Plate Tectonics and Contributions from Scientific Ocean Drilling

Going Back to the Original Data: Results from Deep Sea Drilling Project (DSDP) Leg 3 Senegal to Brazil, December 1968 to January 1969

Teacher Guide

Summary

Students use original data from an early leg in the history of scientific ocean drilling to participate in the excitement of original discovery from authentic data.

Background

You are probably familiar with standard textbook figures showing the relationship between ridge axis and sea floor age (see Figure 1).

The theory of plate tectonics is an established, accepted foundational theory of earth science. But what were the initial discoveries or observations about the seafloor that were key contributions to the development of this theory? Scientific ocean drilling played a critical defining role in the development of the theory of plate tectonics, and DSDP Leg 3 provided definitive proof of seafloor age relationships with respect to the mid-oceanic ridge. When DSDP Leg 3 sailed in 1969, plate tectonics and scientific ocean drilling were still in their infancies.

Compare the number of drill sites on the sea floor in 1969 (Figure 2) to that of today (Figure 3).

Learning Objectives

Students will be able to:

- Interpret data of sediment age and distance from the mid-Atlantic ridge.
- Graph this data.
- Draw conclusions about seafloor spreading based on their graphs.

National Science Education Standards

Standard A: Science as Inquiry

Standard D: Earth and Space Sciences

Standard G: History and Nature of Science

Target Age: Grades 8 -12

Time: One class period

Materials

Graph paper

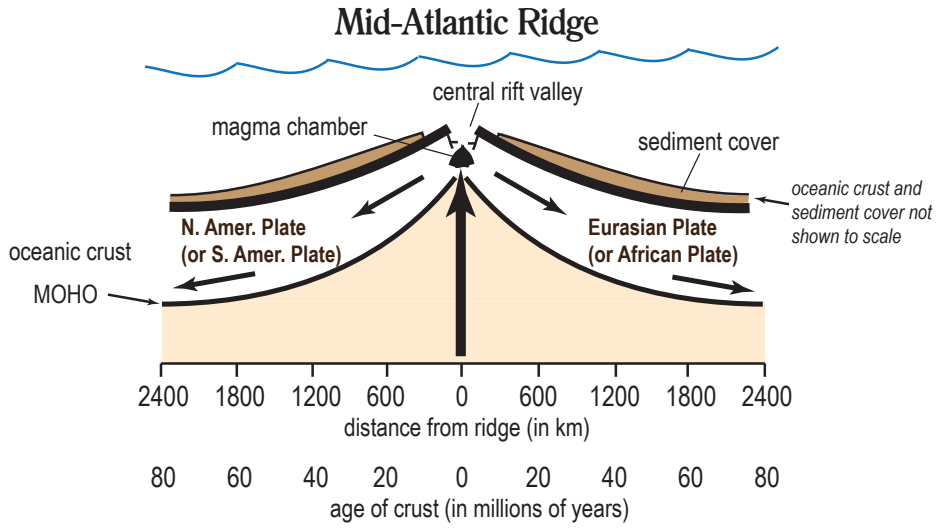


Figure 1. Relationship between ridge axis and seafloor age redrawn from Leckie and Yuretich (2003).

Activities and Questions

1. Familiarize yourself with the map showing the DSDP Leg 3 drilling locations and the position of the South Atlantic mid-ocean ridge (Figure 4) and the accompanying table of data (Table 1). This table shows both the magnetic age of the basement rock and the paleontological age of sediment above basement for the DSDP Leg 3 sites on the map. These ages were determined by Leg 3 scientists based on magnetostratigraphic and biostratigraphic principles.

   Teacher: Don't worry about the magnetic anomaly number or rotational distance in Table 1. These columns were left because there is value in seeing data in its original context.

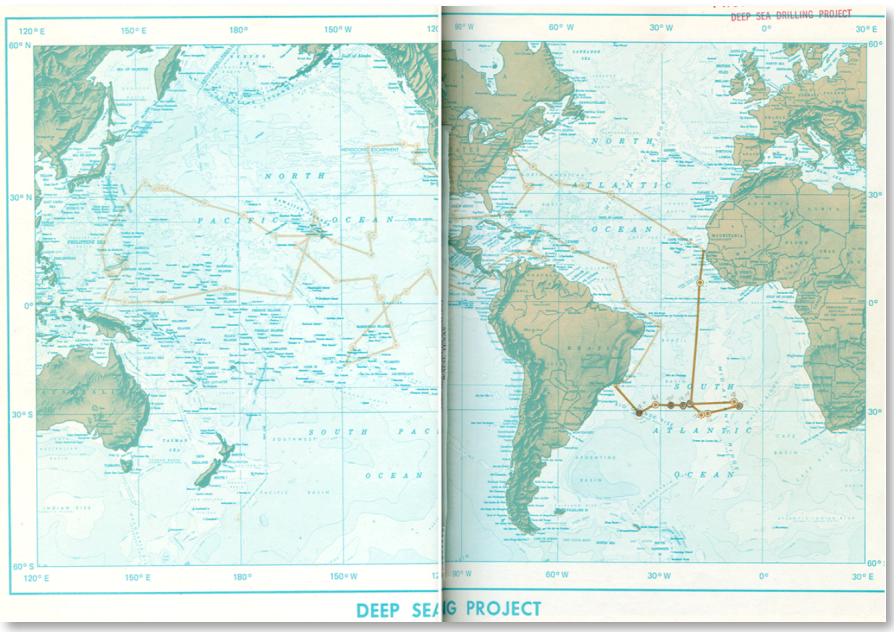


Figure 2. The light brown line marks the ship track of the Glomar Challenger *and the small brown dots indicate drill sites. At this point (January 1969) scientific ocean drilling was still in its infancy. Compare it to the 2006 map of drilled site locations (Figure 3).*

2. Plot on graph paper:
   a. Basement (paleomagnetic) age vs. distance from ridge axis
   b. Bottom sediment age vs. distance from ridge axis

   Teacher: You may decide to give specific guidance on how to construct the graph (setting up axes, scale, etc.) This will depend on your students' background and your comfort with inquiry learning. Allowing students to plot the data on their own can lead to a healthy discussion of the results. For example, is there one best way of representing this data in graphical form? An example for the 2b graph is shown in Figure 8 from the Initial Reports volume, given at the end of this exercise. It is the scientists' graph of sediment age vs. distance. The graph of paleomagnetic age vs. distance would be plotted in a similar way. Notice that sites 17 and 18 are on opposite sides of the ridge axis from the other sites. Students may discover that this makes no difference when plotting because the spreading rate is equal, perpendicular to the ridge axis in both directions.

3. Based on your graph(s), answer the following:
   a. What is the relationship between the age of basement rock and distance from ridge axis?

   Teacher: Basement rocks increase in age as they are farther from the ridge. There is a direct relationship between distance from ridge axis and age.

   b. What is the relationship between the age of sediment overlying basement and distance from the ridge axis?

   Teacher: Bottom sediment increases in age with distance from the ridge. There is a direct relationship between distance from ridge axis and age.

   c. This age vs. distance data from DSDP Leg 3 was essential ground truth needed to test the seafloor spreading hypothesis. The basaltic basement rocks at each of these sites originated (crystallized) at the ridge and have since moved to their present geographic location on the adjacent sea floor. Hypothesize why the ages of sediment overlying basement also show increasing age away from the ridge.

   Teacher: Pelagic (suspension settled microfossils, silts, and clays) sediment can only accumulate on the basement rock (basalt) once the basalt actually exists. In other words, the basalt has to first form at the ridge for the sediment to accumulate on it. Before that time that "piece of property" does not exist for

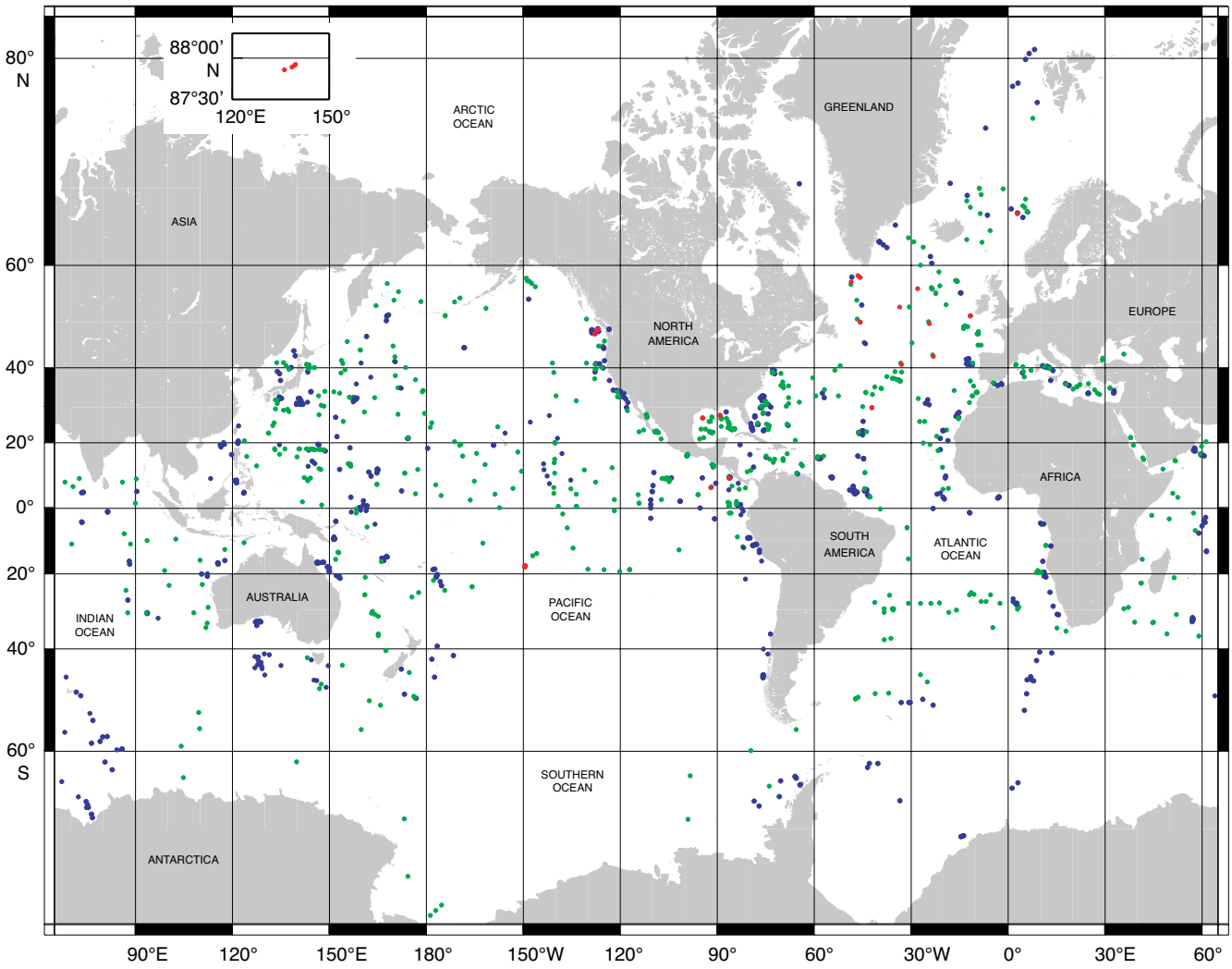
sediment to settle on. As the sediment-draped basalt moves away from the ridge due to seafloor spreading, it continues to accumulate younger and younger sediment on top of it.

d. Calculate the average rate (cm/yr) of seafloor spreading in the South Atlantic using the data from Table 1 or your age-distance plots. (Note that: Rate = Distance/Time.

Teacher: The average spreading half-rate is 2 cm/year and the full spreading rate is 4 cm/yr. In other words, the South Atlantic Ocean is increasing in width at a rate of 4 cm/year. Note: there is often confusion between spreading rate and spreading half-rate; these terms are used interchangeably, but should not be. If the rate of plate motion is calculated for one side of the ridge only, then really what is being calculated is the spreading half-rate. The spreading half-rate is equivalent to the rate of motion of that particular plate. If the rate of spreading in BOTH directions perpendicular to the ridge is taken into account then that is the [full] spreading rate.

e. You can check your scientific reasoning with that of the DSDP Leg 3 scientists by reading the original text and age-depth graph from the Initial Reports of DSDP, Volume III, attached.

Teacher: Text that is particularly interesting or relevant is boxed in red on the journal pages. Encourage students to read this text as it shows scientific results and interpretations in their original form. This is not distilled down for the text book but is the "real deal," so to speak. Students may find satisfaction in knowing their own results and interpretation match that of the scientists.



DSDP Legs 1–96 (●), ODP Legs 100–210 (●), IODP Expeditions 301–312 (●)

Figure 3. Combined IODP, ODP, and DSDP Sites, October 2006 (from http://iodp.tamu.edu/scienceops/maps.html).

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Adapted from School of Rock materials by St. John and Leckie, 2005 for GSA Annual Meeting 2006, Philadelphia, PA

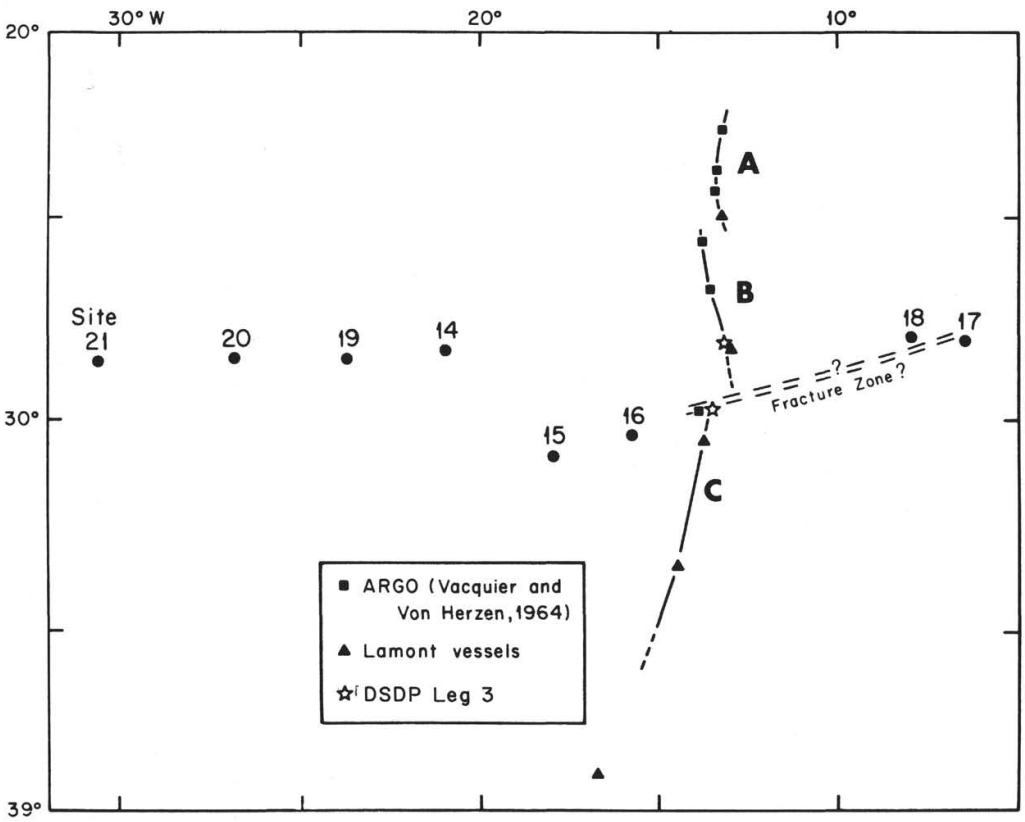

Figure 7. *Location of Leg 3 sites relative to the axis of the Mid-Atlantic Ridge.*

Figure 4. Location of DSDP Leg 3 sites relative to the axis of the Mid-Atlantic Ridge (from Figure 7 in the Initial Reports of the Deep Sea Drilling Project, Volume III, *p. 460).*

TABLE 5[a]
Magnetic Anomaly Numbers and Ages, Paleontological Ages, and Distances of Mid-Atlantic Ridge Sites from the Axis

Site No.	Magnetic Anomaly No.	Magnetic Age of Basement (m.y.)	Paleontological Age Sediment Above Basement (m.y.)	Distance from ridge axis (km) Linear	Rotation at 62°N, 36°W
16	5	9	11 ± 1	191 ± 5	221 ± 20
15	6	21	24 ± 1	380 ± 10	422 ± 20
18	---	---[a]	26 ± 1	506 ± 20	506 ± 20
17	---	34-38[a]	33 ± 2	643 ± 20	718 ± 20
14	13-14	38-39	40 ± 1.5	727 ± 10	745 ± 10
19	21	53	49 ± 1	990 ± 10	1010 ± 10
20	30	70-72	67 ± 1	1270 ± 20	1303 ± 10
21[c]	---		>76	1617 ± 20	1686 ± 10

[a] The number of the magnetic anomaly and its age has been taken from Hertzler, *et al.* (1968).
[b] Location of these sites without the characteristic magnetic anomaly pattern is uncertain.
[c] Basement rock not reached at Site 21.

Table 1. Magnetic anomaly number and ages, paleontologial ages, and distances of Mid-Atlantic Ridge sites from the axis. (From Table 5, Initial Reports of the Deep Sea Drilling Project, Volume III, *p. 461)*