ES 106 Laboratory # 4
THE DYNAMIC OCEAN FLOOR
Sea Floor Topography and Paleomagnetism

Introduction

One of the most significant scientific revelations of the 20th Century is the fact that the ocean basins are geologically young, ephemeral features. Based upon this discovery, a revolutionary theory called plate tectonics has been developed that helps to explain and interrelate earthquakes, mountain building, and other geologic events and processes.

The theory of plate tectonics is the foundation used by Earth scientists to help explain the origin of mountains and continents, the occurrence of earthquakes, the evolution and distribution of plants and animals, as well as many other geologic processes. Using information from the ocean basins, including topography, age, and mechanisms of their evolution, Earth scientists have developed the exciting theory called plate tectonics. Plate tectonics states that Earth's surface is broken in to rigid slabs of lithosphere called plates. The plates are separating at mid-ocean ridges, where new ocean crust is forming. Along the plate margins, earthquakes are generated as plates slide past each other, collide to form mountains, or override each other causing deep-ocean trenches. This laboratory examines some of the lines of evidence that have been used to verify this comprehensive model of the way Earth scientists view our dynamic Earth.

Goals and Objectives

- Locate and describe the general features of the ocean basins with an emphasis on locating and describing the mid-ocean ridge system and deep-ocean trenches
- Determine the rate of sea-floor spreading that occurs along a mid-ocean ridge by using paleomagnetic evidence and determine age of ocean basin

Useful Websites

- http://www.pmel.noaa.gov/vents/nemo/explorer/concepts/pillows.html
- http://earthsci.org/education/teacher/basicgeol/platec/platec.html
- http://www.platetectonics.com/oceanfloors/index.asp
- http://visibleearth.nasa.gov/view_set.php?categoryID=871
- http://www.intute.ac.uk/sciences/worldguide/worldmapbig/385.html
- http://www.metric-conversions.org/

Name_____
Lab Day/Time_____

Pre-lab Questions – Complete these questions before coming to lab.

1. Describe each of the following ocean floor features:
   A. Mid-ocean ridge

   B. Deep-ocean trench

   C. Continental shelf

   D. Continental slope

   E. Abyssal plain

   F. Seamount

2. Suppose that the ratio scale on a map is 1:50,000. This means that 1" on the map represents 50,000" on Earth's surface. If you measure the following distances on the map using a ruler, you can convert the map distances to the real world distances with the ratio scale, and change units with conversion factors. Do this for the distances indicated below. Remember to show the formulas with units that you used to convert these values. Conversion factors can be found in the appendix of your textbook.

   A. 3 inches = _____ miles

   B. 2 cm = _____ km

   C. 10 cm = _____ miles

Part A – Ocean Basin Topography

Understanding the topography of the ocean basins has been critical to developing the theory of plate tectonics. In the mid-20th century oceanographic research vessels mapped the sea floor and by the 1960s research concerning rock magnetism, the cause and distribution of earthquakes, and the age of ocean sediments lead to the development of the theory of plate tectonics.

Various features are located along the continental margins and ocean basin floor. Study the *World Ocean Floor* maps of the *Pacific Ocean* and the *Atlantic Ocean*, and *The World: Physical* map to answer the following questions. (Refer to your textbook as needed.)

1. From the *Atlantic Ocean* map, what is the approximate average ocean depth along the continental shelves bordering North America?

2. Approximately how high above the adjacent ocean floor does the Mid-Atlantic Ridge rise? (Hint: You have to subtract to get this answer.)

3. Give an average depth for a sampling of trenches from the *Pacific Ocean* map, to approximate how deep most of the deep-ocean trenches are.

4. Write a brief statement comparing the width of the continental shelf along the east coast, west coast, and gulf coast of North America, as viewed on *The World: Physical* map, or comparing the *Atlantic Ocean* map and the *Pacific Ocean* map.

5. How would you describe the general topography of the abyssal plains? What do you suppose is the composition of the abyssal plains?

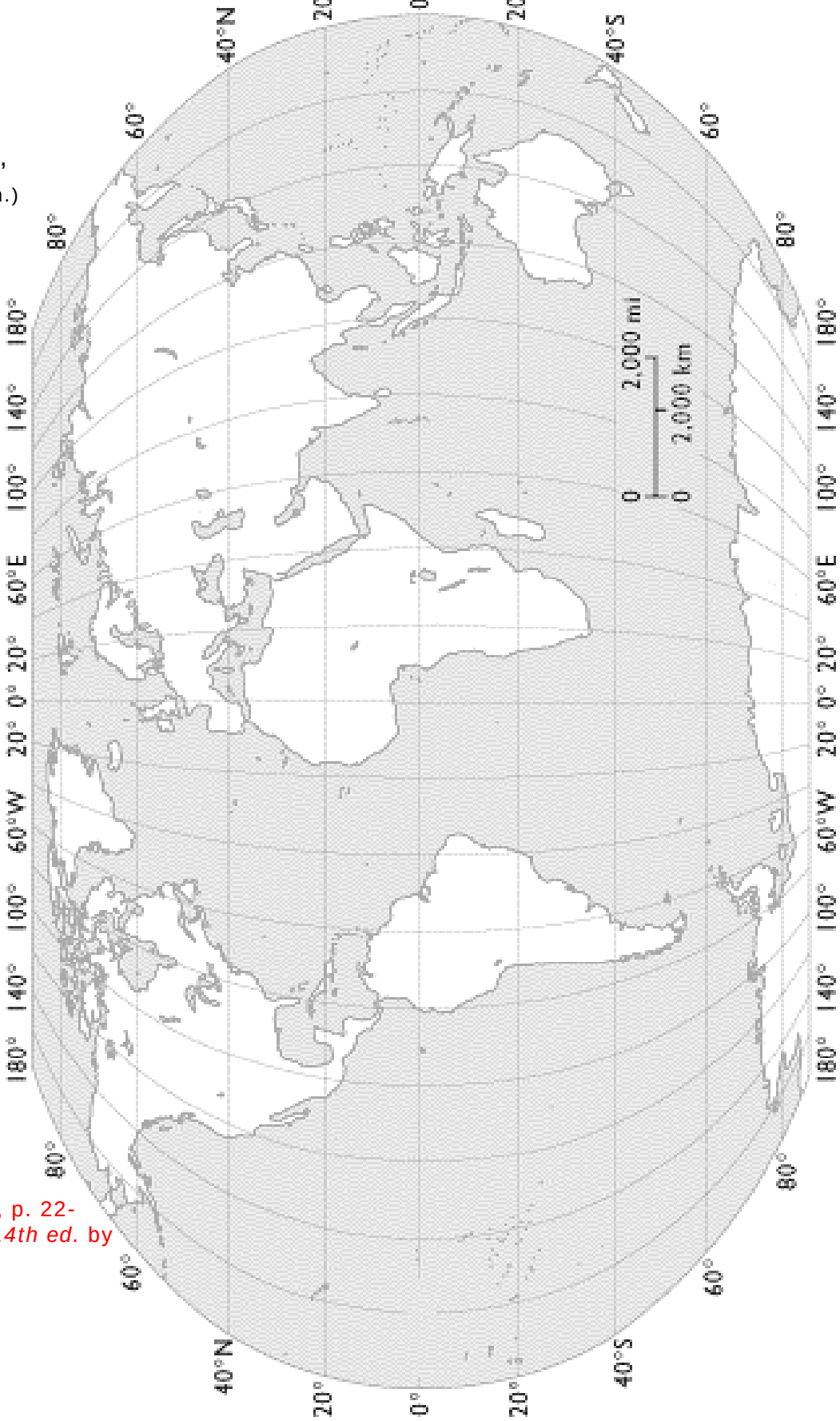
6. What do seamounts represent? What is the generally accepted explanation for the numerous seamounts that dot the Pacific Ocean deep-ocean basin floor?

On the world map below, **draw the global ocean ridge system in <u>red</u>**.

Label each trench with its <u>name</u>.

Locate on the map and **draw a <u>blue</u> line** to represent the trenches listed below.

Puerto Rico,
South Sandwich,
Middle American,
(same as Central Am.)
Peru-Chile,
Aleutian,
Kuril,
Japan,
Mariana,
Tonga,
Kermadec,
Java
Ryukyu



(Hint: see Fig. 1.20, p. 22-23, *Earth Science, 14th ed.* by Tarbuck, et al.)

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Part B – Paleomagnetism and Sea Floor Spreading

The critical evidence for sea-floor spreading is based on studies of changes in Earth's magnetic field through time. Some minerals in igneous rocks (e.g. magnetite) become aligned with Earth's magnetic field at the time of their formation. From detailed paleomagnetic and geochronological studies, geologists have discovered that the polarity of Earth's magnetic field has periodically reversed, meaning that the north magnetic pole becomes the south magnetic pole and vice versa. The sequence of reversals occurring in the past several million years has been dated with the use of radiometric techniques, represented in Figure 1.

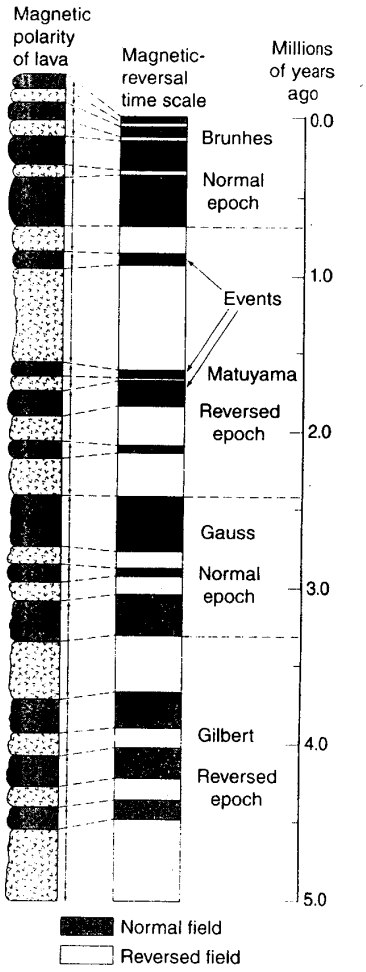


Figure 1: Schematic illustration of magnetic polarities of lava flows used to construct a time scale of magnetic reversals over the past 5 million years.

Study Figure 1 and answer the following questions.

1. How many times has the magnetic field of Earth reversed (changed orientation) in the past 5 million years? _____ times (total number of changes).
2. Approximately how long ago did the current normal epoch (Brunhes Normal epoch) begin? _____ years ago.
3. Two million years ago, what direction would a compass needle have pointed – north or south? _____
4. Based on the pattern, does it appear as though Earth is due for another magnetic polarity reversal in the near future? Briefly explain your reasoning.

Activity: Calculate rate of spreading and age of ocean basins.

As tectonic plates separate along a mid-ocean ridge, magma from the mantle rises to the surface and creates new ocean floor. As the magma cools, the minerals assume a magnetic orientation equal to the prevailing magnetic field. The plates continue to separate and if Earth's magnetic field reverses polarity, new material forming at the ridge is magnetized in the opposite direction. This process results in magnetic striping of the ocean crust running parallel to the mid-ocean ridge.

Earth scientists can measure the magnetic striping by towing a device called a magnetometer behind a ship. The magnetometer records the strength of the magnetic field in a given location. Figure 2 shows magnetic records for the South Atlantic Ocean basin and the North Pacific Ocean basin. Where the rocks have the same magnetic polarity as the present-day field, we find stronger than average magnetic field (represented as a peak called a positive anomaly); where the rocks preserve reverse polarity, we measure weaker than average magnetic field (represented as a trough called a "negative anomaly").

Using the known time scale of magnetic reversals, we can determine the age of a magnetic anomaly. By dividing the distance from the ridge crest to the magnetic anomaly by the age of the magnetic anomaly, we can determine the spreading rate at the ridge.

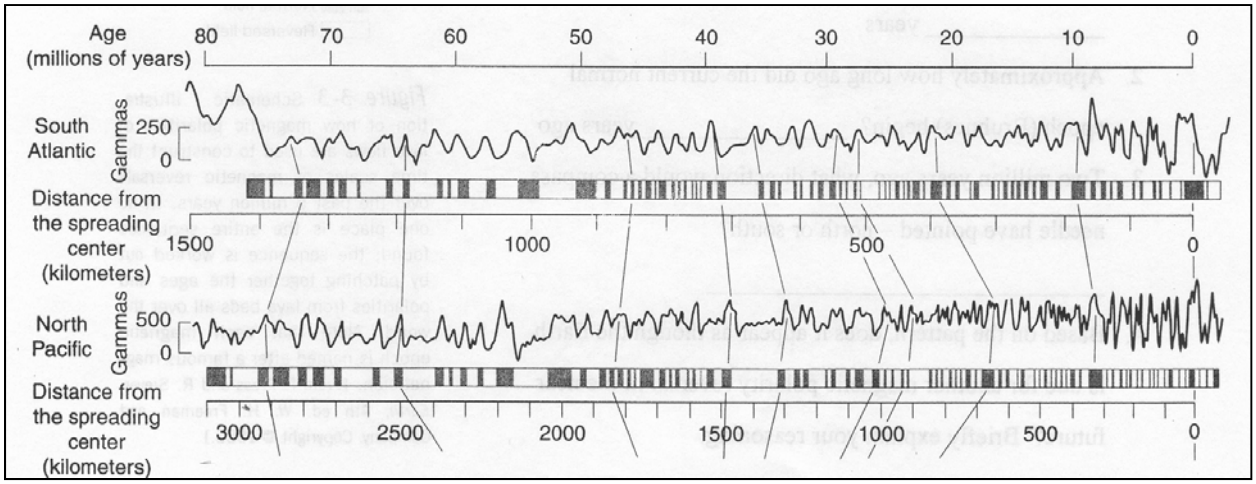
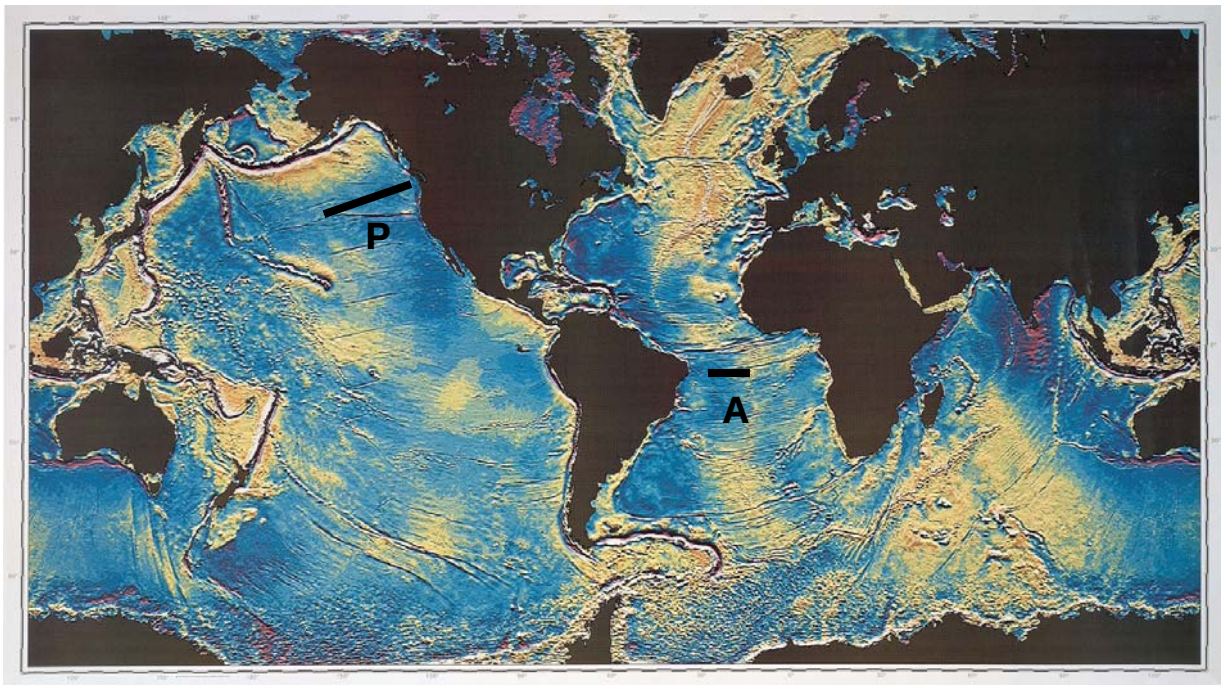


Figure 2: Magnetic anomalies (the peaked curves) recorded perpendicular to spreading centers (ocean ridges) in the major ocean basins reveal a similar sequence of magnetized rocks. **Note**: this figure shows only the ocean floor basins from the ridge toward the western side of the ocean basin to the "0" representing the location of the spreading center (oceanic ridge).

Figure 3: Image of ocean floor with the location of the magnetic anomaly profiles shown.

P: North Pacific Profile **A**: South Atlantic Profile



http://www.britannica.com/EBchecked/topic-art/175962/394/Gravity-map-of-the-worlds-ocean-basins-compiled-from-Seasat

Use Figure 2 to answer the following questions:
Start by drawing a line on Figure 2 at 50 million years, across the anomalies

1. Using the distance scale in Figure 2 which ocean basin has undergone the greatest amount of spreading in the last 50 million years, the Pacific or the Atlantic?

   _____

2. How far in kilometers are the 50 million year-old rocks on the left side of the South Atlantic Ocean basin from the oceanic ridge?

   _____ km

3. How far in kilometers the 50 million year-old rocks on the left side of the North Pacific Ocean basin from the oceanic ridge?

   _____ km

The distances in the questions above are for only one side of the ocean basin (in this case to the left of the ridge). Assuming that the ridge spreads equally on both sides, the actual distance each ocean basin has opened would be twice this amount. With this in mind, answering the following:

4. How far in **total** has each ocean basin opened in the past 50 million years? (Multiply by 2…then convert to cm by multiplying by 100,000.)
   a. South Atlantic Ocean basin - _____km= _____cm
   b. North Pacific Ocean basin - _____km= _____cm

By knowing both the distance that each ocean basin has opened and the time it took to open that distance, the rate of sea-floor spreading can be calculated. Divide the total distance opened (in centimeters) by the number of years. (Useful conversion factors: 1 km = 1000 meters, 1 m = 100 cm)

5. Determine the spreading rate in centimeters per year for the two areas shown in Figure 2. (Show formulas for calculations, with units.)
   a. **South Atlantic**

   b. **North Pacific**

What rate did you calculate for the **South Atlantic Ocean**? _____.
Use it to calculate an estimate of how many millions of years ago the North Atlantic and South Atlantic Ocean basins began to form by following the instructions below.

6. On *The World: Physical* map, find the ratio scale 1:_____

South Atlantic Basin Information	**North Atlantic Basin Information**
7. Record the map distance (in centimeters) between the seaward edge of the continental shelf along eastern South America off of Brazil directly eastward to Africa.	8. Record the map distance (in centimeters) from the eastern edge of the continental shelf near North Carolina on North America to the seaward edge of the continental shelf along at Mauritania (20°N latitude) on northwestern Africa.
Multiply the centimeter distance by the map ratio scale. This gives the distance in centimeters across the Atlantic Ocean in the real world. (Show formulas for calculations, with units, below for each location.)	
9. South Atlantic Basin width	10. North Atlantic Basin width
To determine the age of the ocean basin, **divide the distance** in cm (#9, 10) between the continental shelves **by the rate** of **Atlantic** sea-floor spreading in cm/yr (recorded above). (Show formulas/units, in the box.)	
11. South Atlantic Basin age	12. North Atlantic Basin age

13. Jurassic rocks (basalt dikes and lava flows) occur in New Jersey. These are interpreted as rocks that formed when North America and Africa rifted apart. Why would you expect to find volcanic rocks associated with the onset of rifting? (See Fig. 9.33 B & F, pages 308-309, Tarbuck, et al., *Earth Science* 14th ed).

14. Is your calculated age consistent with this geologic data? Refer to the geologic time scale on the last page of this lab manual. Explain your answer.

Part C – Pillow Lavas

Watch the brief video snippet of pillow lavas erupting near Hawaii on the computer, see the 'useful website':
http://www.pmel.noaa.gov/vents/nemo/explorer/concepts/pillow_lava.html

1. Study the sample of pillow lava in the classroom. In the space below, sketch and describe the sample, making particular note of the texture (grain size) of the margins compared to the center of the rock.

2. Interpret how the pillow lava formed.

3. Pillow lavas can be observed at several locations in the Coast Range of western Oregon, including on Mary's Peak west of Corvallis and in Depoe Bay. What does the presence of pillow lavas on peaks in the Coast Range tell us about the geologic history of the Coast Range? (Did the sea used to be that deep, or is there a piece of sea floor uplifted by convergent tectonic processes?)

Name_____

Lab Day/Time_____

POST-LAB ASSESSMENT

1. In the space here, sketch a general profile of an ocean floor between two continents illustrating a mid-ocean ridge and a deep-ocean trench. Label each and show relative plate motions with arrows.

(Hint: see Fig. 9.33, p. 308-309, Tarbuck and Lutgens, Earth Science, 14th Edition)

2. Imagine that you were to take a deep diving submersible to a mid-ocean ridge. What would be the chemical composition of the lava rocks that you would find (basalt, andesite, or rhyolite)? What shapes would the lava have?

3. A geologist claims to have found a sequence of rocks that was formerly a piece of ocean crust up in a mountain range. What types of rocks would you expect to find in the sequence? (What types of rocks would be on the bottom of the sequence? What types of rocks would sit on the top of the sequence?)

4. If an ocean is opening at a rate of 5 cm/yr, how wide will the ocean be in 125 million years? Give your answer in kilometers. (Show formulas for calculations, with units)