**Name:** **Grade:**

# GEOLOGY 101 LABORATORY – LAB #2 – Isostacy and Plate Tectonics

**How Density and Gravity Control Plate Dynamics**

## Part I. Density and Isostatic Equilibrium

**Introduction:** Why does the Earth have continental areas and oceanic areas? Rephrasing the question a bit, why does the Earth's surface divide into two distinct regions of elevation: the **continents** (average elevation about 0.5 miles above sea level), and the **ocean basins** (average elevation about 2.3 miles below sea level)? The answer relates to the fact that Earth's surface is made up of two different types of crust: the **continental crust** and the **oceanic crust**. These two types of crust differ in both their **thickness** and **density**. In this lab, you will see how these two properties control the elevation of the continents versus the ocean basins.

**Relationship between Volume, Mass, & Density**

**Density** is a measure of mass per unit volume. To use water as an example, a gallon (a unit of volume) weighs about 8.33 pounds (a unit of mass). Therefore, the **density** of water is 8.33 pounds per gallon. We can use any measurement of mass and/or volume to express density. Water's density is also 62.4 pounds per cubic foot (62.4 $lbs/ft^3$), 1.0 kilogram per liter (1.0 kg/L), or 1.0 gram per cubic centimeter (1.0 $gm/cm^3$), which is the same thing as 1.0 gram per milliliter (1.0 gm/mL). You measured water's density in the first lab. What did you calculate for water's density?

In this lab exercise, we will use the standard Metric System unit for density, which is **grams** per cubi**c** centimete**r** (**$gm/cm^3$**). To measure the **density** of something in **$gm/cm^3$**, we need to measure both its **mass in grams** and its **volume in cubic centimeters**. Measuring mass is easy; we just weigh the object on a scale. Measuring volume is more difficult. We will measure volume in two ways: by linear dimensions and by water displacement.

**Question 1:** Heft the pieces of hardwood and redwood in your two hands. Which one feels denser (heavier for a given amount)?

**Determine the density of hardwood and redwood.** Weigh the blocks to the nearest gram. Then use a ruler to measure, in centimeters, the length, width and height of the blocks. Make all measurements to the first decimal place (0.1).

**Hardwood:** **Weight:** _____gm **Length:** _____cm **Width:** _____cm **Height:** _____ cm

**Volume:** (length x width x height): ________ $cm^3$

**Density:** (weight / volume): ______________ $gm/cm^3$ (round to nearest 0.01)

**Redwood:** **Weight:** _____gm **Length:** _____cm **Width:** _____cm **Height:** _____ cm

**Volume:** (length x width x height): ________ $cm^3$

**Density:** (weight / volume): ______________ $gm/cm^3$ (round to nearest 0.01)

**Question 2:** The density of water is 1.0 $gm/cm^3$. Comparing the density of water to the density of hardwood and redwood, predict what proportion (percent) of your blocks will stick up out of the water when the pieces of wood are floating.

**Hardwood:** _________ % of the block will be underwater, and ________ % will stick out of the water.

**Redwood:** _________ % of the block will be underwater, and ________ % will stick out of the water.

**Question 3:** Take the pieces of hardwood and redwood and float them in water. Do your predictions in #3 above fit with what you see?

Draw below a simple side-view sketch of the two blocks across the waterline, labeling each block and showing how different proportions stick above the water. Label the %'s of each block on the sketch. (Note: Keep this observation in mind when you do the final part of the lab.)

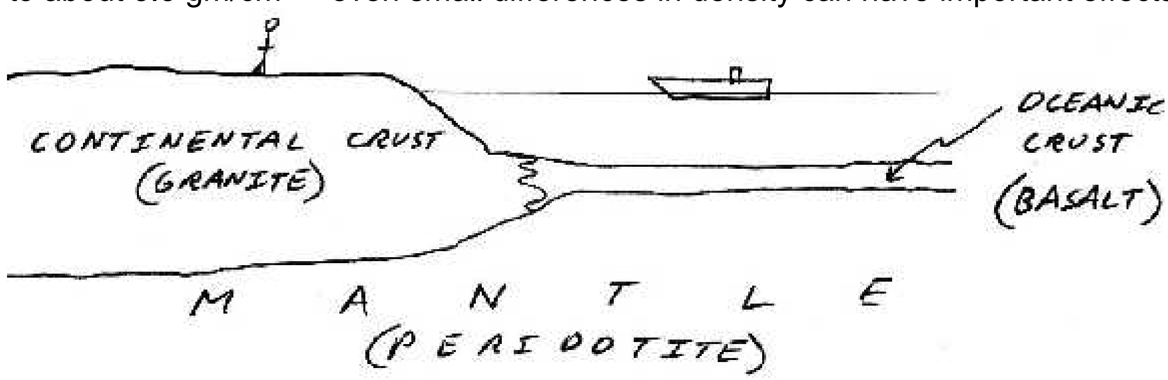
_________________________________________________________________ water line

**Question 4:** Think about what you saw with the blocks of wood floating. What effect did the difference in density between the two types of wood have on how high each one floated?

**ISOSTATIC EQUILIBRIUM OF THE EARTH'S CRUST**

In this part of the lab, we will see how differences in the density and thickness of rock control the elevations of the Earth's crust. We'll also see how the crust adjusts when loads of weight are added or taken away.

The Earth is made up of two kinds of crust: continental crust and oceanic crust. **Continental crust**, which is mostly **granite** and rocks of similar density, makes up the continents. **Oceanic crust** is mostly the rock **basalt**, which makes up the floors of the ocean basins. Both types of crust lie on the Earth's **mantle**, which is mostly the rock **peridotite**. The illustration below shows that the continental crust and the oceanic crust have different thicknesses. Continental crust averages about 22 miles thick (more underneath mountains), while oceanic crust averages about 5 miles thick. The two types of crust, and the underlying mantle, also differ in their density. Most Earth rocks range in density from about 2.6 to about 3.3 gm/cm$^3$ -- even small differences in density can have important effects.




**Determining the Density of Continental Crust: Granitic Rock**

**Directions: a)** Use a small graduated cylinder and a gram balance (scale) to determine the density of a hand sample of granite by dividing its measured mass by its measured volume, in grams per cubic centimeters (g/cm$^3$). **b)** Use your measurements of water's mass and volume to calculate the density of water as accurately as you can. Note: You must show your complete calculations **<u>and units</u>** for full credit.

**Granite Sample Measurements:** **Rock Mass = ______** grams **Rock Volume = _______** cubic centimeters

**<u>Write Calculations for Granite Sample Below:</u>** Note: ***Density = Mass ÷ Volume*** (don't forget units)

**Density of the continental crust** (use your calculated value above): **________ gm/cm$^3$**

**Density of the oceanic crust (basalt): 3.0 gm/cm$^3$**

**Density of the upper mantle (peridotite): 3.3 gm/cm$^3$**

The geologist Clarence Dutton proposed decades ago that the Earth's two types of crust "float" buoyantly on the mantle, much in the way that an iceberg or a block of wood floats buoyantly in water. He called this condition **isostasy** (Greek for "equal standing"). When the crust floats in a balanced, stable manner in the mantle beneath, we have a condition called **isostatic equilibrium**. This turns out to be a very useful concept, as you will see.

**Question 5:** What is the connection between wood floating in water and the crust (either type) floating in the mantle? Use <u>specific values</u> of density for wood, water, crust and mantle in your answer.

**Question 6:** Imagine a <u>thick</u> block of wood and a <u>thin</u> block of wood, both with a density of 0.5 gm/cm$^3$ floating in water next to each other. Would the tops be at the same level? Why or why not?

Draw <u>accurately</u> a side-view sketch showing how these two blocks would look floating next to each other. Note: "accurately" here means that you need to consider the density of the wood relative to water.

_______________________________________________________________ water line

**Question 7:** Geologists know that the continental crust is much thicker underneath mountain ranges than it is in low areas. Thinking about your answers above, explain why.

**Question 8:** Thinking about all of your answers above, explain why the continental crust stands above sea level while the oceanic crust lies more than two miles (on average) below sea level. Your explanation should take into account both thickness differences and density differences.

**ISOSTATIC ADJUSTMENT**

When the Earth's crust floats in a balanced, stable manner in the mantle, we have a condition called isostatic equilibrium. When this stability is changed by the addition or subtraction of weight, the crust adjusts by sinking down or rising up—a process called isostatic adjustment. Over human scales of time, this process is very slow; but over geologic time it can add up to a lot of change.

**Question 1:** An iceberg is floating in the ocean. A bunch of polar bears jump onto the iceberg. How does the iceberg adjust? All the polar bears jump off. How does the iceberg adjust?

**Question 2:** During the Pleistocene geologic period, ice sheets formed repeatedly over parts of Canada and the northern US. The latest ice sheet reached its maximum size about 21,000 years ago, and the ice accumulated nearly two miles thick in some places. How do you suppose the North American continent adjusted to the weight?

**Question 3:** That big ice sheet has now mostly melted away. How do you suppose the North American continent has adjusted?

**Question 4:** That process of adjustment referred to in #9 above is still going on. Looking at a map of North America, predict where the ice sheet 21,000 years ago was thickest. Explain your reasoning.

**Question 5:** Antarctica is the highest continent, as measured by the average elevation of the surface of its ice sheet. But it is also the lowest continent, as measured by where the rock begins below all of that ice (ice that averages 6600 feet thick!). Explain the connection.

## Part II. The Moving Tectonic Plates and their Dynamic Boundaries

This part of the lab studies the nature and dynamics of Earth's tectonic plates, and associated faulting and earthquake. In this part of the lab you will: 1) Become familiar with the global positions of the major tectonic plates; 2) Evaluate the types of stress and associated faults of each of the three types of plate boundaries; and 3) measure and evaluate plate motions.

**Directions:** Illustrate the major plate tectonic boundaries (see **page 36**; World map provided)

**1)** Draw in the three different plate boundaries found worldwide according to boundary type.

**2)** Draw and label each of three boundary types with a different color (red, blue, and black)

**3)** Label (by name) each of the major tectonic plates – 14 plates total

**4)** Draw motion arrows to show the relative motion of the Pacific and North American Plates

## Characteristics of Plate Boundaries

**Directions:** Complete Columns "B", "C" and "E" shown on page 34 using the answer sheet below

**Column A:** Block illustrations of three types of crustal faulting (type named in column D)

**Column B:** General type of crustal deformation associated with type of faulting.

**Column C:** The names of the major types of faults (see column "A").

**Column D:** The names of the major types of faults (already provided) (see column "A").

**Column E:** The type of plate boundary associated with "A", "B", "C", and "D").

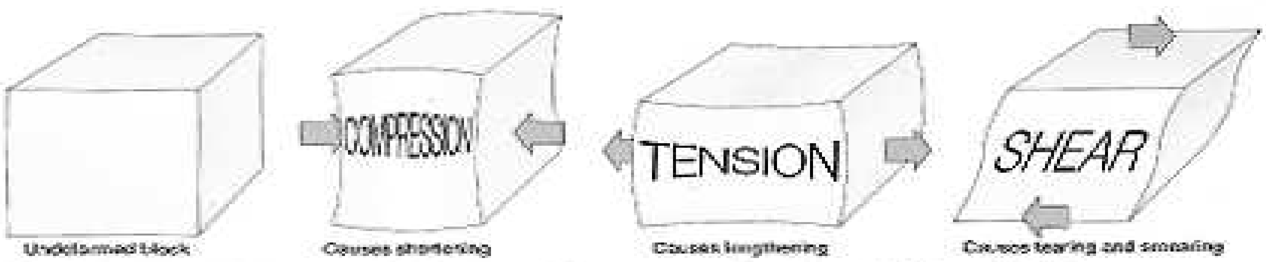



FIGURE 2.2 Three kinds of stress (applied force, as indicated by arrows) and the strain (deformation) that they cause in an undeformed block of rock.

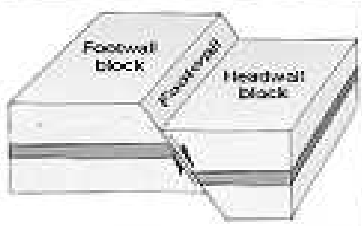
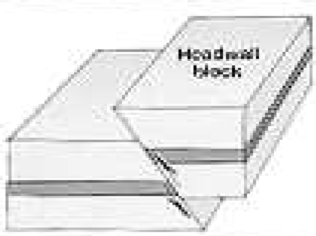
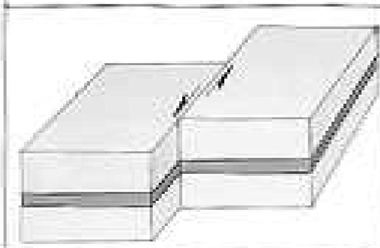
| A. Block diagram | B. Has the crust: • Shortened? • Lengthened? • Neither? (Question 1) | C. Was the stress: • Shear? • Compression? • Tension? (Question 1) | D. Fault type | E. Is the plate boundary type: • Transform? • Divergent? • Convergent? (Question 4) |
|---|---|---|---|---|
|  | | | Normal fault | |
|  | | | Reverse fault | |
|  | | | Strike-slip fault | |

FIGURE 2.3 Chart for comparing fault types (columns A and D) to stress (column C) and strain (column B) in Question 1 and to plate boundary types (column E) in Question 4.

## Measuring and Evaluating Plate Motions

Earth's lithospheric plates slowly move laterally over the asthenosphere – driven by a combination of heat, gravity, and differences in rock density. Geologists use several methods to establish plate velocities, which includes both speed and direction. One method is to analyze hot spot traces. Another method analyzes the age-dated magnetic strips patterns imbedded in the seafloor's basalt. Yet another method looks at the offset along transform faults. In all three cases, the two pieces of data that need to be collected to calculated plate motion are distance and time – to get plate motion rate you divide distance by time as centimeters per year.

**Directions:** Complete the following exercises. (See **page 42** in you lab manual for directions for each specific plate motion exercise)

1. **The Hawaiian Islands and Pacific Plate Motion** (See Exercise 15 on page 42; Figure 2.10)

   **a)**

   **b)**

   **c)**

   **d)**

   **e)**

   **f)** Draw a large arrow and rate-of-motion value on your personally constructed Plate Tectonic Map near Hawaii to show the direction and speed of the Pacific Plate.

2. **Yellowstone Hot Spot and North American Plate Motion** (See Exercise 16 on page 44; Fig 2.11)

   **a)**

   **b)**

   **c)** Draw a large arrow and rate-of-motion value on your personally constructed Plate Tectonic Map near Yellowstone to show the direction and speed of the North American Plate.

**3. San Andreas Fault Motion** (See Exercise 19 on page 46; Figure 2.12)

**a)**

**b)**

**c)**

**d)**

**e)** Draw two large arrows and rate-of-motion values on your personally constructed Plate Tectonic Map on opposite sides of the San Andreas Fault to show the direction and speed of both the Pacific and North American Plates.

## Part III. - Post Lab Exercise: Laboratory Reflection

**Directions:** Write a 120 word minimum reflection of the lab activity, explaining its purpose, the methods used, the results obtained, and a brief personal reflection of what you enjoyed and learned about doing this lab (*3 points possible*). Answer the following 3-point question reflection set on a separate sheet of paper:

***1) What was the purpose of this lab? What did you actually discover and learn during this lab?***

***2) What did you enjoy most about this lab? Also, what was challenging or thought-provoking?***

***3) What are your constructive comments about the design and execution of this lab? What's good? What's bad? Offer suggestions for making the lab better.***