CEEP™

CRUSTAL EVOLUTION EDUCATION PROJECT

Movement Of The Pacific Ocean Floor

Movement Of The Pacific Ocean Floor

TEACHER'S GUIDE

Catalog No. 34W1021

For use with Student Investigation 34W1121
Class time: two 45-minute periods

Developed by
THE NATIONAL ASSOCIATION OF GEOLOGY TEACHERS

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Ward's Natural Science Establishment, Inc. Rochester, NY • Monterey, CA

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.

The material was prepared with the support of National Science Foundation Grant Nos. SED 75-20151, SED 77-08539, and SED 78-25104. However, any opinions, findings, conclusions, or recommendations expressed herein are those of the author(s) and do not necessarily reflect the views of NSF.

Movement Of The Pacific Ocean Floor

INTRODUCTION

In this module students will investigate the following questions:

1. What does the floor of the Pacific Ocean look like?

2. How is the Pacific sea-floor topography related to plate tectonics?

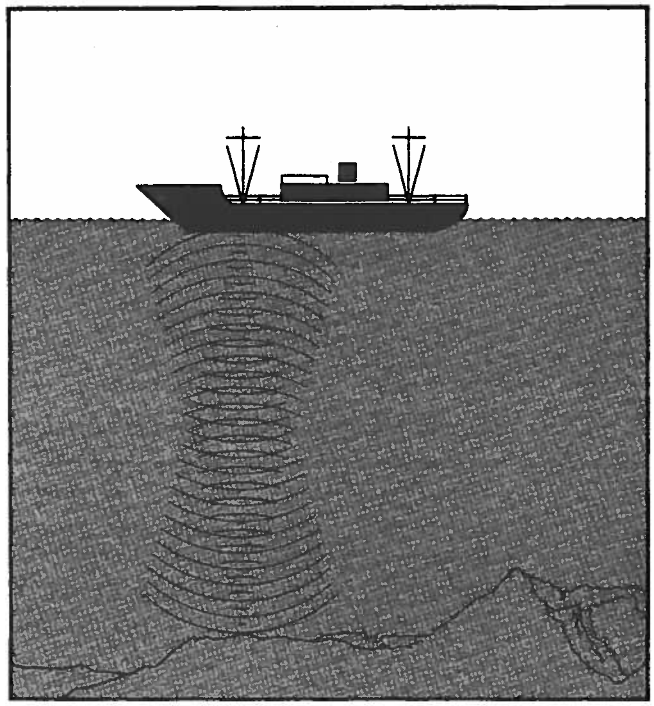
3. How can data on the age of the sea floor at different locations be used to estimate the direction and velocity of apparent sea-floor movement?

What does the floor of the Pacific Ocean Basin look like? Why does it look that way? What else can we discover about it?

The map of the *Pacific Ocean Floor* which your teacher will give you shows how the Pacific Ocean might appear without the seawater. On the map an artist has drawn the ocean bottom landscape as determined by thousands of depth soundings of the sea floor.

The map shows that there are several different kinds of features on the ocean bottom. In the southeast Pacific (lower right of map) lies a ridge, called the East Pacific Rise, which is slowly spreading outward. This mid-ocean ridge is cut by many fractures called **transform faults.**

The Pacific Ocean is mostly bordered by deep trenches. The central area of the map shows numerous volcanic islands and underwater mountains. Many of these, such as the Hawaiian Islands and the Emperor Seamount Chain, are strung out in long, nearly straight lines.



For more detailed geographical information, refer to the conventional map of the Pacific area on the back of the sea-floor chart.

PREREQUISITE STUDENT BACKGROUND

Prior to doing this module, a basic knowledge of crustal processes as developed in Introductory CEEP investigations (e.g. Earthquakes And Plate Boundaries) is necessary. Students should be familiar with the distortion that accompanies Mercator projections. In addition, the notion of vertical exaggeration and a great circle meridian should be discussed. Plotting data on a graph and using a simple rate formula are mathematical skills required of the students.

OBJECTIVES

After you have completed this activity, you should be able to:

1. Locate on a map the principal island chains, mid-ocean ridges and oceanic trenches of the Pacific Ocean Basin.
2. Plot the data and find the relationship between the age and location of the islands.
3. Determine the direction of apparent sea-floor movement in the Central Pacific.
4. Calculate the average rate of Pacific sea-floor movement in centimeters per year.
5. Determine the approximate direction of ocean plate movement on both sides of the East Pacific Rise.
6. Explain what eventually happens to the moving Pacific sea floor.

MATERIALS

Map, *Pacific Ocean Floor,* National Geographic Society, Educational Services, Department 79, Washington, D.C. 20036—one map for each group of students. (Note: This map has English units of measurement. In this module students will be using both metric and English units.)

Physical world globe (optional)—one per class.

BACKGROUND INFORMATION

Nowhere is the relative movement of an entire crustal plate more dramatically illustrated than on the Pacific Plate. As far back as 1838, an American geologist, James Dana, noted that the Hawaiian Islands become progressively older northwestward along the entire Hawaiian chain. Dana could only base his evidence on the relative amounts of erosion and weathering which were noticeable on the islands. Modern radiometric dating now supports the notion that movement of the Pacific Plate has accompanied the formation of a string of volcanoes that are progressively younger. Several other similar chains parallel the Hawaiian chain, i.e. Tuamotu Ridge and the Marshall Islands.

Although other evidence may be used to show the direction of Pacific Plate motion, such as the trend of the "Chalk Line," nothing appears to be a better indicator than the route indicated by the volcanic chains. (The "Chalk Line" is the deposit of carbonate shells of micro-organisms in equatorial waters. Throughout time this white, chalk-like material has been carried northwestward. Consequently, paleontological dating of these micro-organisms indicates a northwest-trending increase in age.)

In recent years the entire system of islands and seamounts has been considered a chain that shows the direction of plate motion. A bend in the volcanic island chain indicates a change in the direction of plate motion. Such a bend is obvious between the Midway Islands and the Milwaukee Seamount. Since the volcanic material in this area was deposited about 40 million years ago, it can be interpreted that this change of direction occurred at the same time. Other volcanic chains in the Pacific (i.e. the Tuamotu Chain) also bend sharply at an age of 40 million years.

SUGGESTED APPROACH

Although not absolutely essential, it would be helpful to have on hand a physical globe (e.g. National Geographic Society, 1971) which shows the same physiographic features of the Pacific sea floor without the distortion inherent in the Mercator projection.

As the maps generate much student interest, any orientation or background material that you deem necessary should be done prior to distributing the maps. The following skills and concepts should be reviewed before students begin the module:

1. The shortest distance between any two points on a sphere is along the arc of a great circle connecting the two points.
2. Review basic graphing skills. (Note that the graph has already been set up for the students.)
3. Review basic direction, rate, and time computations.

Once these skills and concepts have been established, the best way to approach the activity is to hand out the materials and have students get started. Questions that arise are best handled in small groups.

PROCEDURE

Students utilize the map, *Pacific Ocean Floor,* in identifying the location and directional trend of the Hawaiian, Milwaukee, and Emperor Seamount Chains. As the ages of the islands are plotted, it should become apparent that the islands grow progressively older away from the island of Hawaii.

By knowing the age of the different islands and the distance of these islands from Hawaii, the students can calculate an approximate rate of sea-floor movement. The fracture pattern on opposite sides of the East Pacific Rise is additional evidence for the directional trend of Pacific Plate motion.

Finally, students are asked to identify the ocean structure in which a seamount chain appears to end.

Key words: transform fault, seamount, plate, reef, ocean trench, ocean ridge

Time required: two 45-minute periods

Materials: *Pacific Ocean Floor* map

1. Locate the Hawaiian Island chain, approximately in the center of the map. In this island chain, the highest point above sea level is the top of the volcano Mauna Kea on the island of Hawaii. From Hawaii the chain extends thousands of kilometers **west-northwest** to the vicinity of the Milwaukee Seamount group. A **seamount** is an underwater mountain, commonly an extinct volcano. From the vicinity of the Milwaukee group, the trend of the Emperor Seamount Chain changes to the **northwest** direction. Locate the northern end of the Emperor Seamount Chain. At what ocean basin feature does the Emperor Seamount Chain end?

The Emperor Seamount Chain ends at the Aleutian trench.

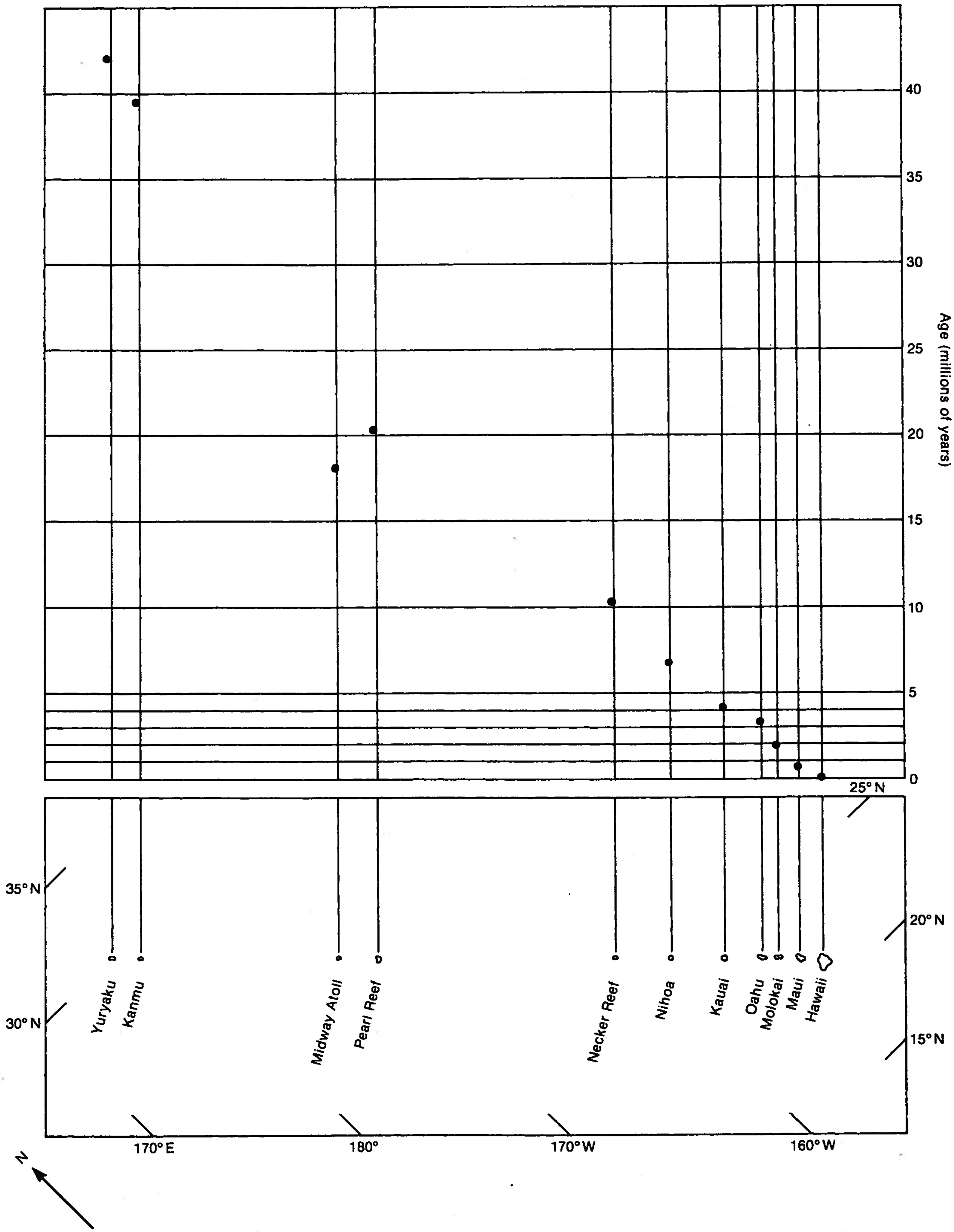
The ages of several islands in the Hawaiian chain are listed in Table 1. The locations of the islands are plotted on the Worksheet. (Note that the age listed for Midway atoll is questionable, due to difficulties in sampling.)

2. Plot the ages of the islands on the graph on the Worksheet, above the map of their location. What happens to the age of the islands as their distance from the island of Hawaii increases?

The data suggest that there is a positive correlation between the age of any given island and its distance from the island of Hawaii. The farther away it is, the older it is.

Table 1.
Hawaiian Island ages

Island (or reef)	*Approximate age (millions of years)*
Hawaii (Kilauea)	0
Kanmu	39.0
Kauai	4.1
Maui (Haleakala)	0.6
Midway Atoll	18.0 (?)
Molokai	1.8
Necker Reef	10.1
Nihoa	7.0
Oahu	3.1
Pearl Reef	20.1
Yuryaku	42.3



Answer Sheet

The earth's crust consists of a number of separate rigid **plates,** some of whose boundaries are marked by chains of volcanoes. For a long time, volcanic mountains near the center of crustal plates, like the Hawaiian chain, were a mystery to many earth scientists. One possible explanation for their formation is that they are the result of hot spots in the earth material beneath the plates. The hot spot is thought to be relatively fixed in position, compared to the crustal plate which is moving over it. (See Figure 1.)

As the plate moves over this hot spot, the crust above is partially melting. Molten material reaches the surface, forming underwater volcanoes and eventually volcanic islands. The volcanic islands that have been formed are then carried away in the direction the plate is moving.

Use the graph on the Worksheet to answer the following four questions:

3. According to the explanation given, which island in the Hawaiian Island chain is presently above the hot spot?

Hawaii (Mauna Loa and Kilauea are active volcanoes on this island).

4. According to the explanation given, which island would have been above the hot spot 20 million years ago?

Pearl Reef

5. Assuming that the Pacific Plate has acted as one rigid plate during the past 30 or 40 million years, in what direction has the Pacific Plate been moving?

Northwest (or more accurately, west-northwest).

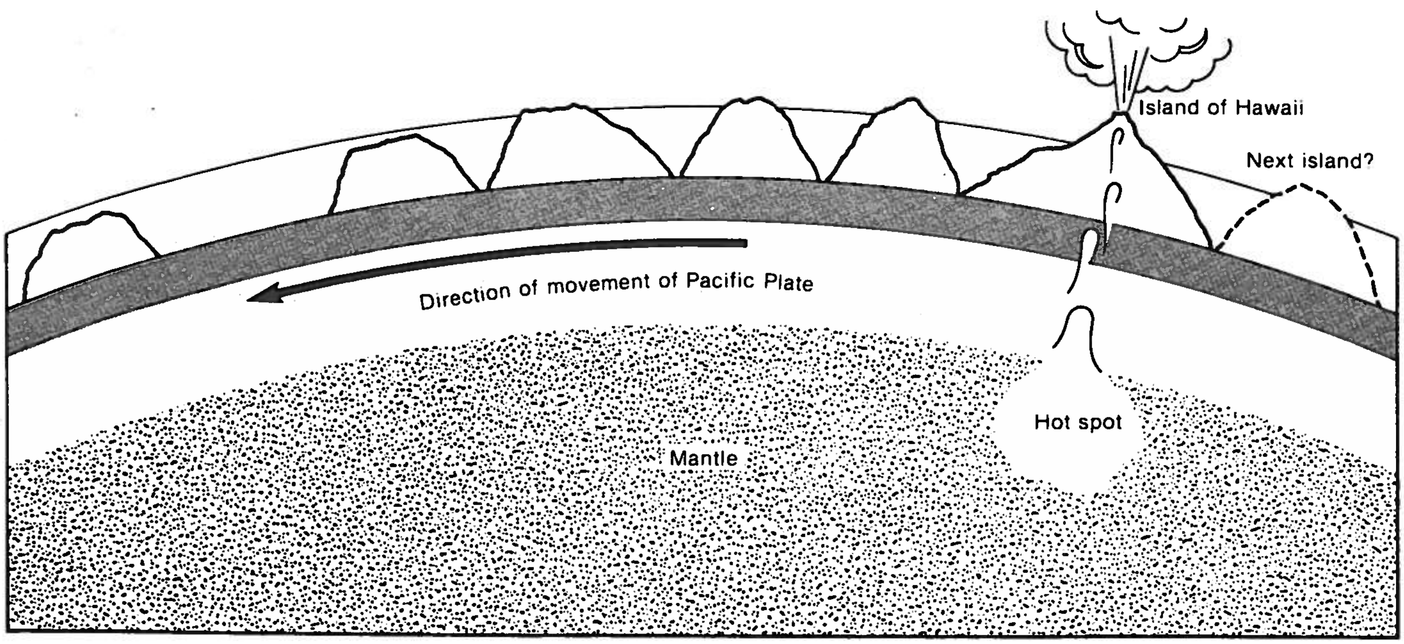


Figure 1. This diagram shows how volcanic islands may be formed by a hot spot which punches through the crust, forming volcanoes as the crustal plate slides by overhead.

The distance from the island of Hawaii to Pearl Reef is about 2,000 km. A **reef** is a ridge of rock, usually coral, which is at or near the surface of the water.

6. What has been the approximate rate or velocity of sea-floor movement, in centimeters per year, during the 20 million years since Pearl Reef was formed? (Note: 1 km = 100,000 cm, so 2,000 km = 200,000,000 cm.)

$$\textbf{rate} = \frac{\textbf{200,000,000 cm}}{\textbf{20,000,000 yr}} = \textbf{10 cm/yr}$$

Note: This is an approximation. Students can utilize the map scale or a globe scale to determine a more precise distance between these two islands.

Use the map, *Pacific Ocean Floor,* to answer the next four questions. Locate the East Pacific Rise in the southeast part of the Pacific basin. This is thought to be a **mid-ocean ridge** (or spreading center) from which new ocean crust material is spreading outward. The many fractures that cut across the ridge are believed to point in the approximate direction of sea-floor spreading.

7. Locate the area **west** of the East Pacific Rise between the Challenger Fracture Zone and the Eltanin Fracture Zone. Looking at the fracture pattern in this area, tell the direction in which the Pacific Plate appears to be moving.

West-northwest

8. Locate the area between the same two fracture zones on the **east** side of the East Pacific Rise. What is the approximate direction of sea-floor spreading?

East-southeast

Notice the deep **ocean trenches** that border the Pacific Ocean basin. Ocean trenches are long, narrow depressions found near the edges of continents. Record the maximum depth of these features:

Peru-Chile Trench	**-26,454**	feet
Aleutian Trench	**-25,194**	feet
Japan Trench	**-27,600**	feet
Marianas Trench	**-36,198**	feet

9. Which of the trenches listed in question 8 is the deepest?

Marianas Trench

How does this maximum depth compare with the height of the highest point on earth above sea level (Mt. Everest: 29,028 ft.)?

The Marianas Trench is more than 7,000 feet deeper than the elevation of Mt. Everest.

10. Trace the Emperor Seamount Chain northward from the Hawaiian Ridge. At what ocean structure does the Emperor Seamount Chain end?

The Aleutian Trench

What may this indicate about what is happening to the Pacific Ocean floor?

It indicates that the Pacific Ocean floor may be plunging downward into the deep bordering oceanic trenches.

SUMMARY QUESTIONS

1. In what direction does the Pacific Ocean floor as a whole appear to be moving?

West-northwest

Evidence from what types of ocean features can be used to suggest this direction?

Island chains; fracture patterns on both sides of oceanic ridges.

2. How can the fractures that cut across an oceanic ridge help in determining the direction of sea-floor spreading?

The fractures are oriented in the approximate direction of sea-floor spreading.

3. Into what kind of ocean feature does the Pacific ocean floor appear to be moving?

The Pacific Ocean floor appears to be plunging downward into deep oceanic trenches.

REFERENCES

Burke, K.C., and Wilson, J.Tuzo, 1976, Hot spots on the earth's surface. *Scientific American,* v. 235, no. 2 (Feb.), p. 46–57.

Canby, T.Y., 1973, California's San Andreas Fault. *National Geographic,* v. 143, no. 1 (Jan.), p. 38–52.

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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 1213
• 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

CRUSTAL
EVOLUTION
EDUCATION
PROJECT

Spreading Sea Floors And Fractured Ridges

Spreading Sea Floors And Fractured Ridges

TEACHER'S GUIDE

Catalog No. 34W1025

For use with Student Investigation 34W1125
Class time: two 45-minute periods

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Spreading Sea Floors And Fractured Ridges

INTRODUCTION

When scientists first mapped the mid-ocean ridge in the Atlantic Ocean, it seemed like a fairly regular mountain range except for being mostly underwater. Then in 1953, Marie Tharp, a geologist at Lamont Geological Observatory, discovered that the Mid-Atlantic Ridge was split down the middle. Further mapping showed an even more curious thing—the ridge isn't a continuous line of mountains! At many places, the ridge line is broken by offsets called **fracture zones.** Fracture zones are long faults in the ocean crust. Many fracture zones are shown on the wall map, *Atlantic Ocean Floor,* that is used with this activity.

You know that earthquakes occur along active faults on the continents. Are there also earthquakes along the fracture zones?

PREREQUISITE STUDENT BACKGROUND

Students should know about the different types of faults and the relative movement of blocks of the earth's crust in each type of fault. They should also be aware of the relationship between faulting and earthquakes. This activity also presumes that students know about the topography of mid-ocean ridges and that they understand the concept of sea-floor spreading.

OBJECTIVES

After you have completed this activity, you should be able to:

1. Tell how the geography of the mid-ocean mountains is different on either side of a fracture zone.

2. Draw a diagram to show the relation between sea-floor spreading direction and direction of rock movement on both sides of a fracture zone.

3. Explain why earthquakes may occur along only part of a fracture zone.

MATERIALS

Wall map, *Atlantic Ocean Floor,* National Geographic Society, Educational Services, Department 79, Washington, D.C. 20036—at least two copies per class.

World Seismicity Map, United States Geological Survey, 1200 S. Eads Street, Arlington, Va. 22202—at least two copies per class.

Sea-floor spreading device (including cardboard base and paper Worksheet)—one for each team of two students, plus one for yourself.

These devices must be constructed in advance as follows:

1. Prepare sheets of stiff cardboard at least 22 x 27 cm in size—one sheet for each pair of students. Corrugated cardboard from old shipping cartons is adequate. See Figure A 1.

2. Place the Worksheet from a Student Investigation (see Figure A 2) on a sheet of the cardboard. Use it as a guide to cut two slits in the cardboard. These slits, about 2 mm wide and 9 cm long, should each be cut under the Worksheet between the large dots shown. After cutting the slits with a sharp knife, you can make them the proper width simply by passing a table knife through the slits. Use the same Worksheet to prepare all of the sheets of cardboard. Print MAR along the edge of the cardboard at the outside end of each slit (Figure A 1).

3. Prepare all of the Worksheets as follows: First, place a short piece of masking tape at each end of each Worksheet in the spaces indicated. Second, slit all sheets down through the center solid line but *do not* cut through the masking tape at the ends of each Worksheet. See Figure A 2. Then, trim off the excess paper around the perimeter of each Worksheet.

4. Place one Worksheet on each piece of cardboard. Holding several index cards together as a "pusher", push down in succession on the words "PUSH HERE" between each pair of the dashed lines on the Worksheet. As you push, each pair of the dashed lines should move toward each other and meet. Repeat this procedure for each Worksheet. See Figure 1.

Students who investigate suggestion 2, EXTENSIONS, will use the National Geographic maps, *Arctic Ocean Floor, Indian Ocean Floor,* or *Pacific Ocean Floor.* These maps are available from the National Geographic Society at the address given above. Order at least one of each map per class.

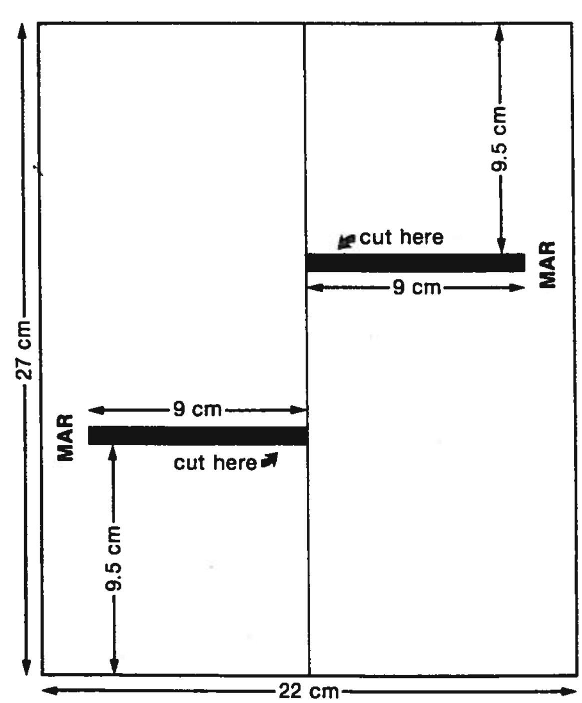


Figure A 1. Cardboard base of sea-floor spreading device.

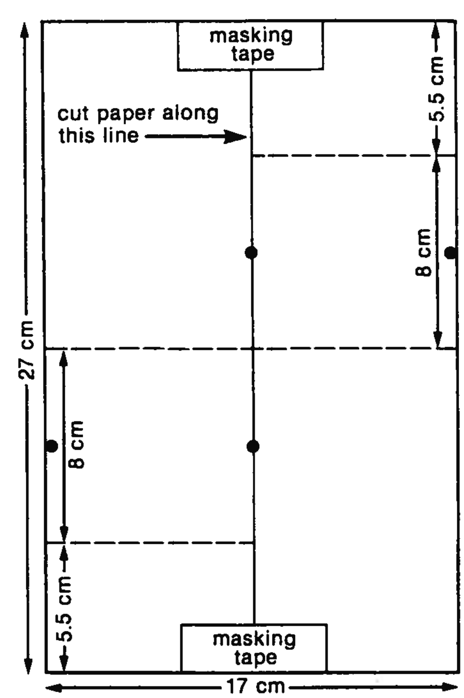


Figure A 2. Worksheet for sea-floor spreading device, from Student Investigation.

BACKGROUND INFORMATION

Beginning in the early 1950s, large fracture zones in the sea floor were first discovered in the eastern Pacific Ocean. In general, fracture zones are long, narrow faults in the earth's crust. They cut across and trend at right angles to mid-ocean ridges. Fracture zones disappear close to the continents. At first it appeared that only the Pacific Ocean had fracture zones, and that it had only a few large ones. However, oceanographers now know that fracture zones are common in all ocean basins. Some scientists think many of them may continue through the continental crust. This seems especially likely in the region of California and adjacent states, where the continental crust may overlie a portion of the mid-ocean mountains of the northern Pacific Ocean. Large fracture zones, such as the Mendocino and Murray, may intersect the hidden mid-ocean mountain range.

In 1965, J. Tuzo Wilson, a Canadian geophysicist, combined information on earthquake and sea-floor spreading to show that active faulting was likely to occur in only a portion of a fracture zone: the portion lying between offset ridges of the mid-ocean mountain range (Figure B). This part of a fracture zone is called a transform fault.

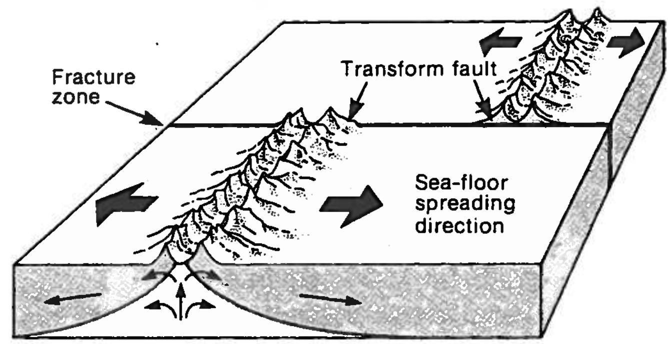


Figure B. A mid-ocean ridge offset along a fracture zone.

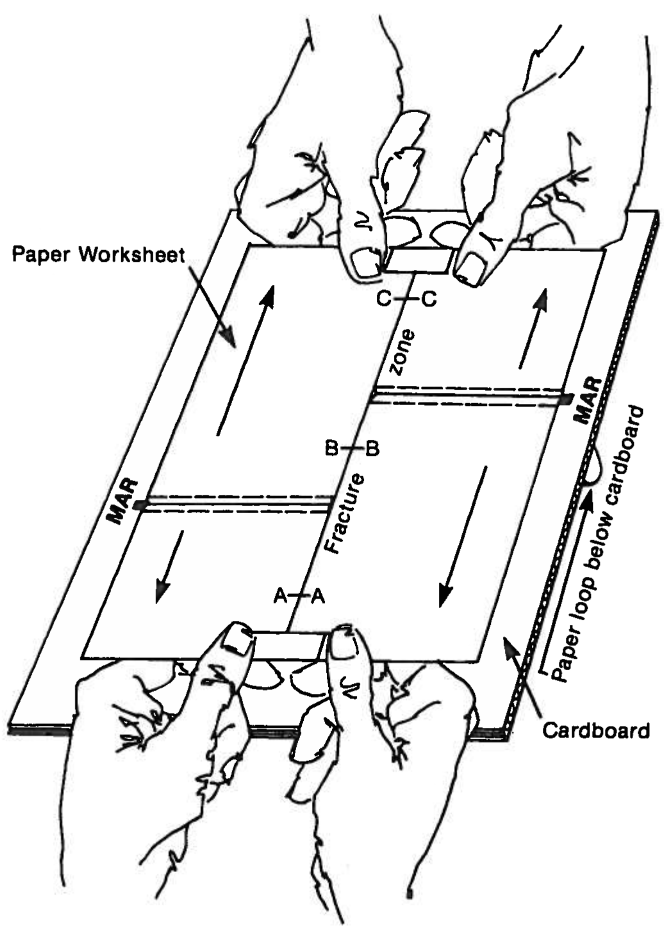


Figure 1. Sea-floor spreading device, labeled as indicated in the instructions. Note the manner in which the device is to be operated, with movement indicated by the arrows.

SUGGESTED APPROACH

The students should be grouped in pairs, preferably with partners facing each other across the lab table, when they begin to use the sea-floor spreading device. If this arrangement is not possible, then students can sit in adjacent seats, facing each other.

As the students begin to make sketches based on use of the two wall maps, there will be a fair amount of movement around the room. Make sure there is easy passage to wall maps which should be in widely separated locations in the classroom. This will avoid traffic jams and overcrowding. This activity will be completed faster if students continue to work as two-person teams for the entire lab period. Therefore, you might choose to collect only one set of answers and sketches from each team.

PROCEDURE

In this activity students use a simple manipulative device which simulates motion on the transform fault portion of fracture zones.

Key words: fracture zone, transform fault

Time required: two 45-minute periods

Materials: pencils, wall maps, *Atlantic Ocean Floor* and *World Seismicity Map,* sea-floor spreading device for each team of two students.

1. Study the sea-floor spreading device at your lab station. The central long slit running lengthwise along the paper Worksheet represents a fracture zone. The sections of Mid-Atlantic Ridge (labeled MAR on the cardboard) are offset by this fracture zone. Label the central slit "fracture zone".

2. a. On your sea-floor spreading device draw a short line across the fracture zone below the lower section of the Mid-Atlantic Ridge. Label both ends of the line "A". (See Figure 1.)

b. Make a similar line between the two sections of the Mid-Atlantic Ridge. Label both ends of the line "B".

c. Make a similar line above the upper section of the Mid-Atlantic Ridge. Label both ends of the line "C".

3. Work with a partner who will face you on the other side of your lab table. Both of you should grasp the Worksheet as shown in Figure 1. Now, both of you should pull your ends of the Worksheet slowly toward yourselves at the same time. CAUTION—stop pulling before the paper loops pull out of the cardboard!

When you perform the pulling motion on the sea-floor spreading device, you are simulating the real motion of the sea floor.

As you both pull on the Worksheet, look to see if the two parts of the Mid-Atlantic Ridge are moving. Also, look to see which parts of the fracture zone are moving past each other and which are not. If necessary, push the paper loops back down through the cardboard and repeat the procedure.

4. In the space below, make a sketch to show the parts of the Mid-Atlantic Ridge and final position of the lines A-A, B-B, and C-C. Draw arrows on both sides of the fracture zone to show the direction of rock movement on each side of the fracture zone.

The students' sketches should look like Figure C.

5. Did the two parts of the Mid-Atlantic Ridge change positions? <u>No</u>

Based on your sketch, write a sentence below that describes where the paper is moving in opposite directions on either side of the fracture zone. This portion of a fracture zone is called a **transform fault.**

The paper is moving in opposite directions on both sides of the fracture zone only between the two sections of the Mid-Atlantic Ridge.

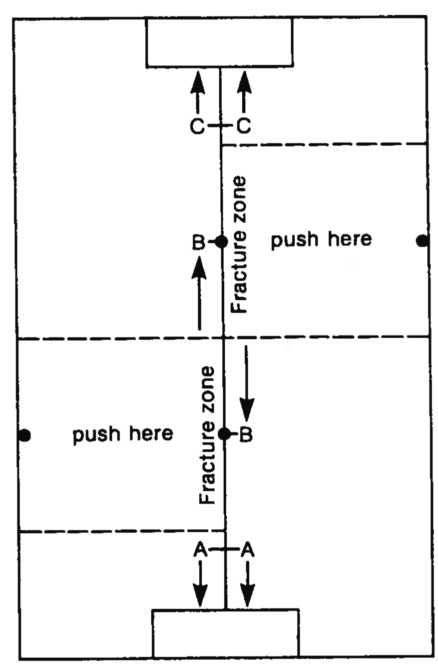


Figure C. Final position of sea-floor spreading device marked with arrows to show movement directions on both sides of a fracture zone.

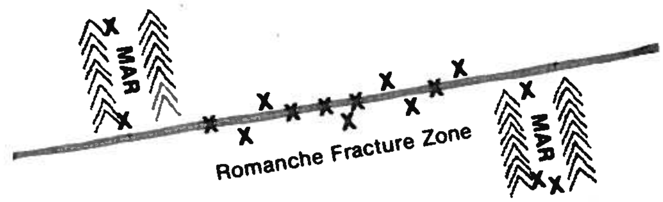
The sea-floor spreading device was designed to represent rocks moving past each other on both sides of the transform fault. Earthquakes occur on any fault where rocks move past each other. Therefore, a map of earthquake epicenters should show places where earthquakes occur along transform faults in the sea floor.

6. Assume that the paper Worksheet represents the Romanche Fracture Zone (in the North Atlantic Ocean) and sections of the Mid-Atlantic Ridge. Find the Romanche Fracture Zone on the *National Geographic* map of the Atlantic Ocean. Write the approximate latitude and longitude of the center of the Romanche Fracture Zone here.

0° (equator) latitude
20° W. longitude

7. Make a sketch of the Mid-Atlantic Ridge and Romanche Fracture Zone in the space below. Label all parts of the diagram. Take your sketch to the *World Seismicity Map* posted in your classroom. Find the Romanche Fracture Zone on the seismicity map. Mark a line of x's on your sketch to show where earthquakes have occurred along the Romanche Fracture Zone. In the space beneath your sketch, write a sentence that tells where such earthquakes occur.

The students' sketches should look something like this:



Earthquakes along the Romanche Fracture Zone occur only between the sections of Mid-Atlantic Ridge. Some students may also correctly locate earthquakes along the Mid-Atlantic Ridge.

You have now discovered the transform fault portion of a real fracture zone. Many other fracture zones contain transform faults. They are indicated by an earthquake pattern similar to the one found along the Romanche Fracture Zone.

SUMMARY QUESTIONS

1. What is a fracture zone?

A fracture zone is a fault separating two blocks of ocean crust which are in motion with respect to each other along only a limited part of the fault.

2. Which part of a fracture zone is a transform fault?

The transform fault occurs only on the part between offset mid-ocean ridge segments.

3. Did sea-floor spreading change the position of the Mid-Atlantic Ridge sections in your model? **No**

4. Define the term "transform fault".

A transform fault is the part of a fracture zone where relative movement of the sea floor is taking place.

5. Why are earthquakes only along the transform fault part of a fracture zone?

Earthquakes occur only on the transform fault part of a fracture zone because that is the only part of the fracture zone where the blocks of rock are moving past each other.

6. Make a sketch of two parts of the mid-ocean ridge that are cut by a fracture zone.

The students' sketches should look like the sketch they made of the Romanche Fracture Zone.

EXTENSIONS

1. Using the *Atlantic Ocean Floor* map and *World Seismicity Map,* locate other transform faults that are part of the fracture zones.

Students will find that earthquake zones do correspond with transform fault locations in the Atlantic. They also will note that the direction of offset of ridges by transform faults is, in some cases, just the opposite of the offset in the vicinity of the Romanche Fracture Zone which was examined in this activity.

2. Study maps of the Arctic, Pacific, or Indian Oceans, such as those found in the *National Geographic* series on the ocean floor. Describe the location (latitude, longitude) of major offsets in the mid-ocean ridge where it crosses a fracture zone. Do these locations correspond with earthquakes along the transform faults?

As in the first extension, students will find that earthquake zones correspond with transform fault locations throughout the world. Again, they will note that the direction of offset of ridges by transform faults is, in some places, just the opposite of the offset in the vicinity of the Romanche Fracture Zone which was examined in this activity.

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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 1213
• 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