? Speculate how long this might take (remember the Earth is ~4.55 Ga).

4. Reset the model. Describe what happens to the block if you:
   a) Increase the liquid density?
   b) Decrease the liquid density?

5. Would you expect the block to rise higher or sink lower in salt water compared to freshwater? Why?

The Density of a substance is its weight per unit volume. This is either expressed in units of grams per cubic centimeter (g/cm$^3$) or grams per milliliter (g/mL). The cm$^3$ and the mL are equivalent units of volume.

The Specific Gravity is the ratio of the mass of a body to the mass of an identical volume of water at a specific temperature (typically 4°C) (unitless).

Thus the density of pure water = 1 g/cm$^3$ and the specific gravity of pure water = 1 (Note: the value of 1 looks like 1,000 on the hydrometer)

a). Fill a graduated cylinder with 200 mL of tap water.
b). Place the hydrometer in the cylinder and record the reading at the air-water interface.

c). Dump the tap water down the drain.
d). Fill the graduated cylinder with 200 mL of saltwater.
e). Place the hydrometer in the cylinder and record the reading at the air-water interface.

f). Carefully pour the saltwater back into the container from which it originated (recycle)

Compare the two values and describe why they are different (what causes the difference).

Given that the normal density of pure water is 1.00 g/cm$^3$ and the normal density of seawater is 1.02-1.03 g/cm$^3$, what can you say about the seawater sample that you measured?

Think about and explain, in a few words, how the “behavior” of the hydrometer, hence the “reading” obtained during the measurements above, is related to density. Predict the position of the hydrometer in a liquid with a density of 0.8 g/mL.
Part 4: Oceanic Crust vs Continental Crust

What observations can be made of rocks of similar sizes and different density? Make detailed observations of samples A-C (Consider: weight, porosity, hardness, etc.)

A.

B.

C.

Based upon your observations of these rocks, predict their densities and list them in order of increasing density. Additionally, guess which is of continental versus oceanic origin.

Part 5: Physiography of the World's Oceans

In this portion of the laboratory you will locate and identify various features on a map of the seafloor as well as answer questions regarding the commonality and location of these features between and within the major ocean basins (Pacific, Atlantic, and Indian).

A). Find and identify the feature located at 45°N, 55°W. Locate other examples of this feature in the Pacific and Indian Ocean basins. Compare their dimensions (how much is present) and speculate why variations exist between the three basins.

B). Find and identify the feature located near 22°N, 155°W. Briefly describe the main differences between this feature and the feature located near 15°N, 145°E. How do these two features differ (speculate).
C). Locate the Mid-Atlantic ridge (MAR) system and provide the range of latitudes and longitudes over which this ridge extends. Estimate the length of the MAR by using a piece of yarn and following the bends and curves in the ridge. What is the latitude and longitude of Iceland and how is it related to the MAR?

D). Examine the Pacific and Atlantic ocean basins on the map provided and name 3 physical features that are commonly present in each basin. Also describe 3 differences between the two basins.

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<thead>
<tr>
<th>Similarities</th>
<th>Differences</th>
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<td>1.</td>
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<td>2.</td>
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E). Indicate which basin has

1) The largest number of seamounts
2) The most deep-ocean trenches
3) Greatest length of mid-ocean ridge
4) Greatest number of island arcs
5) Occurs mostly in one hemisphere

F). Using a piece of yarn and some tape make a straight line (transect) from the tip of India to the Strait of Gibraltar. Identify the major seafloor and coastal structures along this transect and give their respective latitudes and longitudes.

<table>
<thead>
<tr>
<th>Lat and Lon</th>
<th>Structure Name</th>
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<tbody>
<tr>
<td>A). 10°N, 77°E</td>
<td>India (tip)</td>
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<tr>
<td>B). 33°N, 40°W</td>
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<tr>
<td>C). 25°N, 153°E</td>
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<td>D). 30°N, 80°W</td>
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<td>E). 20°N, 155°W</td>
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<td>F). 25°N, 140°W</td>
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<td>G). 15°N, 143°E</td>
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<td>H). 33°N, 45°W</td>
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<tr>
<td>I). 15°N, 130°E</td>
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<tr>
<td>J). 35°N, 15°W</td>
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