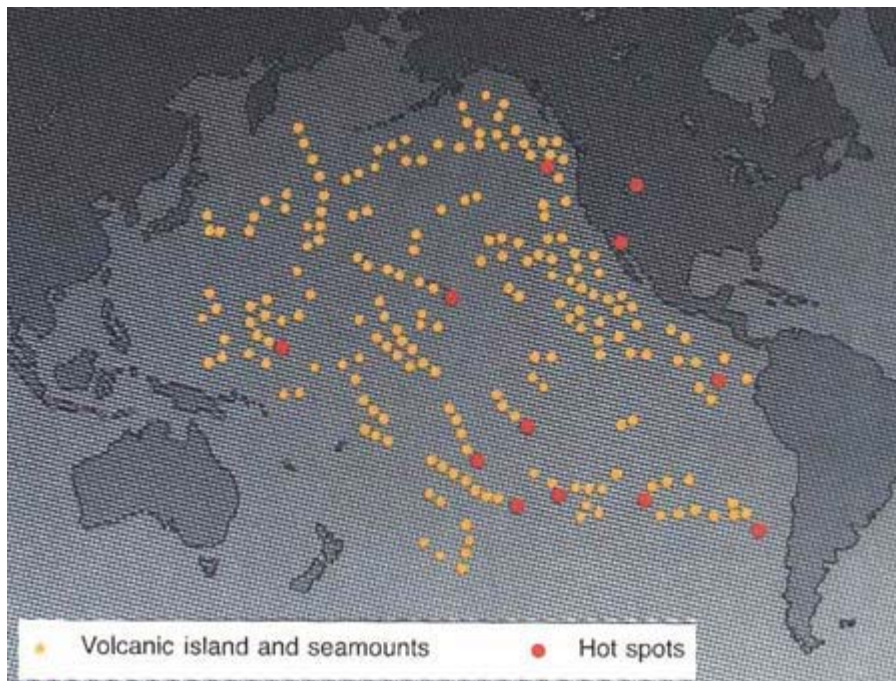


The Seafloor

- Features of the ocean floor
 1. Deep ocean floor is basalt
 2. Abyssal plain: sediments & seamounts
 3. Hot spots
 4. The seafloor's paleomagnetic record
 - Sediments of the ocean floor
-

1. **The deep ocean floor** is basalt rock—a black igneous rock formed from magma rich in iron and magnesium. Basaltic magma is produced at divergent plate boundaries located along the mid-ocean ridges bordering the abyssal plain. The magma is the result of convection currents in Earth's mantle rising to the base of the lithosphere at divergent plate boundaries. As new ocean floor is created by the cooling basaltic magma the plates move away (diverge) from the mid-oceanic ridge.
2. **The abyssal Plain** is the deep ocean floor, characterized by thick sediments, particularly red clays and oozes, covering the basalt substrate. Underwater volcanoes called **Seamounts** dot the abyssal plain. Many appear to be arranged in seamount lines.
3. **Hot Spots:** Hot spots are a form of volcanism. Seamounts are associated with hotspots that are thought to result from mantle plumes, columns of magma rising from the upper mantle. If the overlying plate is weak, some of the magma breaks through to form a volcano.



Hawaii is perhaps the best known hotspot. Most hotspots are located under plate interiors (for example, the African Plate), but some occur near diverging plate boundaries. Some are concentrated near the mid-oceanic ridge system, such as beneath Iceland, the Azores, and the Galapagos Islands. A few are thought to exist below the North American Plate, for example Yellowstone National Park is presumed to be a hotspot under continental crust.

In the above figure note that most oceanic hotspots have a tail of volcanic islands and seamounts.

1. The Hawaiian -Emperor Chain of Islands and Seamounts are a prominent feature of the Pacific Ocean floor. Their geometry provides a key to the direction(s) and rate(s) of movement of the Pacific Plate over a stationary hotspot. Locate this feature on a map/globe of the Pacific Ocean floor.

*Sketch this entire 6000 km feature in the box below labeling Hawaii (a.k.a. The Big Island) on the southeastern end of the chain. Include the Aleutian Trench in your sketch.



Rocks on Hawaii have been radiometrically dated to be from .8 million years (m.y.) old to brand new. Maui's rocks are all less than 1 m.y.; Molokai's rocks are 1.3-1.8 m.y; Oahu's rocks are all 2.2 to 3.3 m.y.; Kauai's rocks are all 3.8 to 5.6 m.y. At the northernmost end of the Emperor Seamount Chain of volcanoes, the Detroit Tablemount is roughly 67 million years old. All the seamounts and islands in the chain formed at the same stationary hot spot now beneath Hawaii.

*Applying plate tectonic theory to the Hawaiian – Emperor Chain of Islands and Seamounts, in what compass direction is the Pacific Plate presently moving?

*Place an X on your sketch indicating the next Hawaiian island expected to appear over the hotspot in approximately a million years.

* Northwest of Midway Island there is an elbow bend in the Hawaiian-Emperor Seamount Chain of Islands. What does this bend indicate about the direction of the Pacific Plate movement? Has the Pacific Plate always moved in the same direction over the hotspot presently beneath Hawaii? (Circle)

YES

NO

* If you answered NO, in what compass direction was the Pacific Plate formerly moving over the hot spot?

* Due to the movement of the Pacific Plate, where did oldest seamounts, no longer on the map, end up (the older seamounts appearing on the map are heading there too)?

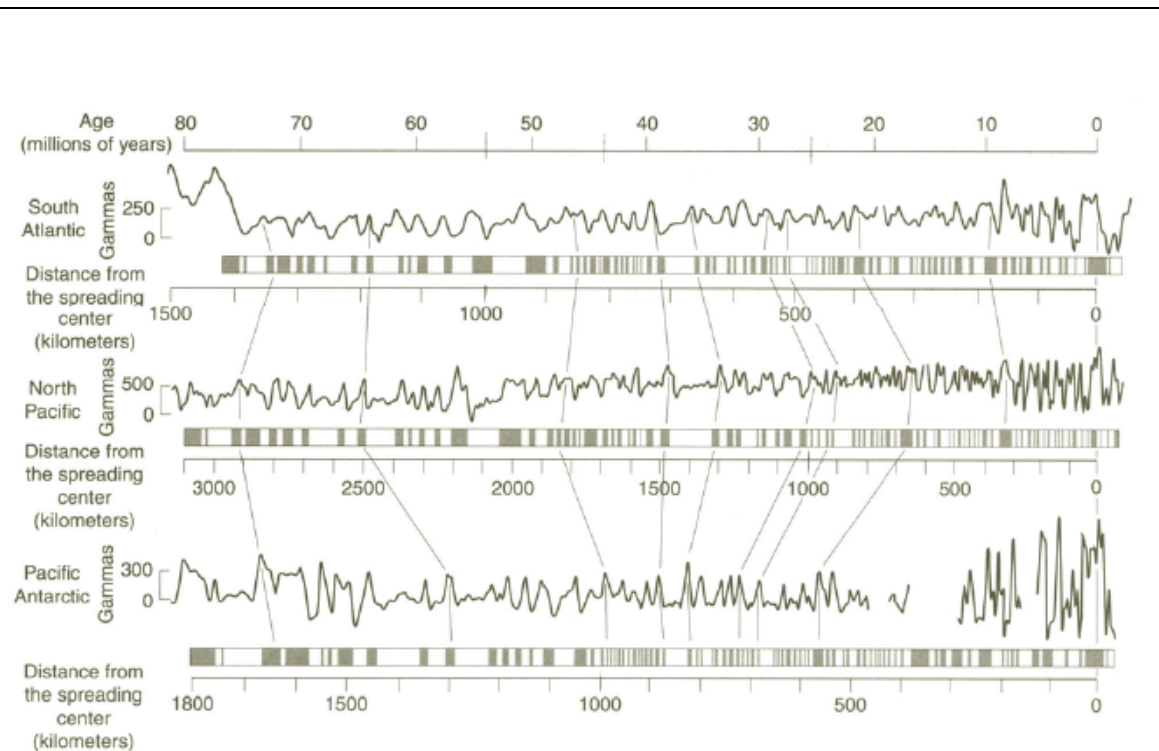


Figure 11: Magnetic anomalies (the peaked curves) recorded perpendicular to spreading centers, or ridges, in the major ocean basins reveal a similar sequence of magnetized rocks. The vertical lines passing through the three curves correlate equivalent magnetic anomalies from different ocean basins. Anomalies are plotted in gammas, which is a measure of magnetic field strength. They are spaced differently because the spreading rates are different at each ridge. However, they all show the same sequence of magnetization.

2a. In the above paleomagnetic record of three ocean floors, the right side is the seafloor at the mid-oceanic ridge; the left side is the edge of the seafloor approaching the continental margin. Over the course of 80 million years which seafloor has moved the fastest from the spreading center?

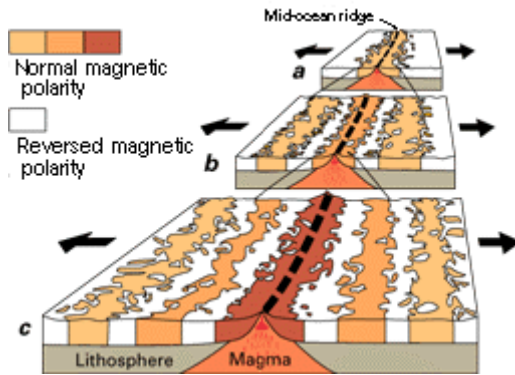
2b. Using the Rate Equation what is its spreading rate in centimeters per year?
(1 kilometer = 100,000 centimeters)

Rate = distance ÷ time

_____ cm/yr

2c. In 2b you actually calculated the half-spreading rate for the sea floor, because you calculated the distance from the mid-oceanic ridge. Double your value to get the spreading rate for the entire seafloor: _____ cm/yr

3. Paleomagnetism and Sea floor Spreading - A case study, ICELAND



The sea floor records magnetic polarity reversals in the geologic past. As new crust is created on the ocean floor (such as at the Mid-Atlantic ridge) it solidifies with its iron oxide acting like miniature compass needles. Presently the iron points to magnetic north. White bands in the figure above represent magnetic reversals where the seafloor iron acts like compass needles pointing south. The magnetic bands on either side of the Mid-Atlantic ridge form a symmetrical pattern out to the edges of the ocean. To determine the distance between the Americas and Europe and Africa at any point since Pangaea, one need only to "roll back" the oceanic crust to the appropriate matching magnetic bands on either side of the ridge.

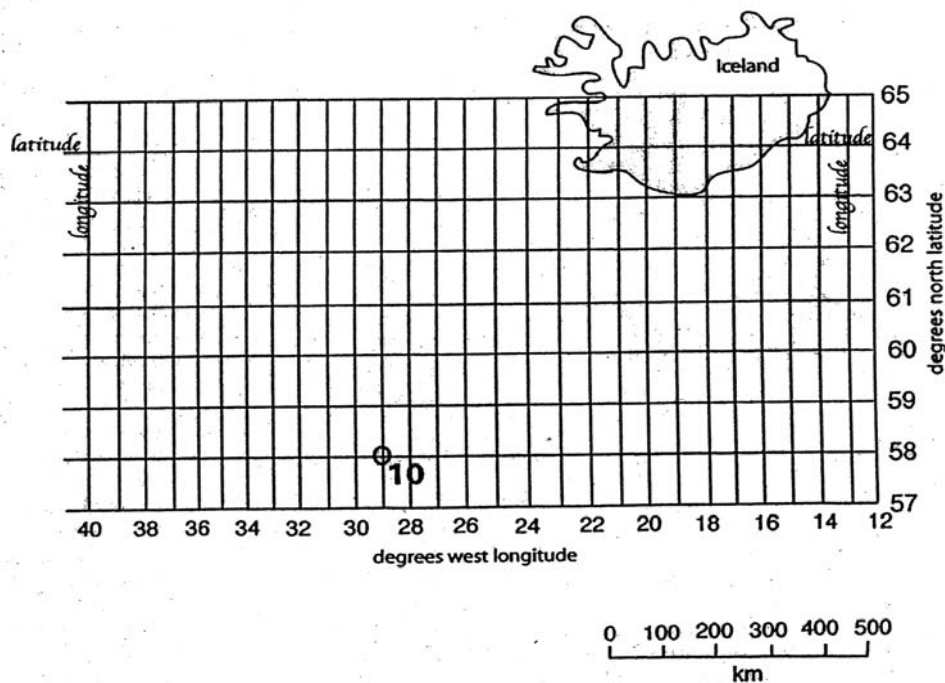
In this exercise you are the resident marine geologist on a cruise to the North Atlantic. You collected magnetic data as you sailed in a zigzag pattern across the Mid-Atlantic Ridge, just southwest of Iceland. Plot your data on the map grid (next page). Use magnetic polarity symbols. After plotting symbols and age color enhance your findings to emphasize magnetic field orientation. You should be able to stripe your data with colored pencils.

TABLE 1. Cruise magnetic data collected southwest of Iceland

Station	North Latitude	West Longitude	Magnetic Field Orientation	Orientation Symbol	Age (Million Years)
1	58.0°	28.0°	Reversed	X	
2	58.0°	29.0°	Normal	O	10 m.y.
3	58.5°	29.5°	Reversed	X	
4	58.5°	31.0°	Normal	O	present
5	59.0°	31.5°	Reversed	X	
6	60.0°	32.0°	Normal	O	10 m.y.
7	61.0°	33.0°	Reversed	X	
8	60.5°	31.0°	Normal	O	10 m.y.
9	60.0°	30.0°	Reversed	X	
10	60.0°	29.0°	Normal	O	present
11	59.5°	28.5°	Reversed	X	
12	59.0°	27.5°	Normal	O	10 m.y.
13	58.5°	26.5°	Reversed	X	
14	59.0°	25.0°	Reversed	X	
15	60.0°	24.0°	Reversed	X	
16	61.0°	24.5°	Normal	O	10 m.y.
17	61.0°	25.5°	Reversed	X	
18	61.5°	26.0°	Reversed	X	
19	61.5°	26.5°	Normal	O	present
20	62.0°	27.5°	Reversed	X	
21	62.0°	28.5°	Reversed	X	
22	62.0°	29.0°	Normal	O	10 m.y.
23	62.5°	30.5°	Reversed	X	

11. On the map below, mark an "X" or an "O" at the location of each station using data from Table 1. Note the "X" indicates reversed magnetism and "O" indicates normal magnetism. Where the age is given (such as Station 2), write this age next to the symbol (using "10" for 10 million years, and "P" for present). Note that station 2 has been plotted for you, with the age of 10 million years plotted right beside the "O" symbol. You can use different colors for the X and O and P if you wish.

Map view



4. OCEAN SEDIMENTS are all the unconsolidated materials on the sea floor, loose fragments of rocks, minerals, ash, or organic material that are transported from their source and deposited by air, wind, ice, or water. Also some sediments are chemically precipitated from overlying water or form chemically in place.

Terrigenous sediment—land derived rock and mineral deposits on the continental margins. The Atlantic Ocean has 20 of the world's major rivers transporting **terrigenous sediment**; the Pacific has 3 major rivers depositing **terrigenous sediment** into it.

Red clay/brown muds – cover 38% of the deep seafloor and 28% of the total seafloor. They are everywhere at depths greater than 4500 meters except in the trenches. These clays are derived from atmospheric dust, volcanic ash, fine grained rock debris from land, and micrometeorites.

oozes- a deep sea sediment consisting of at least 30% of skeletal remains of microscopic floating organisms. The remainder is clay. Oozes are derived from animal and plant remains and are therefore biogenic.

- **siliceous oozes** (rich in $\text{SiO}_2 \cdot n\text{H}_2\text{O}$, opal). are derived from marine protozoa in equatorial waters called radiolarians, and from single-celled plants called diatoms that are most abundant in polar waters.
- **calcareous oozes** (CaCO_3 , limestone and chalk)
 - Foraminiferal ooze – skeletons (tests) of sand-size marine protozoans
 - Coccolith ooze – tiny clay-sized plates and fragments of one-celled plants
 - Pteropod ooze – shells of a pelagic gastropod (snail) not as widely distributed as other oozes.

Note: calcareous ooze will not form below a depth of about 4500 meters; it dissolves below this depth which is known as the **carbonate compensation depth (CCD)**. At the CCD there is a chemical balance at which the dissolution rate of carbonate (CO_3) equals the supply rate. Contributing to the dissolution of carbonate is the corrosiveness of seawater, which increases as temperature decreases, pressure increases, carbonate-ion content decreases, and dissolved carbon dioxide increases. The Pacific generally has a shallower CCD than the Atlantic or Indian Oceans because of its greater carbon dioxide content (colder carbonate dioxide rich Antarctic Bottom Water flows into the Pacific).

Manganese nodules: form where sedimentation is very slow, as in the red clay areas of the abyssal plain. Nodules of manganese grow particle by particle on a nucleus of skeletal material or mineral matter. They are hydrogenous because the manganese chemically precipitates from solution in seawater. Nodules are estimated to cover 10% of the deep ocean floor.

4. On the profile of line AB (Figure 3.4) by the elongate boxed labels, indicate what sediment type one would predictably encounter on the sea floor. Use symbols provided.

Exposed basalt (young) with no sediment covering: **bbb**.

Terrigenous sediments: **+++**

Red Clays: **::**

Siliceous oozes: **~~**

Calcareous oozes: **««**

Manganese nodules: **●●●**

(With respect to the CCD and location of calcareous oozes, note that there are 6 feet/fathom; 1.83 meters/fathom)

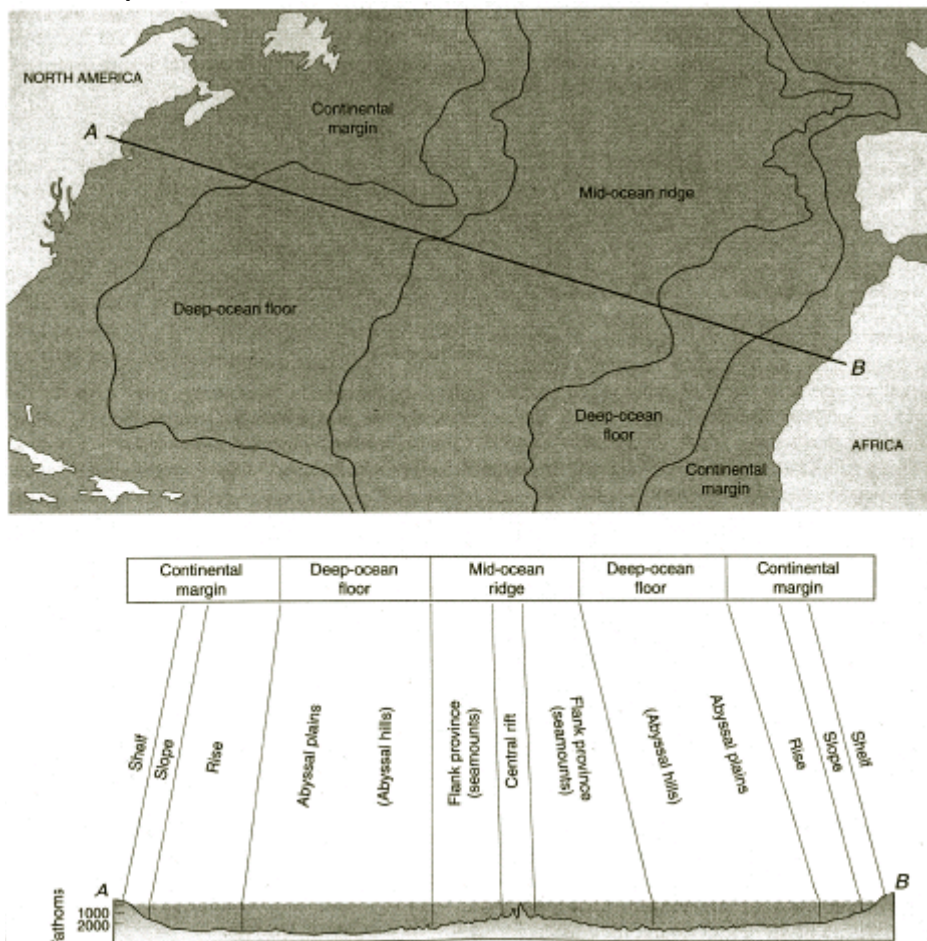


Fig 3.4

Morphological features of the ocean basin. The top part is a simplified map of the Atlantic Ocean basin showing continental margins, the deep ocean floor, and mid-ocean ridge. The bottom is a profile along the line AB detailing features of the North Atlantic Ocean basin. (Heezen, Tharp, and Ewing, GSA Special Paper 65, 1959)

5. Exploratory Ocean Drilling has recovered cores from two different oceans: 9 cores were drilled to sample Ocean A and 7 to sample Ocean B. The drilling log below describes the sediments and rocks recovered from drilling core samples at various depths in each ocean. Included in the description is the length (meters) of sediment recovery.

Core descriptions

Core number	Description	Percentage of calcium carbonate in top 10 centimeters	Water depth (meters)
Ocean A			
1	Fragments of volcanic rock, some ooze	—	1500
2	10 meters of foraminiferal ooze, some volcanic fragments and volcanic ash in top meter	90	2000
3	10 meters of ooze, manganese nodules at top	80	3000
4	9 meters of ooze, manganese nodules at top	75	4000
5	3 meters of reddish clay and ooze over 3 meters of foraminiferal ooze	15	5000
6	8 meters of red clay	3	6000
7	9 meters of red clay	5	7000
8	1 meter of sand grading from fine at the top to coarse at the bottom, over 50 centimeters of muddy clay, over 60 centimeters of graded sand, over 3 meters of red clay	15	4500
9	6 meters of alternating gray clays and brown silts with some fine to coarse sand layers, one sand layer at base with gravel at bottom	—	1000
Ocean B			
10	4 meters of coarse sands and gravels	—	500
11	7 meters of silts with sand and gravel layers averaging about 40 centimeters thick	—	1500
12	9 meters of gray muds with fine sand and silt layers averaging about 20 centimeters thick	—	3000
13	10 meters of gray and brown clays and muds, several fine sand and silt layers 10 centimeters thick	6	4000
14	10 meters of brown mud with a few silt layers about 5 centimeters thick	62	3000
15	10 meters of brownish ooze	78	2000
16	Rock fragments and volcanic ash, rock is basalt	—	1500

5. Working up core log data.

- On the graph below plot the data for percentage calcium carbonate from the table above versus depth for cores 1-16. Use a dot for each sample for Ocean A and a star for each sample for Ocean B (do not connect the dots). If there is no CaCO_3 value, do not plot.

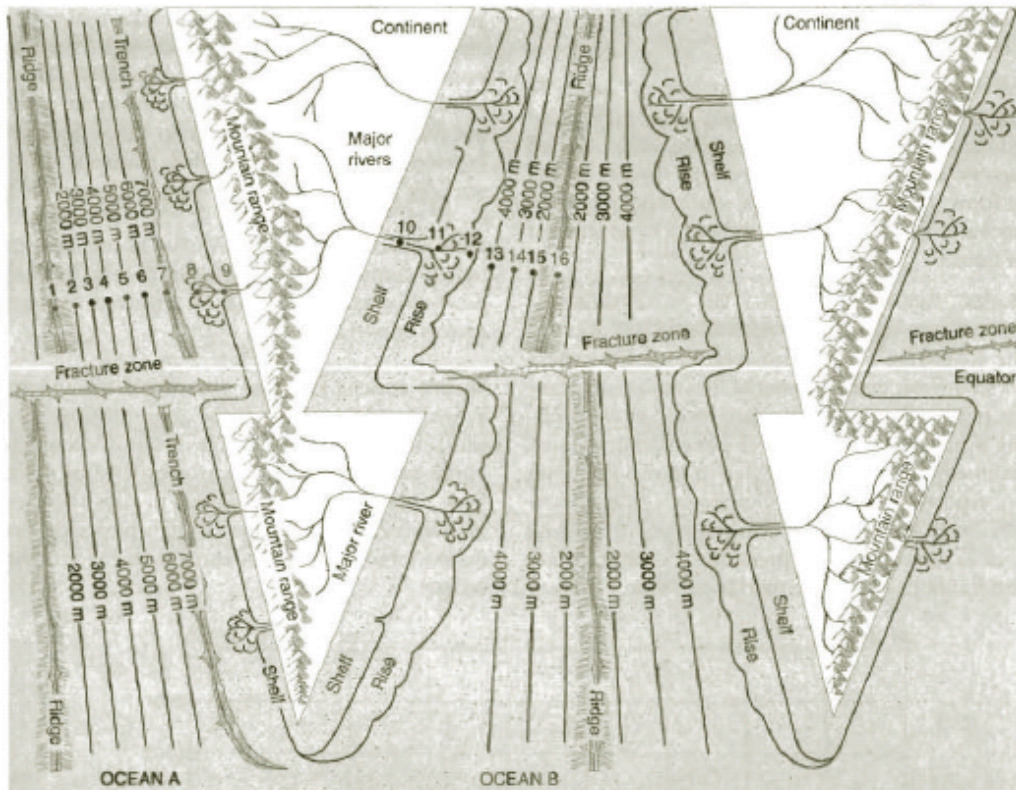
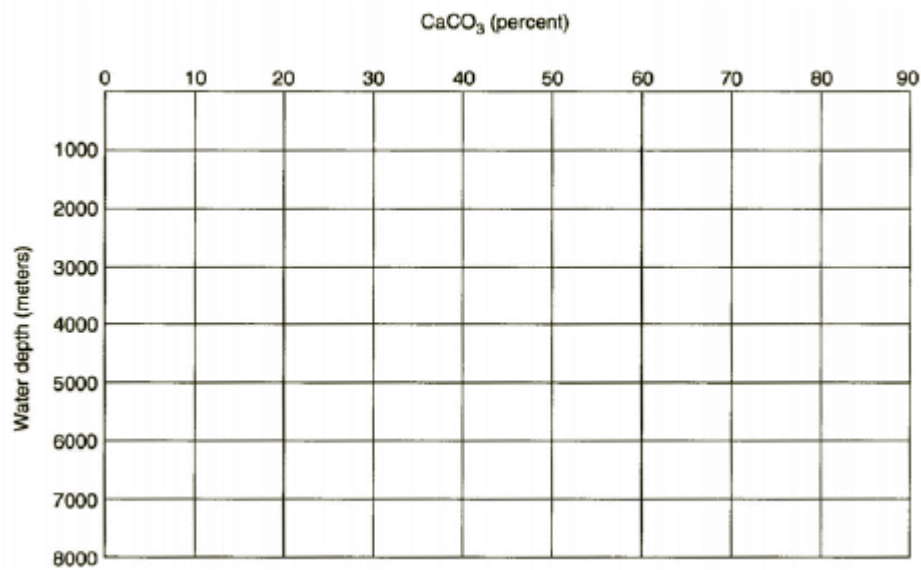
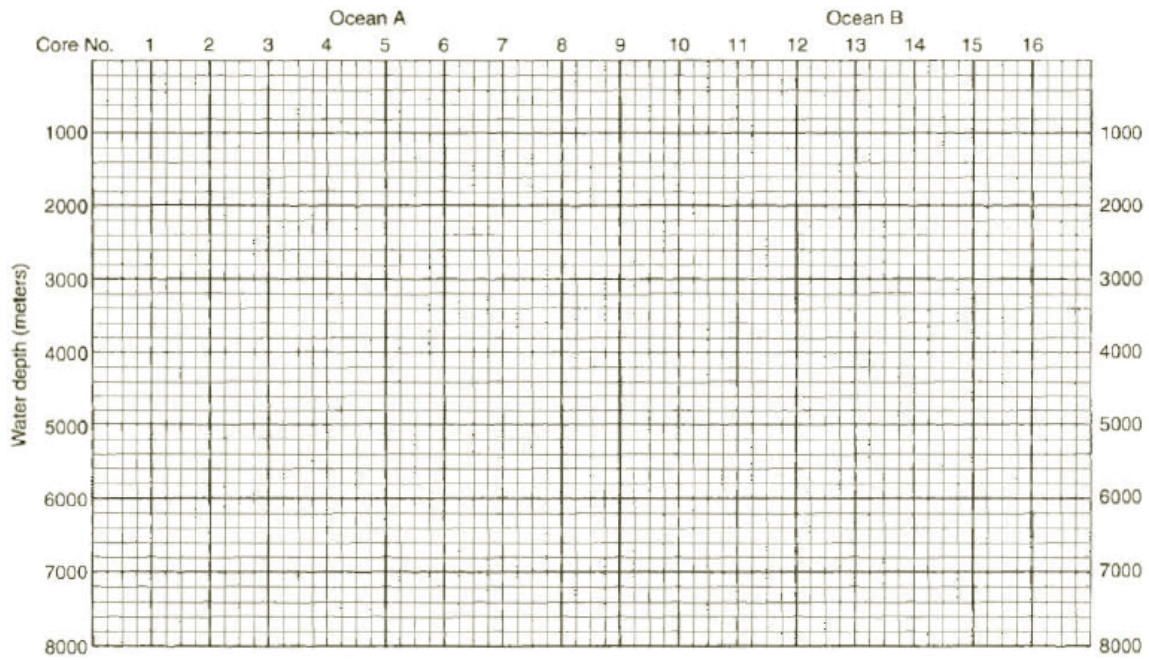


Figure 1: Map of the hypothetical ocean basins showing locations of sea floor cores. Contours indicate sea floor depths in meters. Note that “pacific-like” Ocean A has deep trenches at the base of the continental shelf, whereas “Atlantic-like” Ocean B has a passive continental margin physiography.

b. Why is there a sharp reduction in calcium carbonate below a certain depth in both oceans? _____



- c. On the graph above, plot a depth profile of each line of cores in Ocean A and Ocean B. Use colored pencils to indicate the dominant sediment type in each core. Use Red for clays, Blue for oozes, Yellow for sand-silt-terrigenous clays, and Black for volcanic rock or basalt.

- d. Why do the sediments change as the continent is approached?

- e. Why are there no red clays in the Ocean B profile?

Hint: consider the map/drawing on page 9 of Ocean A and B with respect to terrigenous sediment sources as well as passive and active continental margin features.

- f. In core 5, how do you explain the presence of calcareous ooze below the red clay?

Hint: tectonics.

- g. There are sands in core 14 in Ocean B at 3,000 meters in depth, but none in core 3 in Ocean A at 3,000 meters depth. Suggest a reason for this difference.
- h. Red clay on the deep-sea floor accumulates at an average rate of about 1 millimeter per 1,000 years. Ooze accumulates at rates that are often ten times faster. How much time would be required to deposit 1 inch of red clay? Show your work. (1 inch = 25.4 millimeters)
- i. How many years would a core 10 meters in length represent if it contained 5 meters of ooze and 5 meters of red clay? Show your work. (1 meter = 1,000 millimeters).