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.

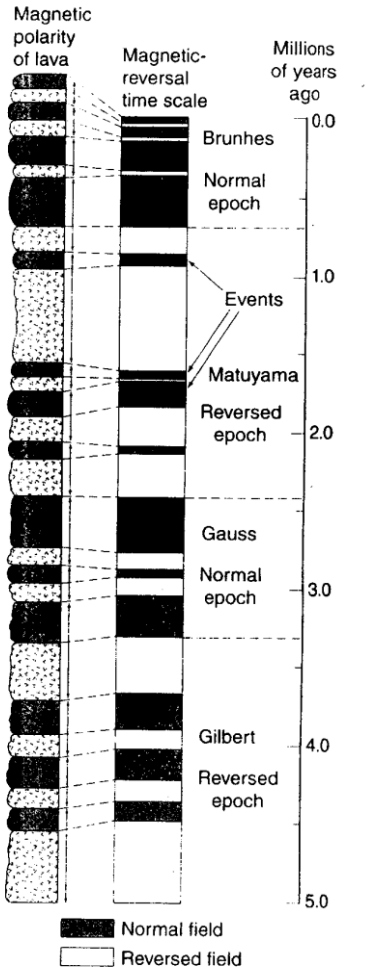


Figure 1: Schematic illustration of magnetic polarities of lava flows used to construct a time scale of magnetic reversals over the past 5 million years.

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.

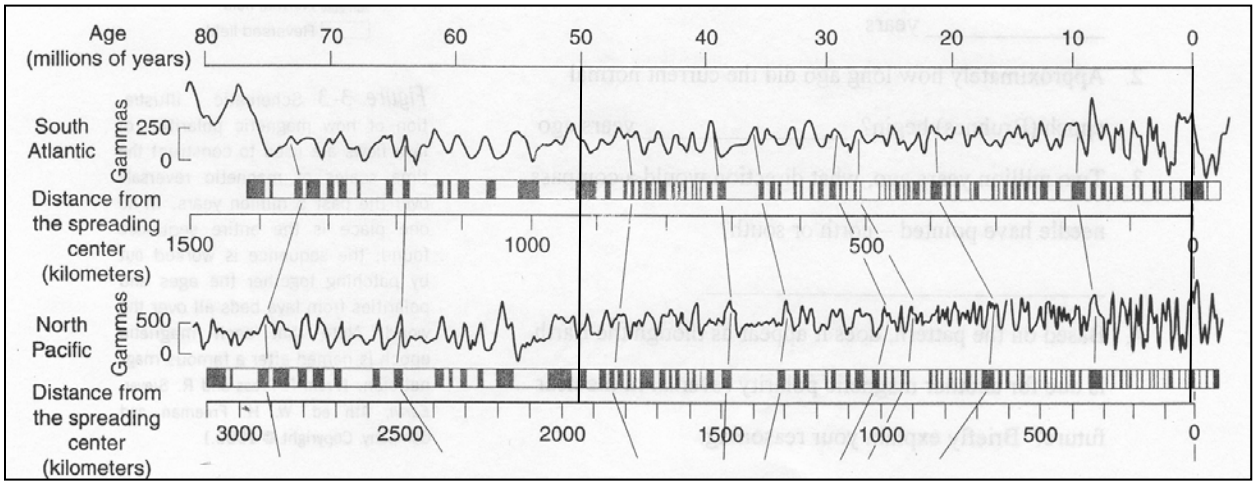
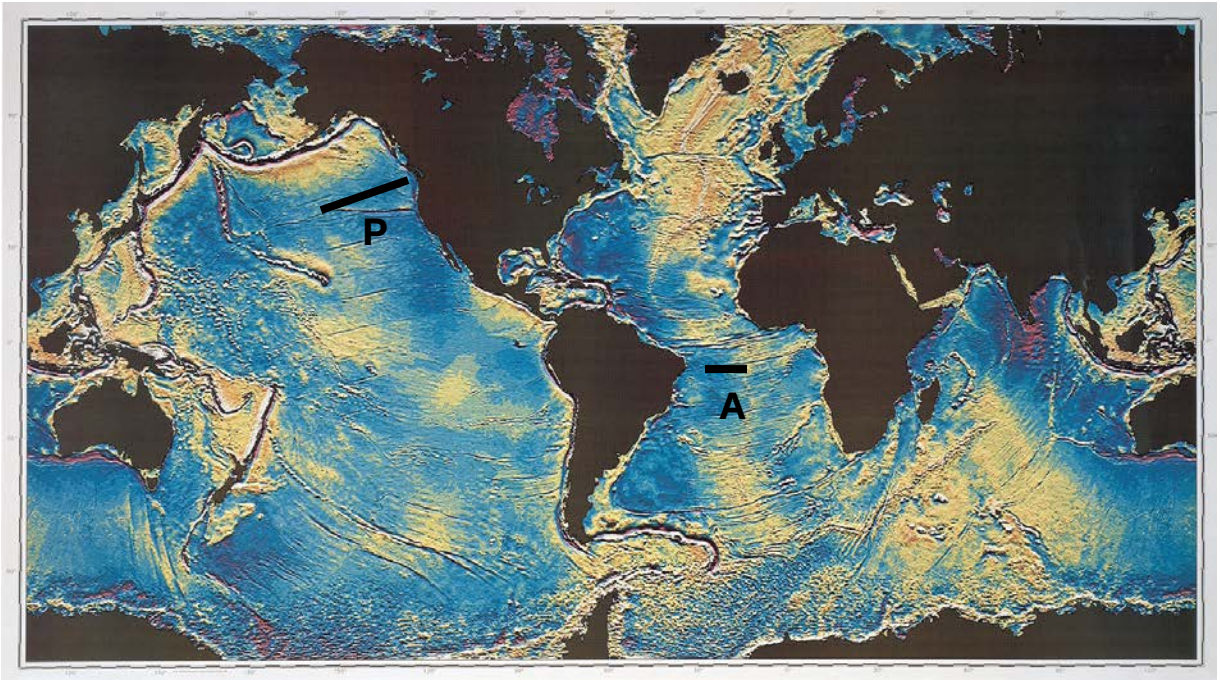


Figure 2: Magnetic anomalies (the peaked curves) recorded perpendicular to spreading centers (ocean ridges) in the major ocean basins reveal a similar sequence of magnetized rocks. **Note**: this figure shows only the ocean floor basins from the ridge toward the

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 next page. Explain your answer.

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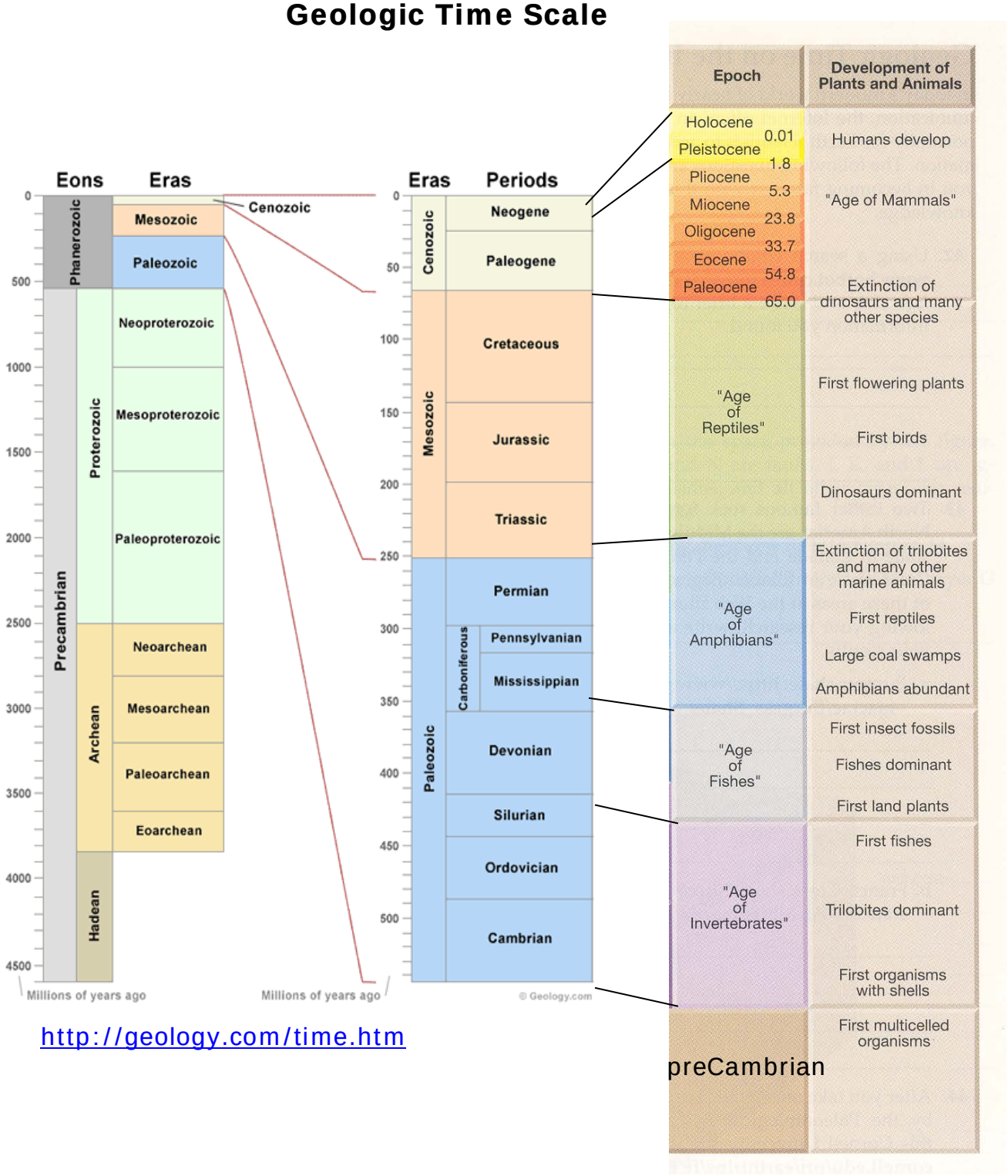
Geologic Time Scale



http://geology.com/time.htm