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How Fast Is The Ocean Floor Moving?

How Fast Is The Ocean Floor Moving?

TEACHER'S GUIDE

Catalog No. 34W1013

For use with Student Investigation 34W1113
Class time: two to three 45-minute periods

Developed by
THE NATIONAL ASSOCIATION OF GEOLOGY TEACHERS

Produced and Distributed by
Ward's Natural Science Establishment, Inc. Rochester, NY • Monterey, CA

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NAGT Crustal Evolution Education Project

Edward C. Stoever, Jr., Project Director

Welcome to the exciting world of current research into the composition history and processes of the earth's crust and the application of this knowledge to man's activities The earth sciences are currently experiencing a dramatic revolution in our understanding of the way in which the earth works CEEP modules are designed to bring into the classroom the methods and results of these continuing investigations The Crustal Evolution Education Project began work in 1974 under the auspices of the National Association of Geology Teachers CEEP materials have been developed by teams of science educators classroom teachers and scientists Prior to publication the materials were field tested by more than 200 teachers and over 12,000 students

Current crustal evolution research is a breaking story that students are living through today Teachers and students alike have a unique opportunity through CEEP modules to share in the unfolding of these educationally important and exciting advances CEEP modules are designed to provide students with appealing firsthand investigative experiences with concepts which are at or close to the frontiers of scientific inquiry into plate tectonics Furthermore, the CEEP modules are designed to be used by teachers with little or no previous background in the modern theories of sea-floor spreading, continental drift and plate tectonics

We know that you will enjoy using CEEP modules in your classroom Read on and be prepared to experience a renewed enthusiasm for teaching as you learn more about the living earth in this and other CEEP modules

About CEEP Modules...

Most CEEP modules consist of two booklets a Teacher's Guide and a Student Investigation The Teacher's Guide contains all the information and illustrations in the Student Investigation plus sections printed in color, intended only for the teacher as well as answers to the questions that are included in the Student Investigation In some modules there are illustrations that appear only in the Teacher's Guide and these are designated by figure letters instead of the number sequence used in the Student Investigation

For some modules maps, rulers and other common classroom materials are needed and in varying quantities according to the method of presentation Read over the module before scheduling its use in class and refer to the list of MATERIALS in the module

Each module is individual and self-contained in content but some are divided into two or more parts for convenience The recommended length of time for each module is indicated Some modules require prerequisite knowledge of some aspects of basic earth science, this is noted in the Teacher's Guide

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How Fast Is The Ocean Floor Moving?

INTRODUCTION

In this module students examine data from sediments on the sea floor. They determine whether the data support the theory of sea-floor spreading, and calculate the rate of spreading of the East Pacific Rise, using sediment data.

Many earth scientists believe that the continents of Africa and South America were once joined together. What is the evidence for this belief? If it is true, how long has it taken for these two continents to break apart and move to where they are now? Is the earth's surface moving in other places?

One way to answer these questions is to study samples of **sediment** taken from the ocean floor. Sediment is loose rock, mineral debris, and plant and animal shells which have settled out of the water. In these activities you will use sediment data, like scientists do, to determine how fast the ocean floor is moving.

The deep sea sediments were obtained by the ***Glomar Challenger***. The *Glomar Challenger* is a specially designed drilling ship that can take samples of sediment and rock from the floor of deep ocean basins. It recovers both sediment and rock cores. A **core** is a cylinder of sediment or rock obtained by using a hollow drill. In many cases, scientists must drill through hundreds of meters of sediment before reaching the solid igneous rock of the ocean floor. This igneous rock forms by cooling and hardening of molten rock material. It is the "floor" upon which the sediments settle.

PREREQUISITE STUDENT BACKGROUND

Students should be familiar with the sea-floor spreading hypothesis in general. The hypothesis states that new ocean crust material is added at the mid-ocean ridge system where the sea floor spreads apart. The students are expected to know how to complete a graph. Some students may need assistance in converting kilometers to centimeters.

OBJECTIVES

After you have completed these activities, you should be able to

1. Make and interpret graphs which show the relationship between the thickness of a sediment sample and its distance from a mid-ocean ridge
2. Make and interpret graphs which show the relationship between the age of deep sea sediments and their distance to a mid-ocean ridge.
3. Form hypotheses about sea-floor movement based on data from sediment cores
4. Calculate the rate of movement of the ocean floor from data on sediment thicknesses, ages of sediment, and locations of the drill sites

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MATERIALS

Map, *Pacific Ocean Floor*, National Geographic Society, Educational Services, Department 79, Washington, D.C. 20036—one or two per class.

Meter stick or metric measuring tape—one per group of 3.

BACKGROUND INFORMATION

The East Pacific Rise is also called the East Pacific Ridge. Published literature indicates that prominent scientists use these terms interchangeably. In this module use of the term East Pacific Rise conforms to historical precedent and popular usage.

The data used in this activity were gathered by the Glomar Challenger on Leg 9 of the Deep Sea Drilling Project. (The section of a cruise between two places is called a leg.) The Glomar Challenger is a specially designed drilling ship which under ideal conditions can take cores of the entire sedimentary sequence and the basaltic rocks of the ocean floor crust. Technological advances allow scientists to drill cores in the ocean floor as much as 4,000 meters below sea level. The drill cores (some are several hundred meters in length) are studied on board the ship and eventually taken to onshore laboratories for more intensive analysis.

Sediments lying on the basaltic ocean floor crust become progressively older with increased distance from the oceanic ridge. In the western Pacific, east of the Philippine Islands, the oldest sediments recovered from the present ocean floor so far are of Jurassic age. This agrees with their expected ages calculated from the spreading rates.

Sediments which cover the ocean floor can either settle out of seawater in the open ocean (pelagic sediments) or come directly from land (terrigenous sediments). Terrigenous sediments are dominant only around the margins of the ocean basins. The sediment cores on which these student activities are based are principally pelagic sediments.

The pelagic sediments making up the cores were largely derived from the remains of organisms whose shells settled to the ocean floor. The cores do contain some other minor constituents. A more extensive discussion of deep-sea sediments can be found in Principles of Oceanography (Davis, 1977). The composition of the sediment core data used in this module can be found in the article by Hays, and others, 1970, listed in the references.

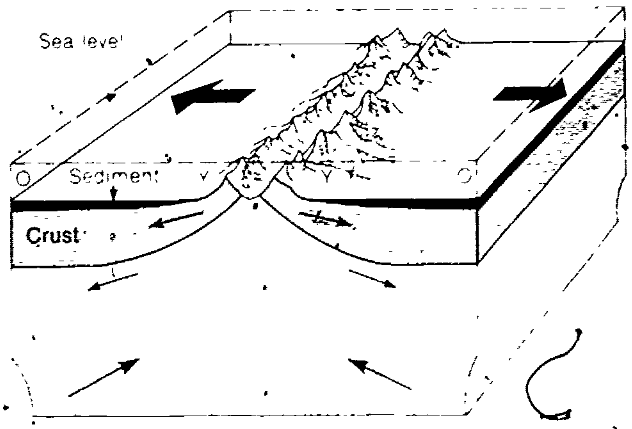


Figure A. Data from sediment cores have helped to confirm the sea-floor spreading theory. Sediments recovered directly above basement (igneous ocean crust) nearer the oceanic ridge are younger (Y) than those recovered farther from the ridge (O).

Sedimentation rates in most parts of the open ocean are slow, ranging from a few millimeters to a centimeter per thousand years (Davis, 1977, p. 411). The rates at which sediments accumulate vary with time. The Deep Sea Drilling Project has shown there were periods of time when sediments accumulated very slowly or not at all. There are places near the equator where the high production of plants and animals results in rapid accumulation of sediments. In any case, we would expect the older portions of the ocean floor crust to have a thicker sediment cover than the younger ocean floor crust.

It is possible to establish the age of the sediments by examining the paleontological (fossil) evidence contained in the cores. Since the sediment cover begins to accumulate when the oceanic crust is first formed at the mid-ocean ridge, it is inferred that the basalt crust and basal sediments (those in contact with the crust) are nearly the same age.

SUGGESTED APPROACH

This activity can be completed where students can work at desks or laboratory tables. Students should be encouraged to discuss their results and hypotheses with each other.

These activities can be done by the students independently or in small groups. The students should be encouraged to complete the EXTENSION section of the module and offer alternative hypotheses to explain the observed data.

Some students may need help when doing the calculations to determine the rate of spreading in PART B of this activity. You may have to assist in converting kilometers to centimeters. All calculations are variations of the familiar "distance equals rate multiplied by time."

Each part should be concluded with a group discussion of the results, questions, and extensions.

PROCEDURE

PART A: What can we learn from deep sea sediments?

Students examine sediment thickness data and the age of the bottom sediments on the sea floor to see if the data support the theory of sea-floor spreading.

Students are asked to explain the data from one site that does not seem to correspond to data from other sites.

Key words: sediment, *Glomar Challenger*, core, East Pacific Rise, sea-floor spreading

Time required: one 45-minute period

Materials: map, *Pacific Ocean Floor*, National Geographic Society.

The students may need help completing the graphs. Remind the students not to plot data from Site 84 until after completing both graphs.

The graph of sediment thickness data is not a straight line. Show students how to adjust a "best fit" line.

The graph of bottom sediment age should be virtually a straight line. The "Bottom Age" data represent the age of the lowermost sediments lying in contact with the basaltic ocean crust. The age, therefore, represents the inferred age of the sea floor (or crust) at a particular site.

The data you will be using in this activity are based on measurements from sediment cores. The *Glomar Challenger* drilled these sediment cores near the **East Pacific Rise**. The East Pacific Rise is part of a 64,000 km-long mid-ocean ridge system. Mid-ocean ridges are thought to be places where the process of **sea-floor spreading** (which results in breakup and separation of continents) takes place. Figure 1 is a map showing where the cores were drilled.

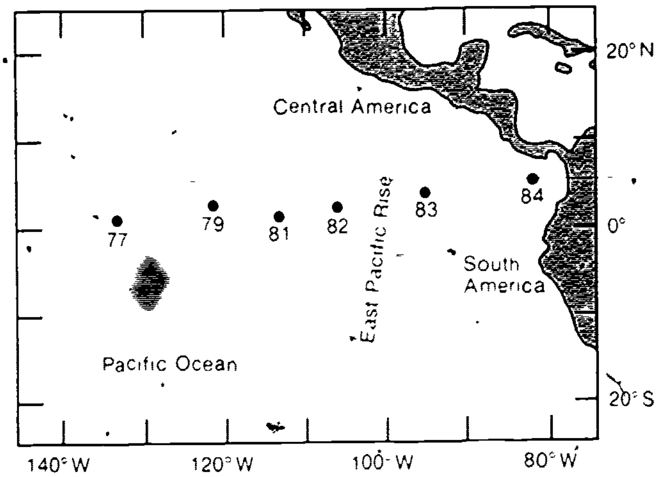
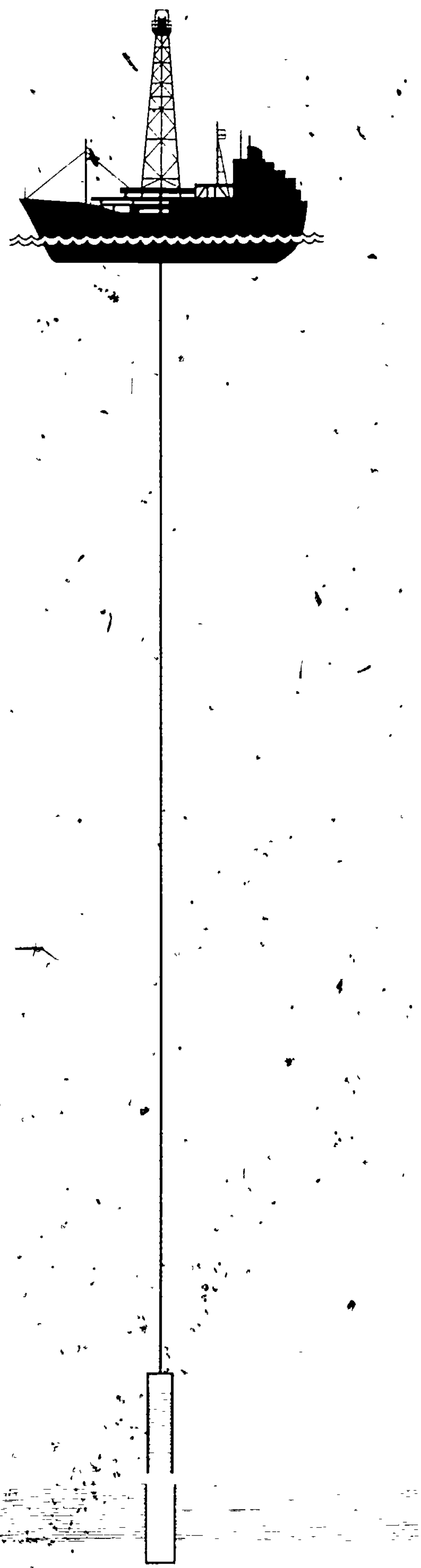


Figure 1 Site locations of Leg 9 deep sea drilling cores (Modified from Hays, J D , and others, 1970, p 12, with permission)

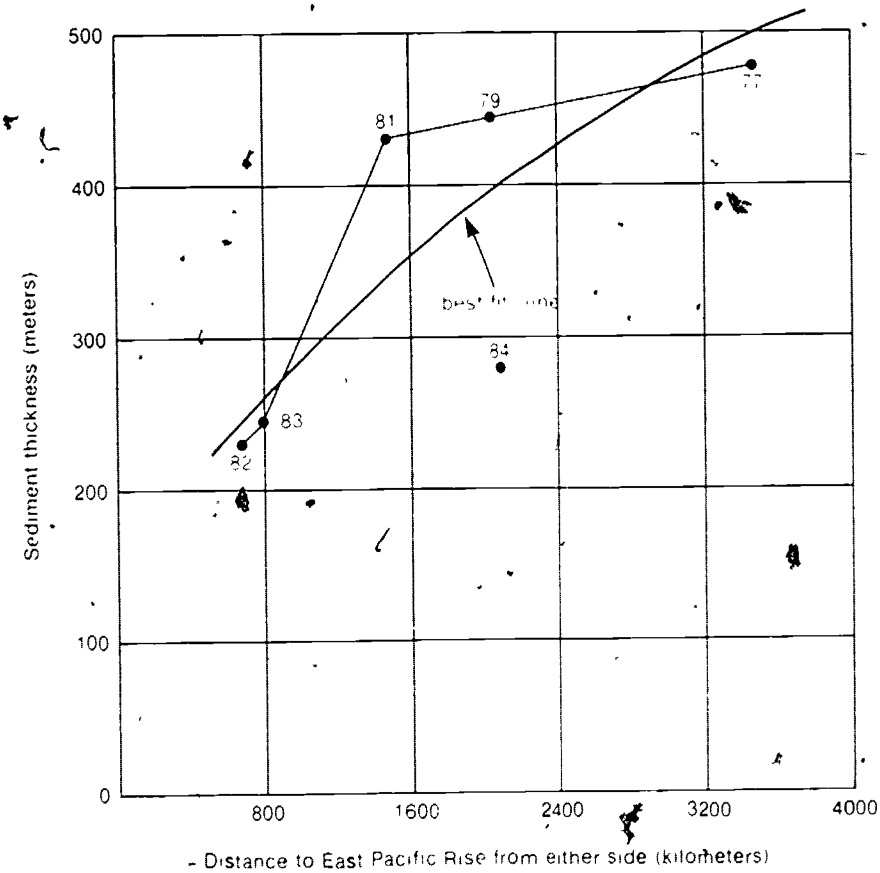
Table 1 contains data about position and thickness of deep sea sediments lying on top of the igneous rock of the ocean floor.

Table 1.
Glomar Challenger Deep Sea Cores, Leg 9.
(Modified from Hays, J.D., and others, 1970, p 12, with permission.)

Drill Site Number and Location	*Distance from Middle of East Pacific Rise*	*Sediment Thickness Down to Igneous Rock*	*Bottom Sediment Age (millions of years old)*
77 (West of East Pacific Rise)	3.359 km	481 m	36
79 (West of East Pacific Rise)	2 086 km	414 m	21 5
81 (West of East Pacific Rise)	1,280 km	409 m	14 5
82 (West of East Pacific Rise)	549 km	214 m	9 5
Approximate Ridge Axis	0 km	none recovered	0
83 (East of East Pacific Rise)	797 km	241 m	10 5
84 (East of East Pacific Rise)	2 000 km	254 m	8 5

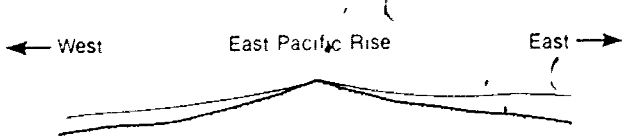


1. Using the sediment thickness data from Table 1, complete the graph below. Plot the distance to the East Pacific Rise along the horizontal axis. Plot the sediment thickness along the vertical axis. Do not plot data from Site 84 at this time. This site is unusual, and you will plot it later.



Graph of sediment thickness versus distance to middle of the East Pacific Rise

2. Shown below is a profile of the igneous rock ocean floor on each side of the East Pacific Rise. Sketch in how you think sediment thickness changes in both directions away from the middle of the East Pacific Rise.



3. Explain what your graph and sketch mean in the space below.

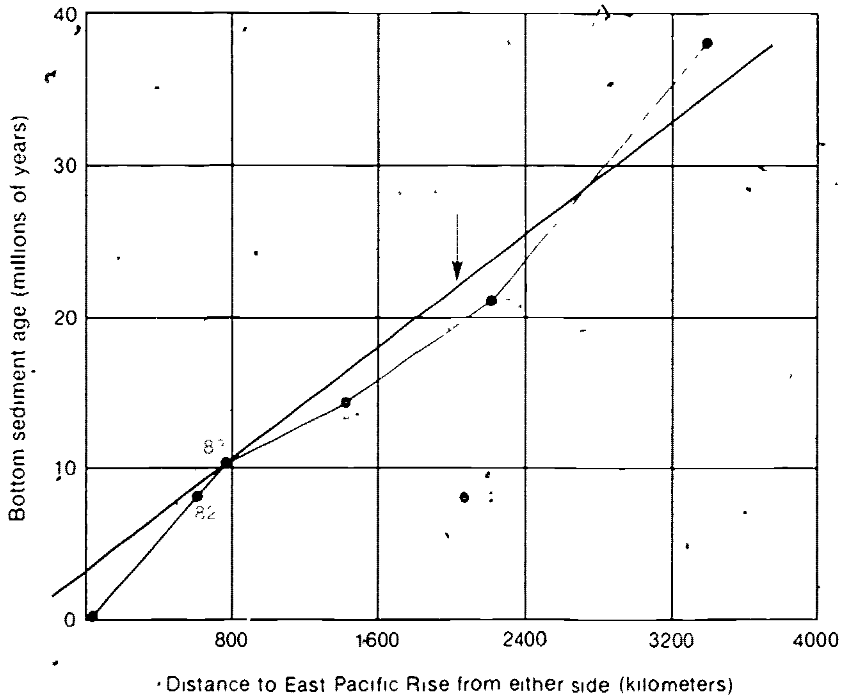
The concept of a "best fit" line may be too difficult for some students. After they connect the points, explain that the pronounced change in slope is due to a change in the rate of sediment accumulation as the Pacific Plate moved into a region where the rate of sedimentation was slower.

Since the "best fit" line on the graph slopes upward, it shows that sediment thickness increases with increasing distance from the East Pacific Rise. The purpose of the sketch is to have the student visualize the information shown on the graph. The sketch should show sediments becoming increasingly thicker as distance from the East Pacific Rise increases.

4. Does your graph of distance versus sediment thickness lend support to the sea-floor spreading theory? Why or why not?

The graph and sketch do support the theory of sea-floor spreading. Since the youngest rocks are at the ridge center, you would expect them to have been exposed for a shorter time to the "rain" of sediment. Older rocks farther from the ridge have been exposed longer and consequently have a thicker sediment cover.

5. Fill in the age of the rocks at the bottom of the sediments in the graph below. For each drilling site number, plot the distance to the ridge center along the horizontal axis. Plot the bottom sediment age along the vertical axis. Do not plot the data from Site 84 at this time. This site is unusual, and you will plot it later.



Graph of age of bottom sediments versus distance to middle of the East Pacific Rise.

6. Explain what your graph shows about the relation of bottom sediment age to distance from the middle of the East Pacific Rise.

The graph indicates that the bottom sediments become progressively older the farther they are from the ridge center. The line is not straight because the spreading rate has varied through geologic time.

7. Does your graph in step 5 support the theory of sea-floor spreading?

The graph (and data) supports the theory of sea-floor spreading since new crustal material is added at the ridge center and hence is young, as is the sediment cover. As spreading occurs, the older rocks, with their overlying sediment, are pushed farther from the ridge as progressively younger rocks are added. Hence, we would expect the oldest sediments at some distance from the ridge and younger sediments adjacent to the ridge.

8. Now plot the data from Site 84 on both of your graphs (steps 1 and 5).

The point for Site 84 should lie well below the "best fit" line on both graphs.

9. Let's be sure you understand why Site 84 is unusual. From Table 1 you can see that Site 84 is located almost the same distance from the middle of the East Pacific Rise as Site 79. But the Site 84 points you plotted on your graphs are not near the points for Site 79. From the first graph you can see the sediment at Site 84 is not as thick as expected. In the second graph, you can see the age of the sediments is less than expected. Something really is unusual at Site 84! What do you think causes this? To find out the answer, look carefully at the location of Site 84 on the core map. Compare its location on the National Geographic map, *Pacific Ocean Floor* (your teacher has a copy). Sketch on the core map any feature of the National Geographic map which might help explain the unusual data from drill Site 84.

Site 84 does not fall close to either line. The data appears anomalous (does not fit the pattern) because the sediments overlying the basalt at Site 84 are younger than Site 83. This suggests the sediments at Site 84 may be influenced by their proximity to the Cocos Ridge (another spreading center). If Site 84 is plotted with respect to the Cocos Ridge as a spreading center, the data do "fit" and further support the theory. Students should sketch in the approximate position of the Cocos Ridge on the core map.

10. Suppose it costs $1,000,000 to drill a core, and you have just received $4,000,000 to drill new cores. You are in charge of the drilling ship. You need more information to explain the unusual data at Site 84. Where would you locate new drill sites? Show your drill sites on the core map and explain the information you hope to gain at each new site.

The four site locations (4 cores at $1,000,000 each) chosen by each student depend on the additional information desired.

If information is wanted to identify the Cocos Ridge as a spreading center, drill the cores on both sides of the ridge, perpendicular to its axis. Some students may wish to drill cores near the Middle America Trench to examine Cocos Ridge/Trench interaction. You might wish to call the students' attention to other modules dealing with trenches and subduction zones.

The student may suggest that cores be drilled closer to, or farther from, Site 84 to determine where the influence of the East Pacific Rise diminishes and the influence of the Cocos Ridge predominates.

Further, some students may want to take core samples in the region of Site 84 to confirm the data derived from the original core sample.

PROCEDURE

PART B How can sediment data be used to determine the rate of movement of the ocean floor?

The students calculate the rate of spreading along the East Pacific Rise, using the familiar formula: Distance = Rate x Time

Key words: none

Time required: one 45-minute period

Materials: meter stick or metric measuring tape.

Some students may need help in converting kilometers to centimeters (100 centimeters/meter x 1000 meters/kilometer = 100,000 centimeters/kilometer or 1×10^5 cm/km).

Examination of Table 2 shows with three different time intervals that the rate of spreading has not been the same throughout geologic history.

Suppose a car starts from a given point and is driven for 10 hours in a straight line. At the end of 10 hours it is found to have traveled 50 km. How fast did the car move? You know that rate equals the distance traveled divided by the time, or,

$$\text{Rate} = \frac{\text{Distance}}{\text{Time}}$$

therefore,

$$\text{Rate} = \frac{50\text{ km}}{10\text{ hours}} = 5\text{ km per hour.}$$

You can use this same formula as you investigate ocean-floor movement.

1. Using Table 1 you can see that the bottom sediment at Site 77 is 36 million years old. What is the rate at which the ocean floor moved to carry the bottom sediments 3,359 km from the middle of the East Pacific Rise? Write your answer in centimeters per year. (You can ask your teacher to help you if you have difficulty changing kilometers to centimeters.)

$$\text{Rate of motion} = \frac{\text{Distance traveled}}{\text{Time in years}}$$

$$\text{Rate} = \frac{(3{,}359\text{ km})}{(36{,}000{,}000\text{ years})} \times \frac{(100{,}000\text{ cm})}{(1\text{ km})}$$

$$= \frac{(3.359 \times 10^3\text{ km})}{(3.6 \times 10^7\text{ years})} \times \frac{(1 \times 10^5\text{ cm})}{(1\text{ km})}$$

$$= 0.933 \times 10^1\text{ cm/yr}$$

$$= 9.33\text{ cm/yr}$$

2. Imagine that the *Glomar Challenger* drilled a core 7,100 km west of the East Pacific Rise. How old would you expect those bottom sediments to be? (HINT. You will have to change the formula to read time equals distance traveled divided by the rate.)

$$\text{Time} = \frac{\text{Distance traveled}}{\text{Rate}}$$

$$= \frac{(7100\ \text{km})}{(9.33\ \text{cm per year})} \times \frac{(100{,}000\ \text{cm})}{(1\ \text{km})}$$

$$= \frac{(71 \times 10^2\ \text{km})}{(9.33\ \text{cm per year})} \times \frac{(1 \times 10^5\ \text{cm})}{(1\ \text{km})}$$

$$= \mathbf{0.761 \times 10^8\ years}$$

$$= \mathbf{76{,}100{,}000\ years}$$

Table 2.
Rates of sea-floor movement west of the East Pacific Rise

Time interval	*Average movement rate*
0–10 million years	6.5 cm/yr
10–20 million years	11.5 cm/yr
20–37 million years	9.4 cm/yr

3. Examine Table 2. You can see that the average movement rate for the first 10 million years was 6.5 cm per year. For the next 10 million years the rate was 11.5 cm per year What do the different movement rates indicate? Has the Pacific Ocean floor near the East Pacific Rise moved at the same rate all through its history?

The different movement rates for the three time intervals indicate that the rate has changed. The rate of movement of the Pacific Ocean floor has varied through geologic time. The cause of these changes is not clearly understood and is the subject of current research. Note that movement rates are not the same as spreading rates, which are a measure of how fast two adjoining plates are moving apart.

4. Measure your height in centimeters How long would it take a rock near the East Pacific Rise to move the same distance as you are tall? (Use the rate of movement from question #1)

Answers will vary, but the answers should be determined as below. Assume a student is 157.5 cm tall (5 feet 2 inches).

$$\text{Time} = \frac{\text{Distance}}{\text{Rate (from question \#1 above)}}$$

$$= \frac{(157.5\ \text{cm})}{(9.33\ \text{cm/yr})}$$

$$= \mathbf{16.9\ years}$$

SUMMARY QUESTIONS

1. Scientists think that the process of sea-floor spreading occurs in the Atlantic Ocean just as it does in the Pacific. Core samples have been drilled in the Atlantic Ocean floor. Do you think bottom sediments drilled near the North American continent are older than the sediments drilled near the Mid-Atlantic Ridge? Explain your answer below.

The sea-floor spreading hypothesis holds for all spreading centers. Therefore, if sea-floor spreading occurs in the Atlantic, the older sediments should be located farther from the Mid-Atlantic Ridge; sediments drilled near the North American continent would be older.

2. Could you figure out how fast the East Pacific Rise is spreading if you didn't know the age of the bottom sediments? Why or why not?

No you couldn't. You need to know the age-to-distance-traveled relationship to determine the rate of motion (this can be clearly illustrated by referring to the algebraic equation: Rate = Distance ÷ Time). The age of the rocks can be determined by methods other than dating the bottom sediments. One such way is by using magnetic anomalies. You may wish to use another module dealing with magnetic anomalies.

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EVALUATION

In addition to formal evaluation you can observe the students' participation and performance as a means of informal evaluation. Alternatively, you may wish to give each student a map of an ocean with the mid-ocean ridge shown. Ask them to show which way the ocean floor is moving and label the older and younger parts of the ocean floor.

EXTENSIONS

Pretend you are a scientist who does not believe the theory of sea-floor spreading. Make alternate hypotheses to explain the data. How would you explain the sediment thickness data?

Put your arguments in written form and "publish" a scientific article so your classmates can read it. Persuade other students to propose different hypotheses and write articles explaining their theories.

This can be the most exciting portion of the lab. Encourage students to offer hypotheses that explain the data.

You can improve their writing skills by asking them each to write an article as if it were to be published in a scientific journal. Have them circulate their articles to other members of the class. The writing of one's ideas and explaining them to colleagues often enhances understanding of the original concepts being presented.

Students should be encouraged to offer their own hypotheses to explain the data presented in this module. It may be difficult, but it can be and has been done, most notably by a Soviet geologist, Belossov, and the American petroleum geologist, Meyerhoff. Syntheses of their arguments can be found in Sullivan's book listed in the references.

A point might well be made here. Any datum presented in this module by itself does not necessarily "prove" the theory of sea-floor spreading. It is the sum of all the observable evidence, including much not presented here, that makes such a strong case in favor of the theory. It should be pointed out, however, that some of the strongest data supporting the theory of sea-floor spreading are the observed magnetic anomalies coupled with age-dating of the corresponding rocks.

Considerations of this sort can lead to a discussion of what constitutes proof. For example, have students "prove" the earth is round and not flat.

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NAGT Crustal Evolution Education Project Modules

CEEP Modules are listed here in alphabetical order. Each Module is designed for use in the number of class periods indicated. For suggested sequences of CEEP Modules to cover specific topics and for correlation of CEEP Modules to standard earth science textbooks, consult Ward's descriptive literature on CEEP. The Catalog Numbers shown here refer to the CLASS PACK of each Module consisting of a Teacher's Guide and 30 copies of the Student Investigation. See Ward's descriptive literature for alternate order quantities.

CEEP Module	Class Periods	CLASS PACK Catalog No.
• A Sea-floor Mystery: Mapping Polarity Reversals	3	34 W 1201
• Continents And Ocean Basins: Floaters And Sinkers	3-5	34 W 1202
• Crustal Movement: A Major Force In Evolution	2-3	34 W 1203
• Deep Sea Trenches And Radioactive Waste	1	34 W 1204
• Drifting Continents And Magnetic Fields	3	34 W 1205
• Drifting Continents And Wandering Poles	4	34 W 1206
• Earthquakes And Plate Boundaries	2	34 W 1207
• Fossils As Clues To Ancient Continents	2-3	34 W 1208
• Hot Spots In The Earth's Crust	3	34 W 1209
• How Do Continents Split Apart?	2	34 W 1210
• How Do Scientists Decide Which Is The Better Theory?	2	34 W 1211
• How Does Heat Flow Vary In The Ocean Floor?	2	34 W 1212
• How Fast Is The Ocean Floor Moving?	2-3	34 W [illegible]
• Iceland: The Case Of The Splitting Personality	3	34 W 1214
• Imaginary Continents: A Geological Puzzle	2	34 W 1215
• Introduction To Lithospheric Plate Boundaries	1-2	34 W 1216
• Lithospheric Plates And Ocean Basin Topography	2	34 W 1217
• Locating Active Plate Boundaries By Earthquake Data	2-3	34 W 1218
• Measuring Continental Drift: The Laser Ranging Experiment	2	34 W 1219
• Microfossils, Sediments And Sea-floor Spreading	4	34 W 1220
• Movement Of The Pacific Ocean Floor	2	34 W 1221
• Plate Boundaries And Earthquake Predictions	2	34 W 1222
• Plotting The Shape Of The Ocean Floor	2-3	34 W 1223
• Quake Estate (board game)	3	34 W 1224
• Spreading Sea Floors And Fractured Ridges	2	34 W 1225
• The Rise And Fall Of The Bering Land Bridge	2	34 W 1227
• Tropics In Antarctica?	2	34 W 1228
• Volcanoes: Where And Why?	2	34 W 1229
• What Happens When Continents Collide?	2	34 W 1230
• When A Piece Of A Continent Breaks Off	2	34 W 1231
• Which Way Is North?	3	34 W 1232
• Why Does Sea Level Change?	2-3	34 W 1233

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CRUSTAL EVOLUTION EDUCATION PROJECT

NAME DATE

Student Investigation
Catalog No 34W1113

How Fast Is The Ocean Floor Moving?

INTRODUCTION

Many earth scientists believe that the continents of Africa and South America were once joined together What is the evidence for this belief? If it is true, how long has it taken for these two continents to break apart and move to where they are now? Is the earth's surface moving in other places?

One way to answer these questions is to study samples of **sediment** taken from the ocean floor Sediment is loose rock, mineral debris, and plant and animal shells which have settled out of the water In these activities you will use sediment data, like scientists do, to determine how fast the ocean floor is moving.

The deep sea sediments were obtained by the ***Glomar Challenger.*** The *Glomar Challenger* is a specially designed drilling ship that can take samples of sediment and rock from the floor of deep ocean basins It recovers both sediment and rock cores A **core** is a cylinder of sediment or rock obtained by using a hollow drill. In many cases, scientists must drill through hundreds of meters of sediment before reaching the solid igneous rock of the ocean floor. This igneous rock forms by cooling and hardening of molten rock material. It is the "floor" upon which the sediments settle.

OBJECTIVES

After you have completed these activities, you should be able to

1. Make and interpret graphs which show the relationship between the thickness of a sediment sample and its distance from a mid-ocean ridge.

2. Make and interpret graphs which show the relationship between the age of deep sea sediments and their distance to a mid-ocean ridge

3. Form hypotheses about sea-floor movement based on data from sediment cores.

4. Calculate the rate of movement of the ocean floor from data on sediment thicknesses, ages of sediment, and locations of the drill sites

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PROCEDURE

PART A. What can we learn from deep sea sediments?

Materials: map, *Pacific Ocean Floor*, National Geographic Society.

The data you will be using in this activity are based on measurements from sediment cores. The *Glomar Challenger* drilled these sediment cores near the **East Pacific Rise.** The East Pacific Rise is part of a 64,000 km-long mid-ocean ridge system. Mid-ocean ridges are thought to be places where the process of **sea-floor spreading** (which results in breakup and separation of continents) takes place. Figure 1 is a map showing where the cores were drilled.

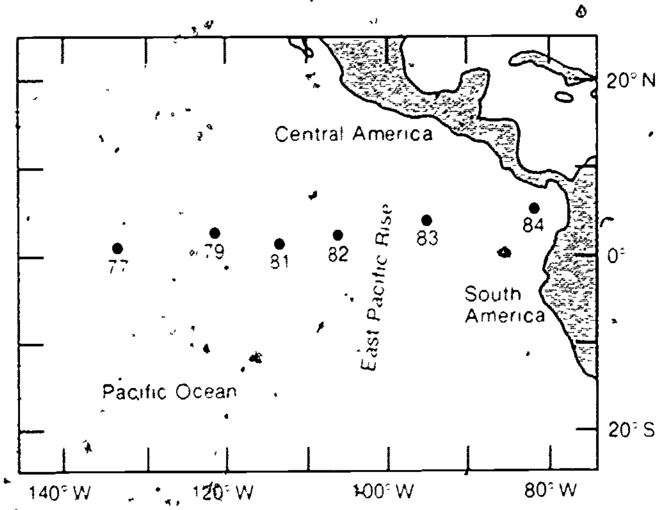

Figure 1 Site locations of Leg 9 deep sea drilling cores (Modified from Hays, J D., and others, 1970, p 12, with permission)

Table 1 contains data about position and thickness of deep sea sediments lying on top of the igneous rock of the ocean floor

Table 1.

Glomar Challenger Deep Sea Cores, Leg 9 (Modified from Hays, J.D., and others, 1970, p. 12, with permission.)

Drill Site Number and Location	*Distance from Middle of East Pacific Rise*	*Sediment Thickness Down to Igneous Rock*	*Bottom Sediment Age (millions of years old)*
77 (West of East Pacific Rise)	3,359 km	481 m	36
79 (West of East Pacific Rise)	2 086 km	414 m	21 5
81 (West of East Pacific Rise)	1 280 km	409 m	14 5
82 (West of East Pacific Rise)	549 km	214 m	9 5
Approximate Ridge Axis	0 km	none recovered	0
83 (East of East Pacific Rise)	797 km	241 m	10 5
84 (East of East Pacific Rise)	2 000 km	254 m	8 5

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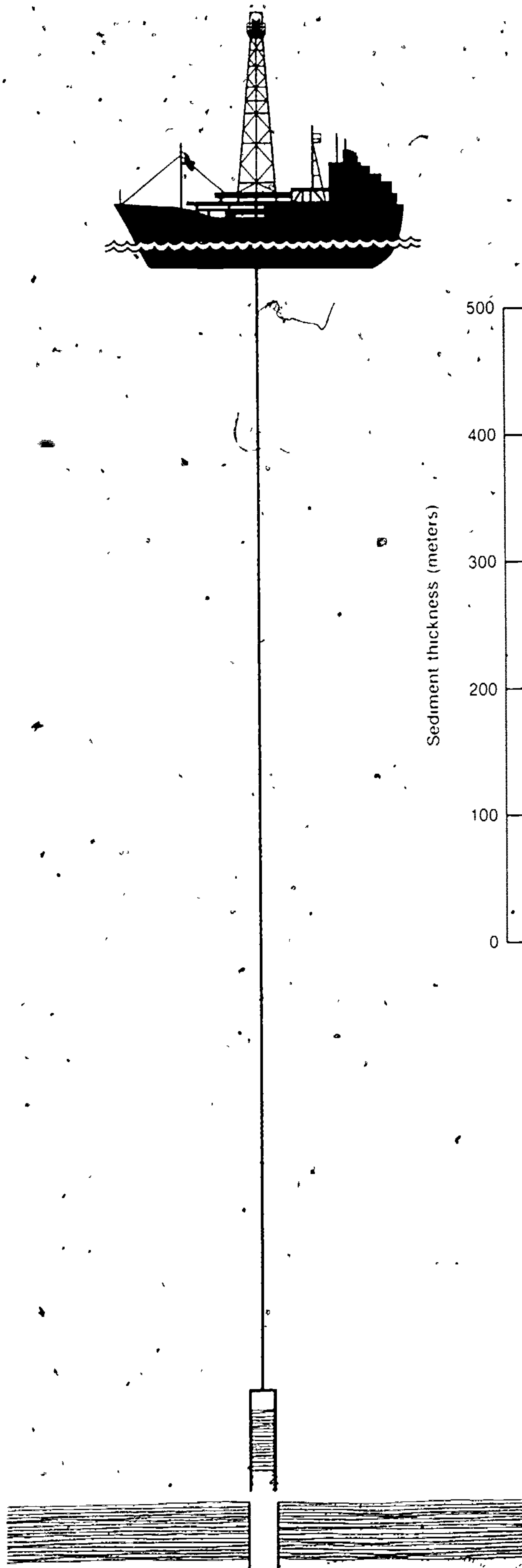
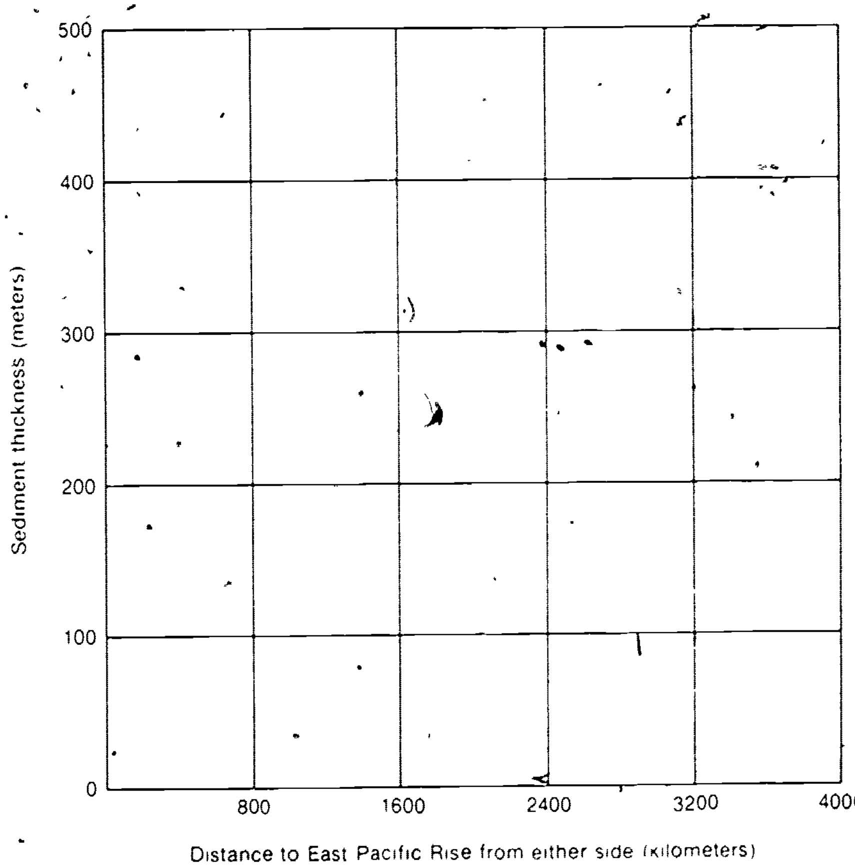
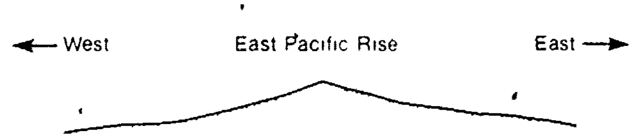


1. Using the sediment thickness data from Table 1, complete the graph below. Plot the distance to the East Pacific Rise along the horizontal axis. Plot the sediment thickness along the vertical axis. Do not plot data from Site 84 at this time. This site is unusual, and you will plot it later



Graph of sediment thickness versus distance to middle of the East Pacific Rise.

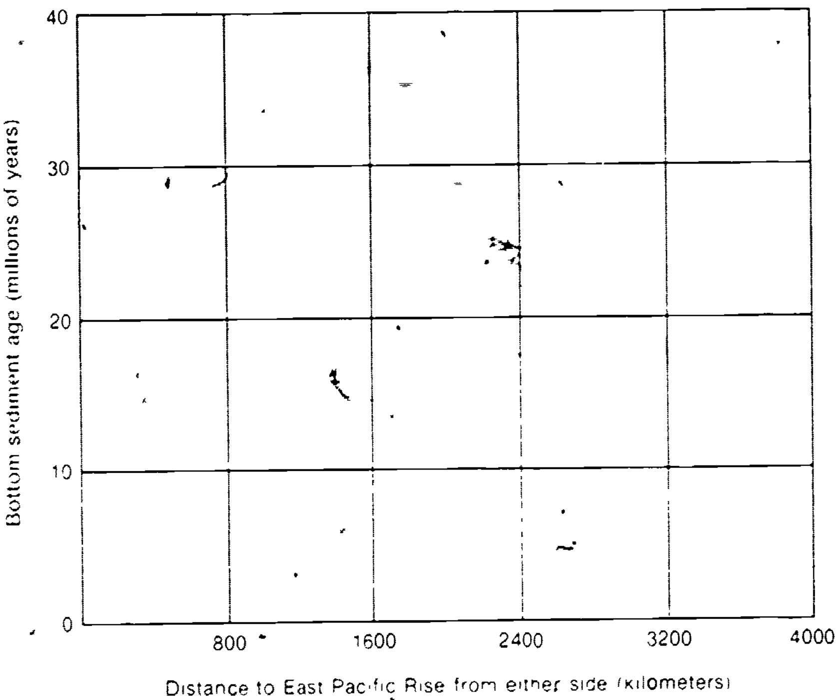
2. Shown below is a profile of the igneous rock ocean floor on each side of the East Pacific Rise. Sketch in how you think sediment thickness changes in both directions away from the middle of the East Pacific Rise.



3. Explain what your graph and sketch mean in the space below

4. Does your graph of distance versus sediment thickness lend support to the sea-floor spreading theory? Why or why not?

5. Fill in the age of the rocks at the bottom of the sediments in the graph below. For each drilling site number, plot the distance to the ridge center along the horizontal axis. Plot the bottom sediment age along the vertical axis. Do not plot the data from Site 84 at this time. This site is unusual, and you will plot it later.



Graph of age of bottom sediments versus distance to middle of the East Pacific Rise

6. Explain what your graph shows about the relation of bottom sediment age to distance from the middle of the East Pacific Rise.

7. Does your graph in step 5 support the theory of sea-floor spreading?

8. Now plot the data from Site 84 on both of your graphs (steps 1 and 5).

9. Let's be sure you understand why Site 84 is unusual From Table 1 you can see that Site 84 is located almost the same distance from the middle of the East Pacific Rise as Site 79. But the Site 84 points you plotted on your graphs are not near the points for Site 79. From the first graph you can see the sediment at Site 84 is not as thick as expected. In the second graph, you can see the age of the sediments is less than expected. Something really is unusual at Site 84! What do you think causes this? To find out the answer, look carefully at the location of Site 84 on the core map. Compare its location on the National Geographic map, *Pacific Ocean Floor* (your teacher has a copy) Sketch on the core map any feature of the National Geographic map which might help explain the unusual data from drill Site 84.

10. Suppose it costs $1,000,000 to drill a core, and you have just received $4,000,000 to drill new cores. You are in charge of the drilling ship You need more information to explain the unusual data at Site 84 Where would you locate new drill sites? Show your drill sites on the core map and explain the information you hope to gain at each new site

PROCEDURE

PART B How can sediment data be used to determine the rate of movement of the ocean floor?

Materials meter stick or metric measuring tape

Suppose a car starts from a given point and is driven for 10 hours in a straight line. At the end of 10 hours it is found to have traveled 50 km How fast did the car move? You know that rate equals the distance traveled divided by the time, or,

$$\text{Rate} = \frac{\text{Distance}}{\text{Time}}$$

therefore,

$$\text{Rate} = \frac{50 \text{ km}}{10 \text{ hours}} = 5 \text{ km per hour}$$

You can use this same formula as you investigate ocean-floor movement

1. Using Table 1 you can see that the bottom sediment at Site 77 is 36 million years old. What is the rate at which the ocean floor moved to carry the bottom sediments 3,359 km from the middle of the East Pacific Rise? Write your answer in centimeters per year (You can ask your teacher to help you if you have difficulty changing kilometers to centimeters)

2. Imagine that the *Glomar Challenger* drilled a core 7,100 km west of the East Pacific Rise How old would you expect those bottom sediments to be? (HINT You will have to change the formula to read time equals distance traveled divided by the rate)

Table 2
Rates of sea-floor movement west of the East Pacific Rise

Time interval	*Average movement rate*
0-10 million years	6.5 cm/yr
10-20 million years	11 5 cm/yr
20-37 million years	9 4 cm/yr

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3. Examine Table 2. You can see that the average movement rate for the first 10 million years was 6.5 cm per year. For the next 10 million years the rate was 11.5 cm per year. What do the different movement rates indicate? Has the Pacific Ocean floor near the East Pacific Rise moved at the same rate all through its history?

4. Measure your height in centimeters. How long would it take a rock near the East Pacific Rise to move the same distance as you are tall? (Use the rate of movement from question #1.)

SUMMARY QUESTIONS

1. Scientists think that the process of sea-floor spreading occurs in the Atlantic Ocean just as it does in the Pacific. Core samples have been drilled in the Atlantic Ocean floor. Do you think bottom sediments drilled near the North American continent are older than the sediments drilled near the Mid-Atlantic Ridge? Explain your answer below.

2. Could you figure out how fast the East Pacific Rise is spreading if you didn't know the age of the bottom sediments? Why or why not?

EXTENSIONS

Pretend you are a scientist who does not believe the theory of sea-floor spreading. Make alternate hypotheses to explain the data. How would you explain the sediment thickness data?

Put your arguments in written form and "publish" a scientific article so your classmates can read it. Persuade other students to propose different hypotheses and write articles explaining their theories.

REFERENCES

Hays, J.D., and others, 1970, Deep Sea Drilling Project, Leg 9. *Geotimes*, v. 15, no. 4 (April), p. 11-13.

Sullivan, W., 1974, *Continents in motion—the new earth debate*. San Francisco, McGraw-Hill Book Company, 399 p.

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