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ABSTRACT

Crustal Evolution Education Project (CEEP) modules were designed to: (1) provide students with the methods and results of continuing investigations into the composition, history, and processes of the earth's crust and the application of this knowledge to man's activities and (2) to be used by teachers with little or no previous background in the modern theories of sea-floor spreading, continental drift, and plate tectonics. Each module consists of two booklets: a teacher's guide and student investigation. The teacher's guide contains all of the information present in the student investigation booklet as well as: (1) a general introduction; (2) prerequisite student background; (3) objectives; (4) list of required materials; (5) background information; (6) suggested approach; (7) procedure, including number of 45-minute class periods required; (8) summary questions (with answers); (9) extension activities; and (10) list of references. Using a map showing ocean depths and features in relief, calculations are made of sea-floor spreading at mid-ocean ridges and profiles of ocean-floor topography related to plate motions are sketched. Objectives of this 2-period activity include naming major plates on both sides of Atlantic ridge, describing major topographic forms of ocean basins, and listing earth processes and topographic forms resulting from plate motions. (Author/JN)

CEEP™

CRUSTAL EVOLUTION EDUCATION PROJECT

Lithospheric Plates And Ocean Basin Topography

Lithospheric Plates And Ocean Basin Topography

TEACHER'S GUIDE

Catalog No. 34W1017

For use with Student Investigation 34W1117
Class time: two 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

Lithospheric Plates And Ocean Basin Topography

INTRODUCTION

The theory of plate tectonics states that the earth's crust and underlying lithosphere are made up of a dozen or more rigid plates, which grow outward from large cracks in the ocean floor called **spreading centers.** These plates move across the mantle at speeds of up to nearly 10 cm per year and are subducted at trenches. **Trenches** are deep depressions which are found at plate boundaries. **Subduction** is the downward movement of the ocean lithosphere of one plate under another plate (See Figure 1.) The subducting plate usually moves downward at a steep angle under the adjacent plate. Scientists now know that most of the earth's major earthquakes occur in areas where subduction is taking place.

The idea of plate tectonics is tremendously important to earth scientists because most earthquakes, volcanoes and mountain building activity are associated with the motion of lithospheric plates. Much of what is known about plate tectonics has been learned through mapping the ocean floor. Research vessels gather data such as the topographic, seismic, magnetic, and gravitational characteristics of ocean basins. How can a study of ocean basin topography tell us about the size and shape of plates? What is the relation between ocean basin topography and the type of plate margin?

PREREQUISITE STUDENT BACKGROUND

Students should know about the theory of plate tectonics and how it explains the breakup of continents. They should be aware that plates are in constant motion. They also should know that rates of sea-floor spreading shown in Figure 2 are based on interpretation of magnetic anomalies derived from measurement of the earth's magnetic field. These anomalies represent variations in the magnetization of basaltic rocks on the sea floor.

Students should know how to draw and interpret a topographic profile of the sea floor where elevations are given at depths below sea level (rather than at elevations above sea level as is done on topographic maps of land features).

OBJECTIVES

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

1. Name the major plates on both sides of the Mid-Atlantic Ridge and give their rates of separation or convergence.
2. Describe the major topographic forms of ocean basins
3. Identify two of the three major types of plate boundaries
4. List some of the earth processes and topographic forms resulting from plate motions
5. Describe typical profiles of ocean basin topography

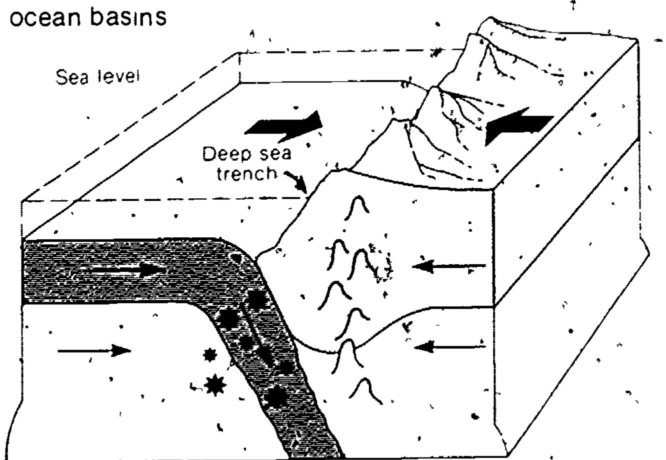

Figure 1. Simplified cross-section of an ocean plate being subducted under another plate. The overriding plate could be continental lithosphere, as shown, or oceanic lithosphere.

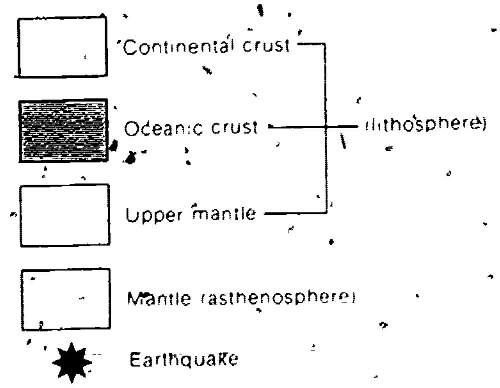

Illustration key

Lithospheric Plates And Ocean Basin Topography

INTRODUCTION

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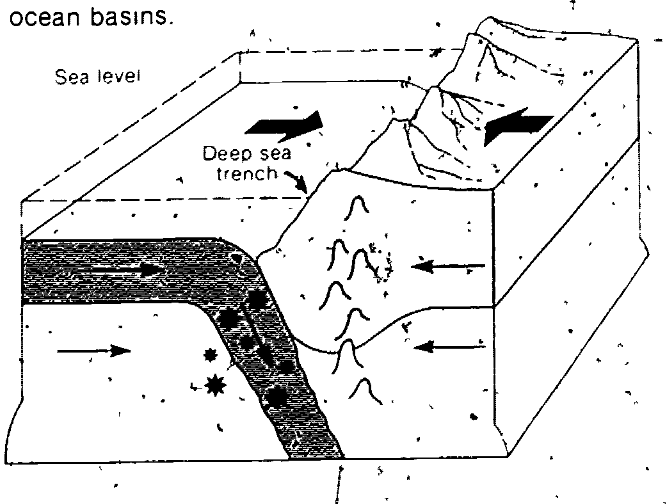


Figure 1. Simplified cross-section of an ocean plate being subducted under another plate. The overriding plate could be continental lithosphere, as shown, or oceanic lithosphere.

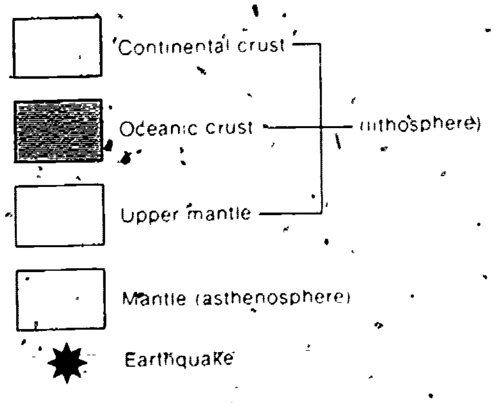


Illustration key

MATERIALS

Physiographic maps of the ocean floor—one map or set of maps for each group of five students. Use a map or maps of the ocean floor that contains bathymetric data, such as *The Pacific Ocean* and *The Atlantic Ocean* (which both also show the ocean floors in relief on their reverse sides), National Geographic Society, Educational Services, Department 79, Washington, D.C. 20036.

BACKGROUND INFORMATION

Since its introduction in 1967, the theory of plate tectonics has come to be accepted by most earth scientists. The motion of lithospheric plates is slow, averaging less than 10 cm per year. Spreading rates shown in Figure 2 are whole spreading rates. The whole spreading rate is the distance that two points, on opposite sides of a mid-ocean ridge, should separate in one year. The spreading rate will vary over the years. Because no one knows the driving mechanism for plate separation, it is difficult to speculate on the reasons for increases or decreases in the rates of sea-floor spreading. However, the reality of sea-floor spreading is revealed, most directly, by the striped pattern of normal and reverse magnetized basaltic rock that parallels the mid-ocean ridges. Rates of sea-floor spreading are found by age-dating these rocks.

The mid-ocean ridges are a boundary of separation (or zone of accretion) between lithospheric plates where new oceanic lithosphere is being formed. Trenches and the earthquake zones on the landward side of trenches are boundaries of convergence. Not discussed in this module is the boundary of translation, where two plates rub past each other. Students are asked to sketch profiles that will reveal the topography of boundaries of separation and boundaries of convergence.

SUGGESTED APPROACH

Students should be able to work independently on this module. However, with some classes the sketching of profiles and simple arithmetic calculations may be facilitated by allowing students to work in teams of two.

Post the physiographic diagrams of the sea floor around the room to avoid crowding. If necessary, a hallway wall just outside the classroom door may be used if the noise from student conversation will not disturb adjacent classes.

No general post-lab discussion of this activity is needed under normal conditions. However, this activity should provide a good overview for a non-lab discussion of all the important aspects of sea-floor topography.

PROCEDURE

In this activity students calculate rates of sea-floor spreading at mid-ocean ridges and sketch profiles of ocean-floor topography that is related to plate motions.

Key words: spreading center, trench, subduction, whole spreading rate, whole convergent rate, rift mountain, rift valley

Time required: two 45-minute periods

Materials map showing ocean depths and features in relief

1. Study Figure 2 and list below the names of the six largest lithospheric plates

The major plates are the American Plate, Eurasian Plate, African Plate, Antarctic Plate, Pacific Plate and the Australia-India Plate. (Commonly, the American Plate is subdivided into the North American and South American plates, but this module will consider them as one plate.)

There are also at least a half-dozen smaller major plates. These include the Caribbean Plate, Cocos Plate, Nazca Plate, Philippine Plate and Arabian Plate. Not shown on the map are a large number of minor plates and subdivisions of the major plates.)

2. Locate the Mid-Atlantic Ridge on an Atlantic Ocean map that shows features in relief Write the ridge name on Figure 2 in its proper location

The Mid-Atlantic Ridge extends from the Arctic-North Atlantic Ocean boundary to south of the Cape of Good Hope.

3. In the space below, list the names of the plates on both sides of the northern Mid-Atlantic Ridge

Western side	Eastern side
American Plate	Eurasian Plate
	African Plate

The arrows in Figure 2 show the direction in which the plates are moving Places where the arrows are pointing away from one another show areas where new sea floor is being produced from basaltic lava. Places where the arrows are pointing toward one another are usually areas where sea floor is being destroyed. These areas are called island arcs and deep sea trenches. In other places, arrows are pointing toward each other where collision of crustal plates has caused mountains to form.

The numbers by each pair of arrows show how fast two points on opposite plates are moving toward or away from each other. When the plates are moving toward each other the number is called the **whole convergent rate.** When the plates are moving away from each other, the number is called the **whole spreading rate.**

4. What is the whole spreading rate for the separation of the northern part of the American and the Eurasian plates? (Hint Take an average rate based on the numbers shown in Figure 2)

1.8 cm/yr + 2.3 cm/yr =
4.1 cm/yr ÷ 2 = 2.1 cm/yr

5. What is the whole spreading rate for separation of the southern part of the American and the African plates?

2.5 cm/yr + 3.0 cm/yr + 4.1 cm/yr =
9.6 cm/yr ÷ 3 = 3.2 cm/yr

6. Use Figure 2 and the relief map to find the location of a place where ocean crust is being subducted under a continent Name the two plates involved

The Nazca Plate is being subducted under the South American Plate. Another prominent zone of subduction is where the Pacific Plate is being subducted under the Eurasian Plate, the Philippine Plate and the Australia-India Plate.

7. Use the same map to name an island in the North Atlantic Ocean where the mid-ocean ridge is above sea level

Iceland is the most prominent, but others are the Azores.

8. Find a plate boundary on land where two plates are colliding to form a mountain range. Name the plates and the mountain range

The plates are the Eurasian Plate and the Australia-India Plate. The mountain range is the Himalayas.

9. Mountain ranges are sometimes formed by volcanic activity resulting from subduction. Name the mountain range on land that was caused by subduction at the Peru-Chile Trench

The Andes Mountains.

10. Find a plate in the western Pacific Ocean that is completely surrounded by trenches One of these trenches contains the deepest spot in the ocean Use Figure 2 and a relief map to find the names of the plate and the trench with the greatest ocean depth Name the plate and the trench, write the depth of the deepest spot

Philippine Plate; Mariana Trench (Depth is 36,198 feet, or 11,022 m.)

11. Name a plate in the southern hemisphere that is completely surrounded by mid-ocean ridges

Antarctic Plate

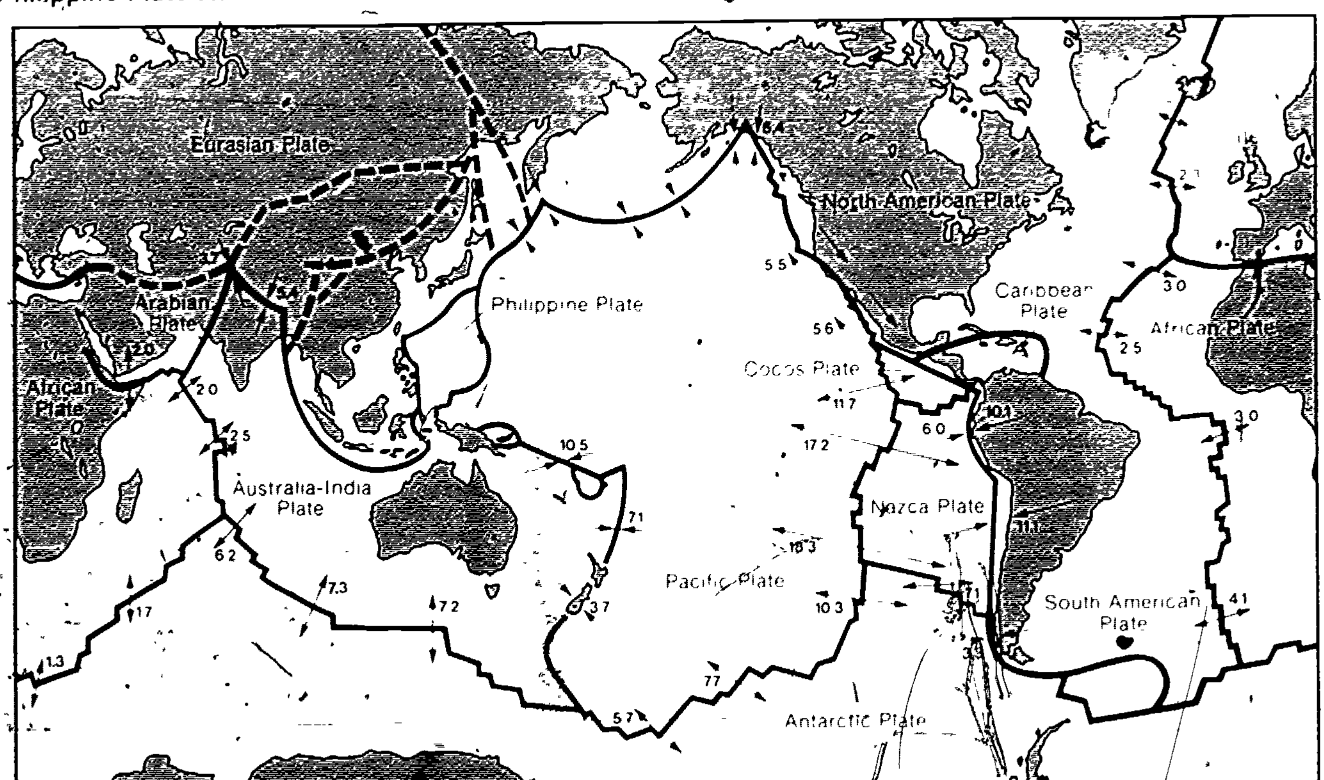
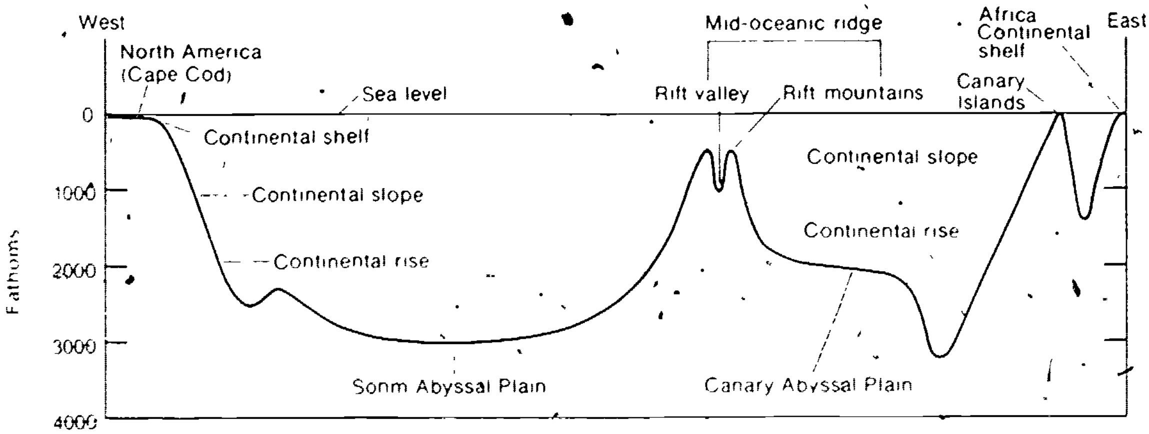


Figure 2. The major plates of the earth and their whole spreading or convergent rates of motion in centimeters per year

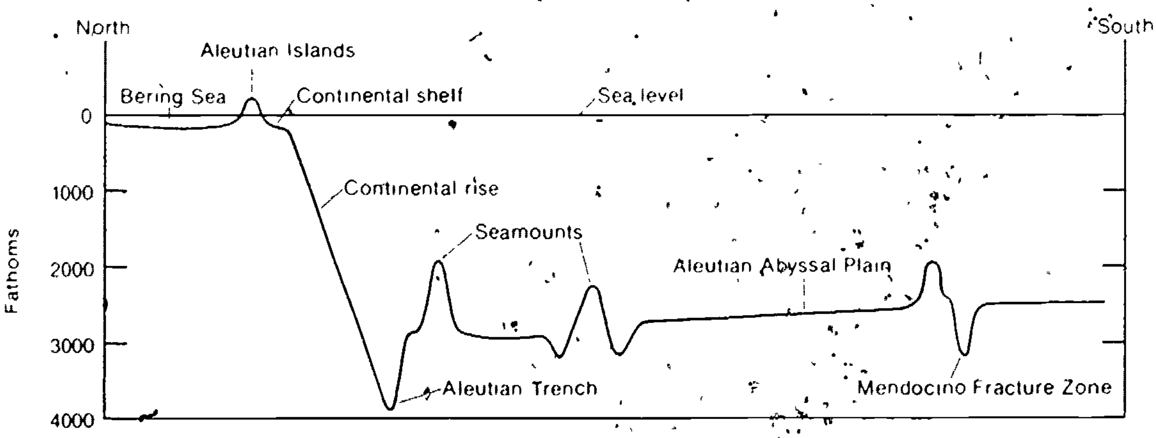
12. In the space below, draw a generalized profile across the Atlantic Ocean from Cape Cod, Mass., to the African continent east of the Canary Islands. Label the *continental shelf, continental slope, continental rise* and *abyssal plain* on both sides of the Atlantic Ocean. Also label the *mid-ocean ridge, rift mountains,* and *rift valley.* The **rift mountains** are the mountains which form on each side of the mid-ocean ridge. The **rift valley** is the valley in the middle of the mid-ocean ridge.

Students may need to look into one of the references for this activity, or a recent earth science text for location of some of the topographic elements mentioned. Few of them are named on the relief maps. The depth scale shown here conforms to the National Geographic map; if other maps are used, the scale on the profiles may have to be altered to feet or meters.

Students will not be able to draw an accurate profile because exact data is lacking on the map. The few contour lines on the map will help students to draw a reasonable profile.



13. In the space below, draw a profile from the middle of the Bering Sea (Pribilof Islands) across the Aleutian Abyssal Plain, in a southeast direction, to an area just south of the Mendocino Fracture Zone Label all topographic features



SUMMARY QUESTIONS

1. The earth's lithosphere is made up of how many major plates? Name them.

There are six major plates. They are the American Plate, Eurasian Plate, African Plate, Pacific Plate, Australia-India Plate and the Antarctic Plate.

2. Generally, how fast are the plates separating?

Whole spreading rates range up to about 18 cm/yr.

3. What topographic features are found where plates are moving toward or away from each other?

Island arcs and deep sea trenches are found where plates are moving together. There may be associated mountain ranges. Mid-ocean ridges are found where plates are separating.

4. Name the topographic features all the way across the North Atlantic Ocean floor, from west to east.

Continental shelf, continental slope, continental rise, abyssal plain, mid-ocean ridge with rift mountains and rift valley, abyssal plain, continental rise, continental slope, continental shelf.

5. Name the topographic features of the Pacific Ocean floor between the Bering Sea and Mendocino Fracture Zone.

Aleutian Islands, Continental shelf, Continental rise, Aleutian Trench, Seamounts, Aleutian Abyssal Plain, Mendocino Fracture Zone.

EXTENSION

Using 6400 km as the distance between North America and Europe, and the plate separation rate you already calculated in question 4, figure out how long ago North America and Europe were part of the same landmass.

About 200 million years. This is obtained in the following manner. The distance from North America to Europe is:

a) $(6.4 \times 10^3 \text{ km}) \times \frac{(10^3 \text{ m})}{1 \text{ km}} \times \frac{(10^2 \text{ cm})}{1 \text{ m}} = 6.4 \times 10^8 \text{ cm}$

Using 2 cm/yr as an average rate of separation (average whole spreading rate found from Figure 2), the time for separation of North America and Europe was about:

b) $\frac{6.4 \times 10^8 \text{ cm}}{2 \text{ cm/yr}} = 3.2 \times 10^8 \text{ yrs}$ **(320 million years)**

This calculation assumes an average separation rate of about 2 cm/yr. The result is a "ball park" answer that is too great. The breakup of Pangaea, the original supercontinent, actually began about 200 million years ago. North America and Europe began their latest separation about 70 million years ago. Therefore, the present rate of spreading in the North Atlantic Ocean is much less than was the average rate of spreading during the past 70 million years. (That is, the average rate must have been 9 cm/yr to allow a 6.4×10^8 cm separation in 70×10^6 years.)

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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

WARD'S

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MODULE NO. NYS 5-2
0-89873-032-5

CRUSTAL EVOLUTION EDUCATION PROJECT

NAME DATE

Student Investigation

Catalog No 34W1117

Lithospheric Plates And Ocean Basin Topography

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OBJECTIVES

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

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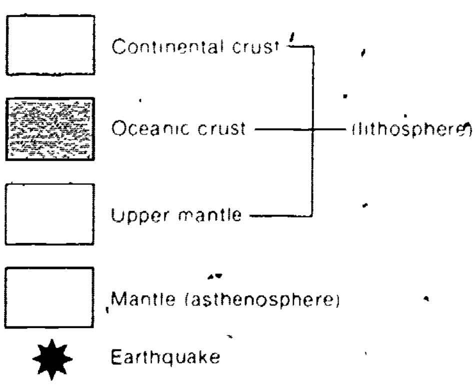

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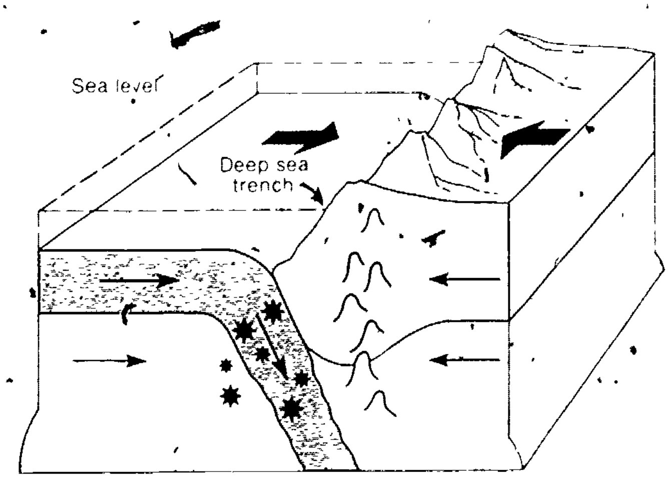


Figure 1 Simplified cross-section of an ocean plate being subducted under another plate. The overriding plate could be continental lithosphere, as shown, or oceanic lithosphere

PROCEDURE

Materials: map showing ocean depths and features in relief.

1. Study Figure 2 and list below the names of the six largest lithospheric plates.

2. Locate the Mid-Atlantic Ridge on an Atlantic Ocean map that shows features in relief. Write the ridge name on Figure 2 in its proper location.

3. In the space below, list the names of the plates on both sides of the northern Mid-Atlantic Ridge.

Western side	Eastern side

The arrows in Figure 2 show the direction in which the plates are moving. Places where the arrows are pointing away from one another show areas where new sea floor is being produced from basaltic lava. Places where the arrows are pointing toward one another are usually areas where sea floor is being destroyed. These areas are called island arcs and deep sea trenches. In other places, arrows are pointing toward each other where collision of crustal plates has caused mountains to form.

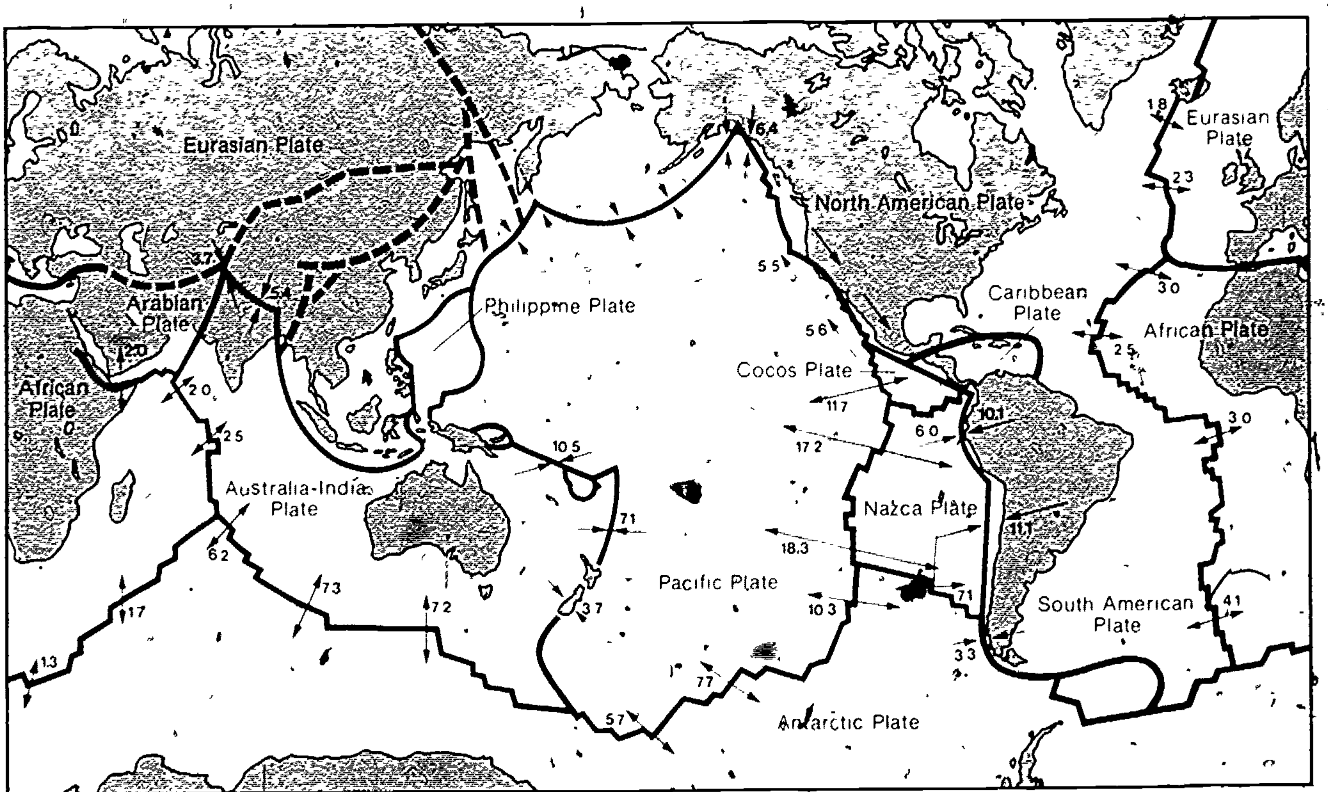


Figure 2. The major plates of the earth and their whole spreading or convergent rates of motion in centimeters per year.

The numbers by each pair of arrows show how fast two points on opposite plates are moving toward or away from each other. When the plates are moving toward each other the number is called the **whole convergent rate.** When the plates are moving away from each other, the number is called the **whole spreading rate.**

4. What is the whole spreading rate for the separation of the northern part of the American and the Eurasian plates? (Hint: Take an average rate based on the numbers shown in Figure 2.)

5. What is the whole spreading rate for separation of the southern part of the American and the African plates?

6. Use Figure 2 and the relief map to find the location of a place where ocean crust is being subducted under a continent. Name the two plates involved.

7. Use the same map to name an island in the North Atlantic Ocean where the mid-ocean ridge is above sea level.

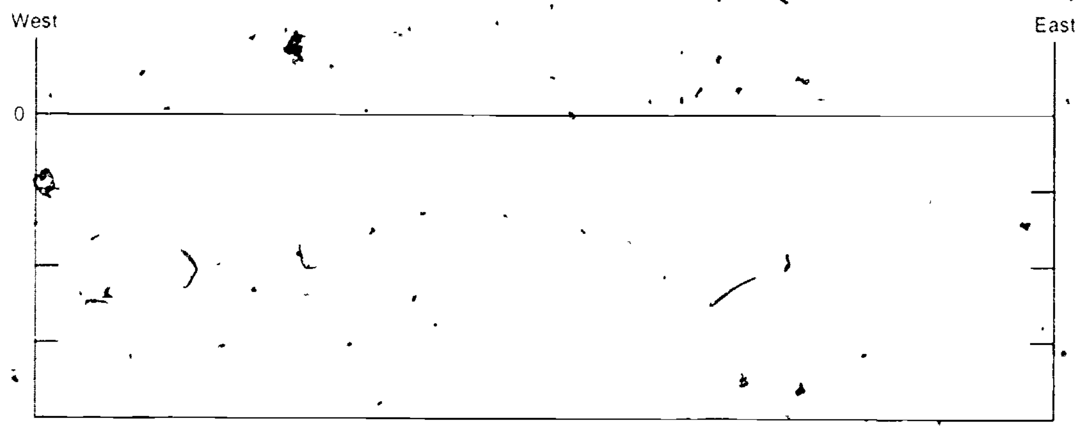
8. Find a plate boundary on land where two plates are colliding to form a mountain range. Name the plates and the mountain range.

9. Mountain ranges are sometimes formed by volcanic activity resulting from subduction. Name the mountain range on land that was caused by subduction at the Peru-Chile Trench.

10. Find a plate in the western Pacific Ocean that is completely surrounded by trenches. One of these trenches contains the deepest spot in the ocean. Use Figure 2 and a relief map to find the names of the plate and the trench with the greatest ocean depth. Name the plate and the trench, write the depth of the deepest spot.

11. Name a plate in the southern hemisphere that is completely surrounded by mid-ocean ridges.

12. In the space below, draw a profile across the Atlantic Ocean from Cape Cod, Mass., to the African continent east of the Canary Islands. Label the *continental shelf*, *continental slope*, *continental rise* and *abyssal plain* on both sides of the Atlantic Ocean. Also label the *mid-ocean ridge*, *rift mountains*, and *rift valley*. The **rift mountains** are the mountains which form on each side of the mid-ocean ridge. The **rift valley** is the valley in the middle of the mid-ocean ridge.



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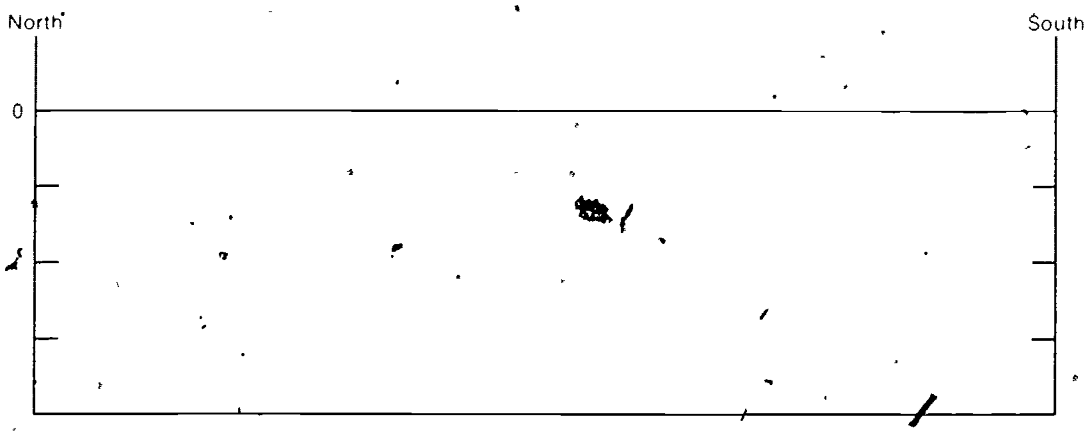

SUMMARY QUESTIONS

1. The earth's lithosphere is made up of how many major plates? Name them.

2. Generally, how fast are the plates separating?

3. What topographic features are found where plates are moving toward or away from each other?

4. Name the topographic features all the way across the North Atlantic Ocean floor, from west to east.

5. Name the topographic features of the Pacific Ocean floor between the Bering Sea and Mendocino Fracture Zone.

EXTENSION

Using 6400 km as the distance between North America and Europe, and the plate separation rate you already calculated in question 4, figure out how long ago North America and Europe were part of the same landmass.

REFERENCES

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