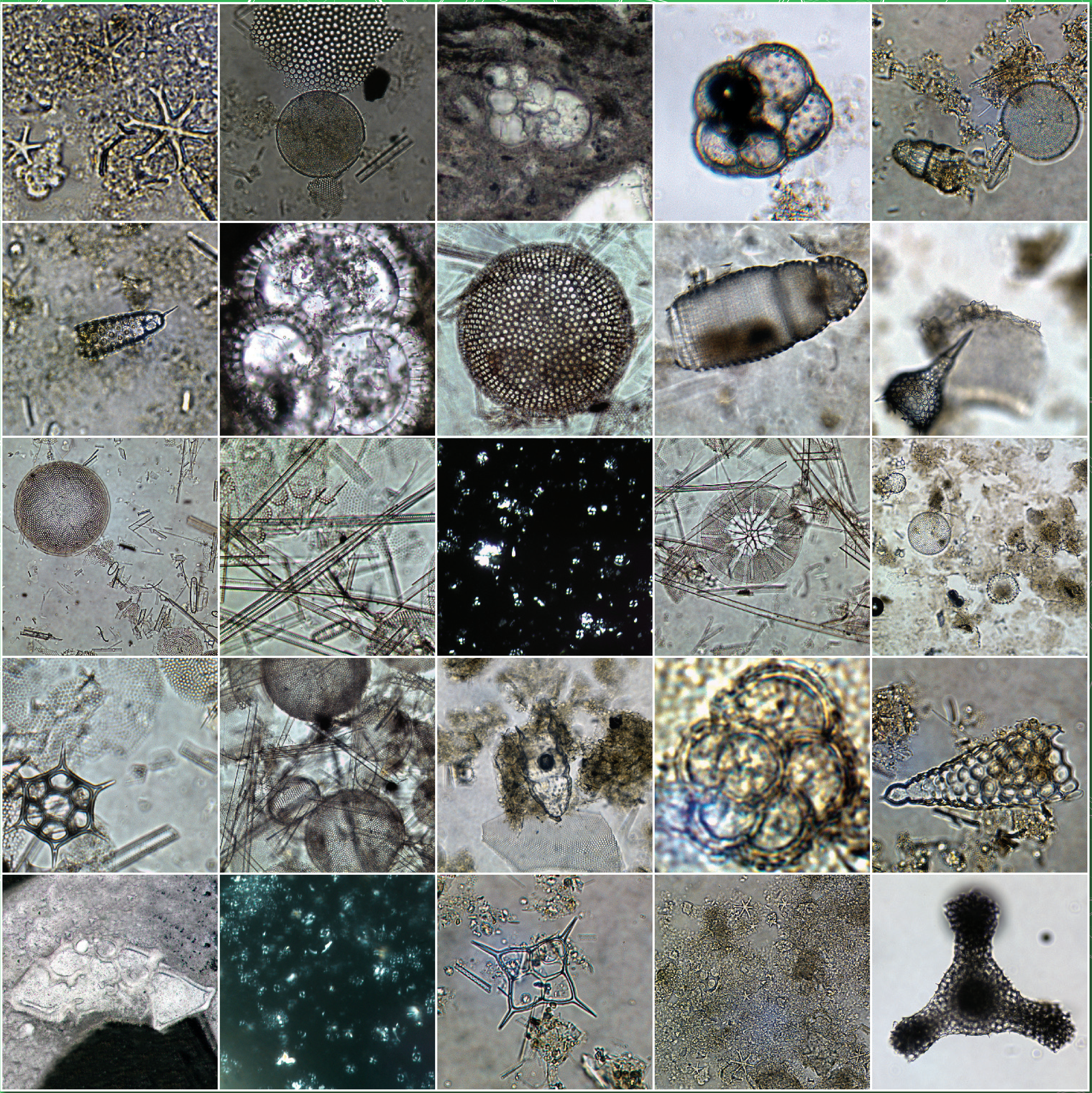

Note about size: These images have been enlarged using various magnifications. The microfossils range in actual size from less than 10 microns up to 2 millimeters. 1 micron = 1 x 10^{-6} meters.

MICROFOSSILS
the ocean's storytellers

Deep Earth Academy

CONSORTIUM FOR OCEAN LEADERSHIP

Small Creatures, Big Science

Introduction for Teacher

This poster was designed for middle and high school Earth systems, life science, chemistry, and/or environmental science students. While "Microfossils Reveal Seafloor Spreading Truth!" and "Secrets of the Sediments" are a bit challenging, the activities in "Small Creatures, Big Science" are adaptable for younger audiences. The text and activities address the following National Science Education Content Standards for grades 5-8 and 9-12: Standard B: Physical Science (structure and properties of matter), Standard C: Life Science (diversity, biological evolution), Standard D: Earth and Space Science (Earth's history), and Standard G: History and Nature of Science (nature of scientific knowledge and historical perspectives). Visit *www.oceanleadership.org/materials/activities* for teacher's guides and answer keys.

Background

What's in a smear slide of sediment? Tiny fossilized creatures filled with big science! A smear slide is a clear glass slide with a tiny amount of sediment spread into a very thin layer and protected by a cover slip. Aboard the *JOIDES Resolution*, smear slides are made from sediment cores in order to characterize the types of minerals and fossils that make up ocean sediments. If the deeply buried sediment has hardened into rock, then a very thin slice of the rock is cut and mounted onto a glass slide; this is called a thin-section. Using a microscope, scientists on board the ship are able to examine smear slides and thin-sections and see some of the world's smallest fossilized creatures (not visible to the naked eye). These tiny organisms are called microfossils. When a core is brought up on deck, scientists look at these slides to identify the microfossils found in cores and determine the age of the sediment, as well as something about Earth's past climate.

Microfossils are microscopic single-celled organisms that belong to the Kingdom Protista (or Protoctista). Examples include calcareous nannofossils, foraminifera, diatoms, radiolarians, and silicoflagellates; planktonic organisms that inhabit the sunlit surface waters of the world ocean. The calcareous nannofossils and diatoms are types of algae at the base of oceanic food chains. The tiny shells of microfossils are the sediments that cover vast areas of the seafloor. In some areas of the seafloor, they are mixed with mud or sand.

The following microfossils appear in the smear slides and thin-sections pictured on the front of the poster:

Calcareous nannofossils are a type of very small (smaller than dust) microfossil algae. They're much smaller than most other microfossils. It is often easier to view these tiny microfossils against a black background using cross-polarized light and high magnification. Discoasters are a group of calcareous nannofossils distinguished by their 5- or 6-pointed star shape. They have two faces; one is concave and the other convex. In smear slides they appear as colorless, bright disks or pustules.[5, 6] Look for the star-shaped microfossils.

Foraminifera, or "forams" for short, are sand-sized unicellular organisms with calcium carbonate ($CaCO_3$) shells. During growth, a series of chambers are added, increasing in number as the cell grows. In smear slides and thin-sections, some planktonic forams are globular or globe-like with inflated chambers (that look like fish eggs) and a rounded outline, while others have flattened, compressed, less globular tests (shells). Look for the microfossils with chambered shells.

Diatoms are delicate unicellular algae with siliceous walls. There are two different groups, the pen-shaped pennate diatoms and the radial or cylindrical species known as the centric diatoms. In smear slides their rims appear as small rings or half rings, little "C" or "O" shaped structures that look like pores.[2, 5] Look for the long, thin and circular-shaped microfossils.

Radiolarians are unicellular organisms that absorb silica from the marine environment. There are two groups -- the cone-shaped nassellarian radiolarians and the lace-like spumellarian radiolarians. They occur in spherical, discoid, conical, radial arm-like, or ring-like forms and appear to be heavier than diatoms. In smear slides they appear as huge open latticework fragments attached to ridged spines.[3, 5] Look for the cone-shaped and lacy arm-like microfossils.

Silicoflagellates are a group of unicellular algae found in marine environments. In one stage of their life cycle, they produce a siliceous skeleton, composed of a network of bars and spikes arranged to form an internal basket. In smear slides they have a distinctive open lattice; even more open than most radiolarians.[4, 5] Look for the microfossils with the spikes.

Part 1: The identification of microfossils is not easy. In fact, a micropaleontologist typically specializes in just one microfossil group! The key to identifying microfossils lies in describing visual features unique to each type of microfossil. Look at the smear slides and thin-sections pictured on the front of the poster. Identify and label each microfossil using the descriptions provided above. How many of each kind of microfossil did you identify? Which is the most common? Least common?

The organisms you just labeled are not only fun and interesting to look at, they can tell scientists important information about Earth's conditions at the time of their deposition on the seafloor. As fossil plankton communities evolve through time, microfossil groupings or assemblages found in marine sediments become unique to a particular interval of geologic time. By studying the sedimentary layers based on the fossil content (biostratigraphy) scientists can determine the relative age of ocean sediment and gather insight about the Earth's past climate.

Answers (from top down, left to right):
1st Row: discoasters (calcareous nannofossils), centric diatom, planktic foraminifer, planktic foraminifer, nassellarian radiolarian and centric diatom
2nd Row: nassellarian radiolarian, planktic foraminifer, centric diatoms, nassellarian radiolarian, nassellarian radiolarian
3rd Row: centric diatom, pennate diatoms, calcareous nannofossils, pennate and centric diatoms, centric diatoms
4th Row: silicoflagellate, pennate and centric diatoms, nassellarian radiolarian, planktic foraminifer, nassellarian radiolarian
5th Row: planktic foraminifer, calcareous nannofossils, silicoflagellate, discoasters and other calcareous nannofossils, spumellarian radiolarian

Part 2: Now that you're an expert at identifying microfossils, put yourself to the test! Make two photocopies of the front of the poster. Cut out each individual smear slide and thin-section photomicrograph (squares). Place each square face down, so that you can't see the image. Play a matching game to test your memory. How long did it take you to match up the microfossils? How much time do you think scientists spend in the lab matching and identifying microfossils?

Extensions

1. Want to see microfossils in motion? Check out *nhm.ac.uk/hosted_sites/ina/rotatingnannos/index.html* for cool 3-dimensional microfossil images. What kind of microfossils are on this web site?
2. Tour the paleontology and other labs (*iodp.tamu.edu/publicinfo/drillship.html*) where scientists aboard the *JOIDES Resolution* identify microfossils.

References

[1]http://www.ucmp.berkeley.edu/foram/foramintro.html; [2]http://www.microscopy-uk.org.uk/mag/indexmag.html?http://www.microscopy-uk.org.uk/mag/wimsmall/diadr.html; [3]http://radpage.univ-lyon1.fr/rad_en.html; [4]http://www.answers.com/topic/silicoflagellate; [5]http://gc.ucsd.edu/Proc/fossilsPROC2htm.html; [6]http://www.nhm.ac.uk/hosted_sites/ina/terminology/discoasters.htm

We'd like to hear from you! Please contact us with questions or comments. Visit *www.deepearthacademy.org* for more education materials and resources.

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Secrets of the Sediments - Student Guide

Using Marine Sediments to Study Global Climate Change

Before You Begin

1. Think about these questions and record your answers on your own paper or on the back of this page.
a. What is climate?

b. How would you describe the climate in your city, town or village?

c. Does climate have any direct effects on your life? Does climate change? Talk to your parents and grandparents about any climate changes they recall.

2. Brainstorm and record some ideas for this essential question:
a. How can we study global climate changes?

b. What pieces of evidence can we look for to see how the Earth's climate has changed over the planet's long history?

Background

The *JOIDES Resolution* (JR) is a ship that travels the world coring rock and sediments from the bottom of the ocean. When sediment cores are removed from the ocean floor, they undergo a variety of processes including visual descriptions, studies of the microfossils, analysis for paleomagnetism, determination of sedimentation rates, and chemical studies of the sediments including stable oxygen isotopes and carbonates.

Objectives

During this activity, you will graph and analyze data from sediments collected off the coast of Santa Barbara, California to determine whether this information can be used to study historical climate change.

Vocabulary

stable isotope	sediment
core	microfossil

Materials

1. Graph paper
2. Rulers

Activities

1. Isotopes are atoms with the same number of protons, but different numbers of neutrons; the more neutrons, the heavier the isotope. Unstable isotopes, like uranium, decay over time and geologists can use them for age determination and dating. Stable isotopes do not decay and can therefore provide indirect records or proxies of past climate change. Oxygen occurs in three stable isotopes: oxygen-16 (^{16}O), oxygen-17 (^{17}O), and oxygen-18 (^{18}O). Which isotope is heavier?

2. Water's chemical composition is H_2O. The oxygen in water is usually ^{16}O but sometimes ^{18}O. ^{17}O is very rare. In terms of the hydrological cycle and evaporation, which oxygen isotope would evaporate first? Why?

3. Calcareous microfossils use oxygen from the water as one component of their carbonate ($CaCO_3$) shells, and are a good indicator of the oxygen chemistry of the water when they were alive. Table 1 shows the ^{18}O:^{16}O ratios and the ages of marine microfossils found in the Santa Barbara sediment core. Plot the ^{18}O:^{16}O ratio vs. sediment age and connect the points on a sheet of graph paper.

4. Analysis
a. Look at the graph and describe what you see.

b. During what three ages or time periods can you find the highest ^{18}O:^{16}O ratios?

c. Identify and list the time periods with the lowest ^{18}O ratios.

TABLE 1

Age (in thousands of years)	^{18}O:^{16}O Ratio
2	2.2
6	2.4
8	2.5
11	3.1
13	3.5
15	3.1
16	3.6
18	4.1
20	3.8
21	4.0
30	3.5
42	3.0
50	3.1
57	3.3
58	3.4
62	4.2
68	3.6
74	3.4
82	3.0
94	3.0
102	2.8
109	2.4
124	2.2
131	3.7
136	3.9
144	3.7
149	3.9
150	3.8
157	3.5

Table adapted from Kennett, 1995

d. Why do you think this pattern occurred? What might have been happening geologically? Climatologically?
(Think about the hydrological cycle, snow and the formation of large ice sheets like those covering Greenland and the Antarctic continent.)

e. Predict and explain what will happen to the ^{18}O:^{16}O ratios as global warming continues. (CAUTION: Oxygen isotopes are simply a record, not a cause of climate change.)

f. Do you think the levels of ^{18}O can also indicate the amount of ice found on land? Explain.

Extensions

1. Read and discuss "Fossil Thermometers for Earth's Climate" by Lear et al., from the ODP Highlights (*www.oceandrilling.org/greatest_hits2/*).

2. Research and examine global temperatures for the past 160,000 years and see how temperatures relate to the ^{18}O:^{16}O ratios for the glacial and non-glacial periods.

3. Research and describe modern and/or fossil foraminifera, the organisms used in oxygen isotope studies.

4. Would you expect high or low ^{18}O:^{16}O ratios in ice cores? Investigate and track down an answer.

References

Kennett, James, 1995. Latest Quaternary Benthic Oxygen and Carbon Isotope Stratigraphy: Hole 893A, Santa Barbara, California. *Proceedings of the Ocean Drilling Program Scientific Results*, v. 146, 16pp.

The Secrets of the Sediments - Teacher's Guide is available for download at *www.oceanleadership.org/materials/activities*

Activity written on the School of Rock Expedition by Ramona Smith, 11/2005 (for more information contact: learning@oceanleadership.org)

Nannofossils Reveal Seafloor Spreading Truth!

Introduction for Teacher

Background

The goal of the Deep Sea Drilling Project (DSDP) was to investigate the sediments and rocks beneath the deep oceans by drilling and coring. The data featured in this exercise were taken from cores collected by the *Glomar Challenger* drill ship, at seven sites east and west of the Mid-Atlantic Ridge during DSDP Leg 3, in late 1968 (see Figure 2). The holes were drilled in the South Atlantic between Rio de Janeiro, Brazil and Dakar, Senegal. The age of the contact between the sediment and the basalt of the ocean floor was determined by identifying the nannofossils found at each contact.

Objectives

- Students will analyze real data collected from the Deep Sea Drilling Project to discover evidence of seafloor spreading.
- Students will use graphing and slope analysis to determine the relationship between distance from the spreading center and age of the sediments. Students will gain an historical perspective of scientific research.

Vocabulary

basement rock	nannofossil
core sample	ocean sediment
Deep Sea Drilling Program	

Nannonfossils Reveal Seafloor Spreading Truth! was adapted by School of Rock Expedition participants Jerry Cook and Virginia Jones from "Plate Tectonics and Contributions from Scientific Ocean Drilling" (*www.oceanleadership.org/classroom/plate_tectonics_DSDP3*) an undergraduate-level activity written by Dr. Kristen St. John and Dr. Mark Leckie, 11/2005 (learning@oceanleadership.org)

Alfred Wegener first proposed the theory of continental drift but could not explain how it happened.
(photo from USGS, http://pubs.usgs.gov/publications/text/wegener.html)

Materials

1. Graph Paper
2. Pencil

Methods

1. Using data from Table 1 (from DSDP Initial Reports, Vol. 3), plot coordinates representing the age and distance from the ridge at each site. For time values, use the column labeled Paleontological Age of Sediment (in millions of years). For distance use the column labeled Distance from Ridge Axis. Choose a scale that allows you to plot distance on the Y-axis and age on the X- axis. Label each coordinate with the site number.

2. Locate the position of the core samples relative to the Mid-Atlantic Ridge by looking at Figure 2 (also from Initial Reports of DSDP, Volume 3). (Hint - they are not in order.)

Analysis

(Answer these questions on your own sheet of paper.)
1. These DSDP Leg 3 observations were the ground truth needed to test the seafloor spreading hypothesis. Where are the youngest samples? Where are the oldest samples? What do you think might have caused this relationship? Does this relationship support the theory of seafloor spreading?

2. These data show a straight-line relationship between age and distance. What does this tell us about the rate of seafloor spreading?

3. Should your lines of best fit pass through (0, 0)? What does this mean?

4. Calculate the rate of seafloor spreading west of the Mid-Atlantic Ridge in km/m.y., then convert your answer to cm/year. Be sure to show your work!

5. Calculate the rate of seafloor spreading east of the Mid-Atlantic Ridge in km/m.y., then convert your answer to cm/year. Don't forget to show your work!

6. If you could acquire data of a different type from these same sites, what other data might be used to study seafloor spreading? Explain how this data would be useful.

Table 1
Distances and Ages of Mid-Atlantic Ridge Sites from the Axis

Site Number	Paleontological Age of Sediment (m.y.)	Distance From Ridge Axis (km)
16	11	221
15	24	422
18	26	506
17	33	718
14	40	745
19	49	1010
20	67	1303
21	76	1686

Adapted from Table 5[a], from Initial Reports of DSDP, Volume 3

Extensions

1. To learn more about the *Glomar Challenger*, read the article found on the following web page: *iodp.tamu.edu/publicinfo/glomar_challenger.html*

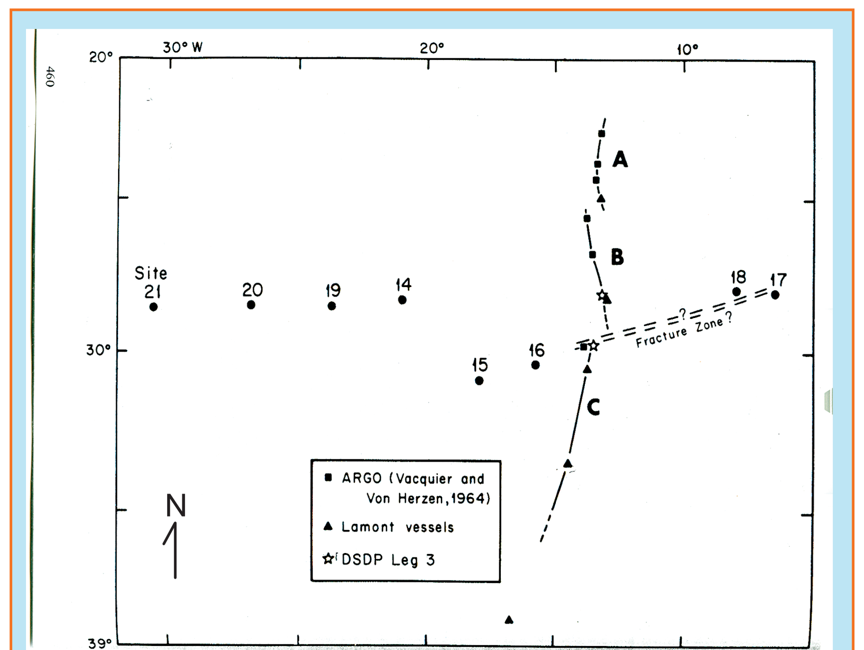

Figure 2. *Location of DSDP Leg 3 drillsites relative to the axis of the Mid-Atlantic Ridge in the South Atlantic. Lines of latitude are in degrees South (i.e., 20° to 39°S)*

2. Locate the DSDP Leg 3 drill sites on the DSDP drill site map at: *iodp.tamu.edu/scienceops/maps/dsdpmap.gif* Using a map of the seafloor, locate the Mid-Atlantic Ridge.

3. Find out how core samples are drilled and processed by reading, "One Core at a Time" (*www.oceanleadership.org/classroom/one_core.html*), and "Life of a Core" (*www.oceanleadership.org/classroom/Life_of_a_core.html*).

4. See *www.oceanleadership.org/classroom/plate_tectonics_DSDP3* for related, but more challenging, activities about DSDP 3 and plate tectonics.