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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 suggested; (8) summary questions (with answers); (9) extension activities; and (10) list of references. Two to three class periods are recommended to study possible explanations for large changes in sea level that occurred during and since Cretaceous time. Relationships between rock temperatures and volumes that rocks occupy are examined. Applications of this knowledge (and knowledge of sea-floor spreading) are used to explain sea level changes by gathering data from a model of sea-floor spreading constructed of blocks on a paper grid. (Author/JN)

CRUSTAL EVOLUTION EDUCATION PROJECT

Why Does Sea Level Change?

TEACHER'S GUIDE

Catalog No. 34W1033

For use with Student Investigation 34W1133
Class time: two to three 45-minute periods

Developed by
THE NATIONAL ASSOCIATION OF GEOLOGY TEACHERS

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Why Does Sea Level Change?

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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Why Does Sea Level Change?

INTRODUCTION

In this module students study a possible explanation for large changes in sea level that occurred during and since Cretaceous time. In PART A the students learn the relationship between the temperature of a rock and the volume that the rock occupies. In PART B the students apply this knowledge, and a knowledge of sea-floor spreading, to explain sea level changes. They do this by gathering data from a model of sea-floor spreading constructed of blocks on a paper grid.

Geologists have found evidence that sea level has not always been the same. In fact, many geologists believe that it may have changed by as much as 300 meters in the past 200 million years. At one time large areas of what is now the United States were under sea water. The sea extended as far north as the Dakotas. Even the Appalachian mountain area might have been covered by the sea. What could have caused such a great rise in sea level? Then, why did sea level go back down?

PREREQUISITE STUDENT BACKGROUND

Students should be familiar with the theory of sea-floor spreading. They should understand the significance of subduction zones in the consumption of crust and the significance of mid-ocean ridges as places where new crust is produced. They should know what is meant by sea level and the relationship between sea level and the formation of marine sedimentary rocks.

OBJECTIVES

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

1. Describe the relationship between the temperature and the volume of a rock.
2. Describe how the rate of sea-floor spreading affects the volume of the mid-ocean ridge.
3. Predict the effect of a change in the rate of sea-floor spreading upon sea level.

MATERIALS

One set of the following for every two students:

Map, *The Atlantic Ocean Floor*, National Geographic Society, Educational Services, Department 79, Washington, D.C. 20036.

Thirty-six blocks, Loc Blocs™ are listed in Ward's Materials List.

The grid on Worksheet 2 is designed to accommodate Loc Blocs. If you use some other type of block, you may have to supply a new grid with rectangles the same size as the blocks that you use.

BACKGROUND INFORMATION

Geologists, through their study of marine sedimentary rocks, have known for over a century that there have been major transgressions (flooding) of the continents during the Upper Cretaceous (85 million years ago). They occurred throughout the world. Over the years, various causes of these transgressions have been suggested. Some of the suggestions are: 1) the gradual filling of the ocean basins by sediment, displacing the water onto the continents, 2) downfaulting of ocean basins to cause regression of the sea, accompanied by vertical movements of both continents and ocean basins, 3) periods of mountain building causing horizontal compression, increased elevations and regression or withdrawal of water and conversely, a quiescent period which would reduce compression and consequently cause a relative subsidence of continental areas and transgressions of the seas.

During the 1960s and early 1970s, it was being suggested that changes in the volume of the ocean basins due to changes in volume of mid-ocean ridges could account for transgressions and regressions (retreat) of the sea. James D. Hays and Walter C. Pitman III of Lamont-Doherty Geological Observatory have calculated the volume of most of the mid-oceanic ridges at several different times, beginning in the Cretaceous and extending into the upper Tertiary. After applying corrections due to the weighting of continental platforms by sediments and the sloping of continental areas inland, they arrived at estimates of changes in sea level for each of the specific times. These estimates agreed well with estimates of sea level changes based on the occurrence of marine sediments on the continents.

They were therefore able to link changes in sea level to changes in the volume of the ridges. What causes the change in volume of the ridges? That is the topic of PART A of this module. Since warmer rock takes up more space than colder rock, a warmer portion of a ridge will occupy more volume than a colder portion. Since temperature is related to the recency of the formation of the ridge, the faster a ridge is forming, the greater will be its volume and therefore, the greater the amount of water that will be displaced by the ridge. Therefore, ridge volume is directly related to the rate of sea-floor spreading. Any change in this rate will affect sea level. If the rate is increased, sea level will rise. If the rate is decreased, sea level will fall, since the proportion of cooler rock is then increasing and therefore the ridge is shrinking in volume.

The earth's water surface moderates and stabilizes climate. If the area of water surface increases, as it did during the Cretaceous, we should find that the climate moderated. All evidence in the Cretaceous record does indicate a moderating of climate. The rate of sea-floor spreading can then be linked to changes in climate. There is also evidence that it is linked to faunal diversity, that is, the range and numbers of types of organisms. Periods of climatic stability, such as those of the Cretaceous, allow great faunal diversity. There is also a link between spreading rate and ocean circulation. The rate of sea-floor spreading, therefore, seems to have had dramatic consequences for life throughout the past.

SUGGESTED APPROACH

You may want to conduct a class discussion and a series of demonstrations for that section of PART A that deals with the relationship between temperature of a substance and its volume.

You should pair students for PART B. One student can construct the model while the other records the data from the model. Hold a post-laboratory discussion when all students have completed the activities. Use the SUMMARY QUESTIONS as a guide.

PROCEDURE

PART A: What is the relationship between the temperature and the volume of a rock?

The first four steps of PART A assure that students understand the relationship between the temperature of a substance and its volume

This relationship is then applied to rocks in the ocean's crust. It is established that young igneous rocks are warmer than old igneous rocks, and therefore they have larger volume. This is what produces the ridge system.

Key words: heat flow, microcalorie, calorie

Time required: two to three 45-minute periods, unless demonstrations are necessary for students to be able to answer the first four questions.

Answer the following questions from your previous study of science or from the demonstrations your teacher may conduct.

1. What happens to the liquid in a thermometer when you put the thermometer in hot water? In cold water?

When a thermometer is placed in warm water the liquid will rise in the tube. Students should be able to understand that this is because of the expansion of the liquid due to warming. The opposite happens when the liquid is cooled by immersion in cold water.

2. You may have seen a hot-air balloon. Can you explain how it is able to rise? What will cause it to descend?

Hot air expands, taking up more space than an equal mass of cold air. The hot air in the balloon is less dense, or lighter, than the cooler air around it. It will be buoyed up by this cooler air. While the air is heated by the burner, the balloon will stay aloft. When the burner is extinguished, the air begins to cool. When the weight of the air in the balloon (added to the weight of the balloon and gondola) is the same or greater than the weight of the volume of air it displaces, the balloon will begin to descend. See Figure A for a demonstration to be used if necessary.

3. The metal lid on a glass jar can often be loosened by placing it in hot water. Why does this work?

The metal expands faster than the glass. Therefore, it will expand more and loosen.

4. What property do these liquids, gases and solids have in common?

The property that all these materials have in common is that they expand, or become less dense, when heated. There are a few exceptions, such as the behavior of ice and water at certain temperatures. The general rule, however, is that materials expand when heated and contract when cooled.

5. What would happen to rocks in the earth's crust if they were heated? cooled?

Students should conclude from the above that rocks in the earth's crust will act as other materials act: they will expand when heated and contract when cooled.

We have learned that a given mass of material takes up more volume when warm than when cool. Does this also apply to the ocean's crust? Examine the map, *Atlantic Ocean Floor*, and answer the following questions:

Students should have been familiar with plate tectonic theory before they started this module. Therefore, they should be able to identify areas of young rock and areas of old rock from the topographic features of the ocean floor.

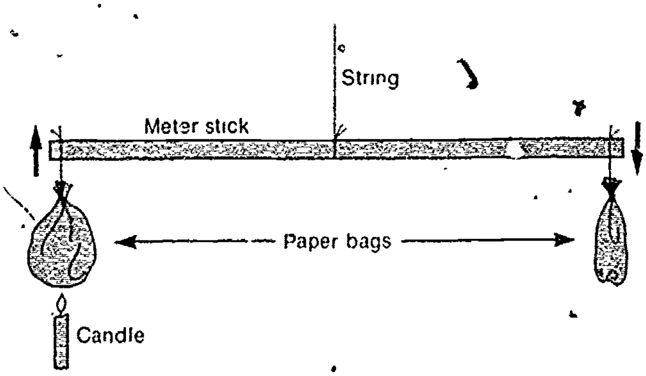


Figure A. Diagram for hot air demonstration.

6. Locate the Mid-Atlantic Ridge and the Sierra Leone Rise. Is the crust in those areas young or old? How do you know?

Both of these features are composed of relatively young oceanic crust because new crustal material is being formed at these ocean ridges.

7. Locate the Hatteras Plain and the Sierra Leone Basin. Is the crust in those areas young or old? How do you know?

These features are relatively old because they are far from the ridges.

8. Locate the areas identified in 6 and 7 above on the profile on Worksheet 1. Where would you expect the temperatures of the crust to be high? low? Why?

In this question students are asked to establish the connection between age of a rock and its temperature. Many will not be able to do this. Therefore, you will need to discuss this relationship with the class.

The temperatures would be high over the relatively high features and low over the low features. The lower features are older and have had a much longer time to cool. Therefore, the rock there is denser, making up a smaller volume of the crust.

- Scientists can actually take the temperature of ocean crust. They can do this by measuring what is called **heat flow,** which is heat that is given off by the crust. The higher the heat flow, the higher the temperature of the crust. Table 1 contains some actual measurements of heat flow in the Atlantic Ocean Basin. These measurements are in **microcalories** per square centimeter per second. A **calorie** is the amount of heat it takes to raise the temperature of one gram of water one degree Celsius. A microcalorie is one thousandth of a calorie. These measurements, then, are of very small differences in rock temperature.

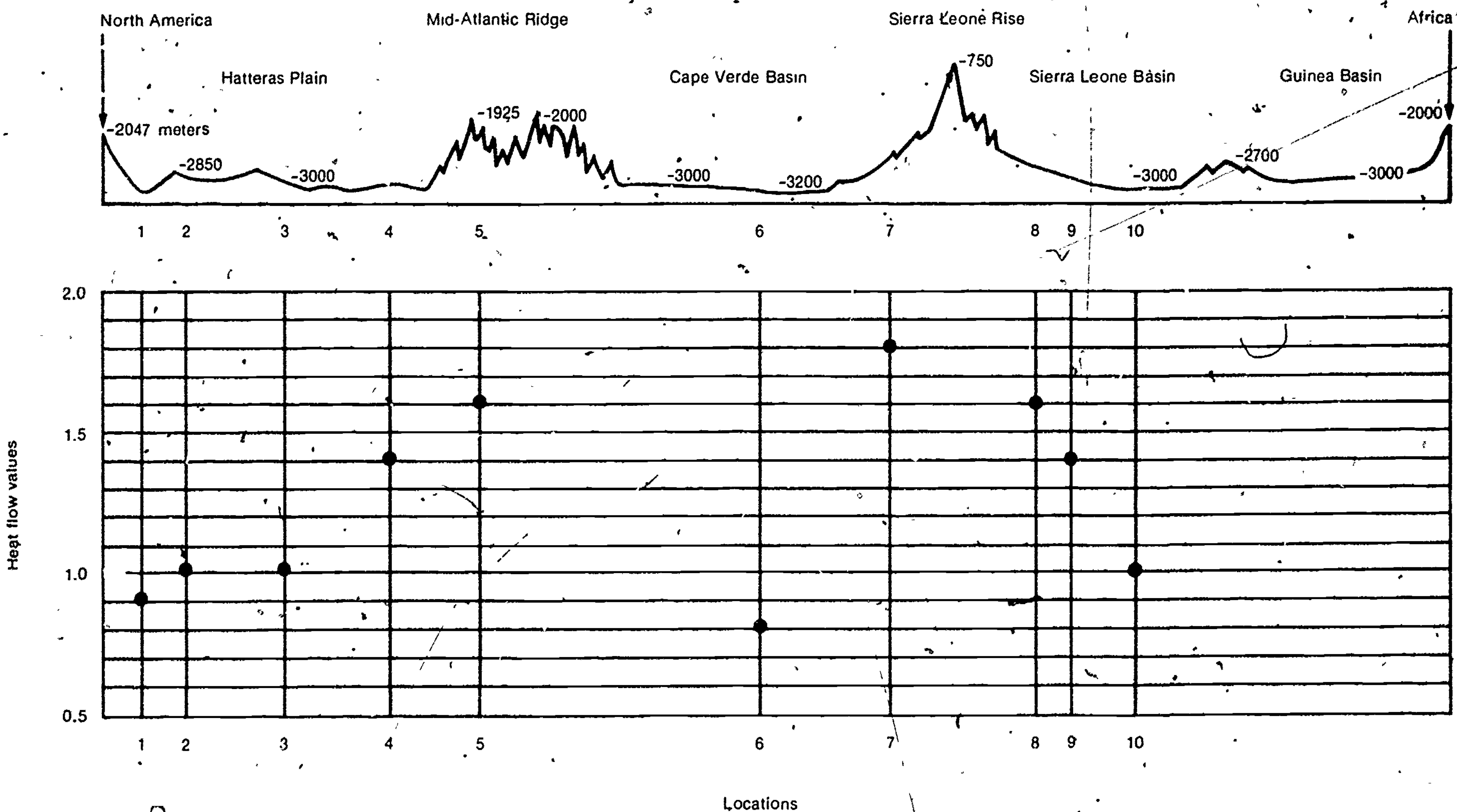
9. Plot the heat flow values on the profile on Worksheet 1. Were your conclusions in question 8 correct?

The heat flow data are average values for a 5-degree square area of the ocean bottom. Students should see that the temperature is higher over young crust. See Answer Sheet 1.

Table 1.
Heat flow data for use with Worksheet 1.
(Langseth, Le Pechon and Ewing, 1966)

Location	*Heat flow*
1	0.9
2	1.0
3	1.0
4	1.4
5	1.6
6	0.8
7	1.8
8	1.6
9	1.4
10	1.0

Profile of the Atlantic Ocean Floor



PROCEDURE

PART B: How could changes in the rate of sea-floor spreading influence sea level?

Students record data from a model of the sea-floor spreading process. The data illustrate the gradual change in volume of the ridge because of the change in sea-floor spreading rate and the effect of this change in volume on sea level. The model simulates changes in sea level during and since the Cretaceous Period.

Key words: none

Time required: If students are introduced to the activity the previous day and the procedure explained to them, then the activity can be completed in one 45-minute period.

Materials: set of 36 blocks for model ocean on Worksheet 2, transparent tape, scissors, colored pencils.

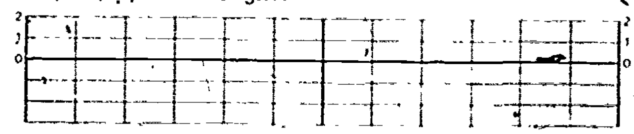
Scientists suggest that big changes in sea level are caused by changes in the volume of the mid-ocean ridge. Its volume can be decreased by the destruction of parts of the ridge or by the decrease in the rate of sea-floor spreading. The volume of the ridge can be increased by the formation of new ridges or by increasing the rate of sea-floor spreading.

In this activity you will be using a model ocean consisting of a paper grid (Worksheet 2) and blocks. You will investigate the effect of a change in the rate of sea-floor spreading upon the volume of the mid-ocean ridges and the height of sea level. Notice that the grid is ruled into rectangles the same size as the blocks. Also notice that subduction zones, a mid-ocean rift and sea level are indicated on the grid. This model is of all the world's ocean basins combined. In other words, the ridge represents all places where new crust originates and the ends of the paper represent subduction zones where crust is destroyed. The blocks will represent the crust. You will collect data on the effect of two changes of rate of sea-floor spreading upon your model ocean.

1. Cut out and tape together the two sections of the paper grid on Worksheet 2. Follow the instructions right on the grid. The bottom of the grid represents the ocean floor during a period when sea-floor spreading was not taking place. Notice that there is no ridge present. This is time interval 0. Sea level is now at 0.

Be certain that you have gone through these procedures prior to class time. They can be confusing to the students. It may be best to "talk them through" with your class, demonstrating each step. It would help to use a transparency of the grid on an overhead projector while demonstrating the steps of the PROCEDURE.

Step 1, preparation of grid.

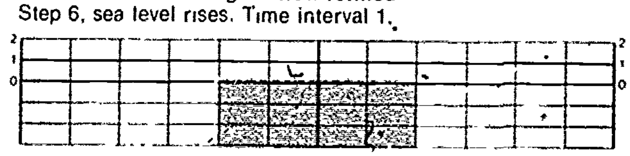


2. Build four stacks of blocks, each stack three blocks high. Lay the stacks down on the grid on Worksheet 2, two stacks on each side of the rift. You have started an episode of sea-floor spreading. This is time interval 1. The four columns represent the mid-ocean ridge.

When students put the blocks on the grid, be sure that the columns are laying on their sides, not standing up. Each block should be filling one rectangle on the grid, and the bottom blocks should come to the bottom line of the grid. See illustration for steps 2-5.

In this activity the rate of sea-floor spreading is represented by the number of stacks you use. Four stacks of blocks would represent a faster spreading rate than two stacks.

Steps 2-5, first addition of material at mid-ocean rift. Ridge is now formed
Step 6, sea level rises. Time interval 1.



3. Count the number of blocks added at the rift. Record the number in column 2 of Worksheet 3. As you continue this activity, some blocks will be removed, by going into subduction zones (off the grid). Also, the ridge will cool and shrink down. Therefore blocks will be removed, to represent shrinkage. The total number of blocks removed is recorded in column 3. (In step 2 above, total blocks removed = 0.)

Be sure that students record the number of blocks added and removed *as they do each step.* In the first step, no blocks are removed for cooling and shrinking. The assumption is that the crust, represented by the bottom line of the grid, is very old, and therefore as cool as it can get.

4. Determine the difference between the number of blocks added (column 2) and the number removed (column 3). In the **first** time interval this is equal to 12, which is the total number of blocks added. Record this in column 4.

See Answer Sheet 3.

5. Determine the change in sea level by dividing the number in column 4 by 12, which is the total number of block lengths across the grid. Enter this number in column 6. This will give the change in sea level in units of block height. In this case it is one.

In the real world, as the volume of the ocean basin occupied by the ridge increases, so does sea level, since the ridge displaces sea water. The activity models this but only in two dimensions—area rather than volume. By dividing net number of blocks added less those removed (the area) by 12 (length of the ocean basin expressed in block lengths) students determine the change in the height of the water column (area/length = height). If the difference in blocks added-removed is positive, sea level rises. If negative, sea level falls. Again, since the model used is two-dimensional (area) you may have to help the students relate these two-dimensional results to changes in volume—three dimensions.

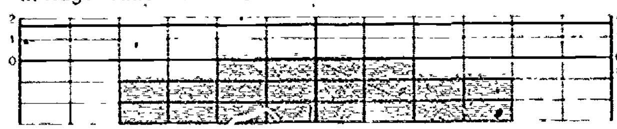
6. Using the data from column 6, draw a line across the grid (Worksheet 2) to represent the new sea level. Use a colored pencil. Each new sea level should be drawn in a different color.

Question the students to be sure they understand that the total area of each sea level change on the grid (Worksheet 2) relates to the area of blocks used.

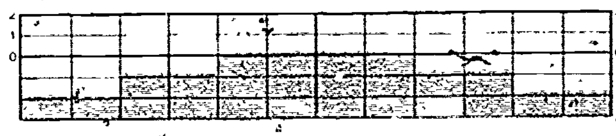
7. Repeat all of the procedures above until there is no change in sea level. Remember to do the same thing on both sides of the ridge at each step throughout the PROCEDURE. The old crust (blocks) must be pushed away from the rift (to the right and left) so that there is room to insert the new crust (blocks). Remember that at each time interval, you must first insert new material only at the rift and then you remove one block from each stack of all old parts of the crust. This represents shrinkage due to the cooling of the older rock. Add the number of blocks removed due to shrinkage to the number of any blocks subducted off the ends of the grid, and record the total in column 3.

Be certain that students remember to remove one block from each column representing old crust. This is to account for cooling during the period that the old crust has been spreading apart. When all data for time interval 4 has been completed, students will find that insertion of new material will not result in a change in volume of the ridge or in sea level.

Step 7, further additions of material at ridge Time interval 2.



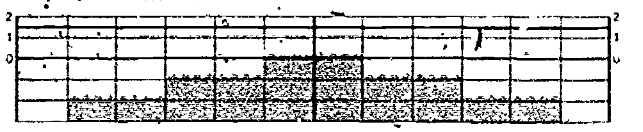
Time intervals 3 and 4 (both will look alike)



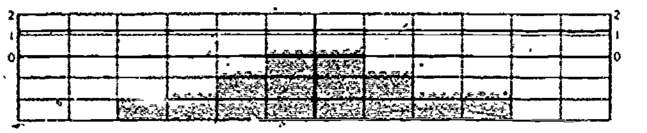
8. Now add "new crust" at the slow rate (two stacks of three blocks each; one stack on each side of the rift) and record your results until once again there is no change in sea level.

The model has reached equilibrium. Students should now reduce the rate of sea-floor spreading by one-half. Now in step 8 they will begin to add one stack on each side of the rift, a total of two stacks of blocks, three blocks per stack.

Step 8; time interval 5



Time interval 6.



Time intervals 7 and 8
(both will look alike)

9. Complete column 5 by adding the data from column 4. (Add each new ridge volume to the previous ridge volumes.)

The students may need help completing column 5. The first number entered in column 5 (time interval 1) is 12. Then add the second number (8) from column 4 to 12 and enter the sum (20) in the next space (time interval 2). Continue until the column has been completed. See Answer Sheet 3.

10. On the graph on Worksheet 3 marked Change in Ridge Volume, plot the data you recorded in column 5. The resulting curve represents changes in the volume of the mid-ocean ridge.

See Answer Sheet 3.

11. On the graph on Worksheet 3 marked Total Change in Sea Level, plot the data you recorded in column 7. The resulting curve represents changes in sea level.

See Answer Sheet 3.

12. Examine the two graphs. What happened to the volume of the mid-ocean ridge and to sea level at the first introduction of new crust (time interval 1)? What do you think caused this?

There was a dramatic increase in the volume of the ridge, from 0 to 12. This resulted in a sudden increase in sea level as a result of the displacement of water.

13. As you continued with the high rate of sea-floor spreading, what happened to the volume of the ocean ridge? sea level?

The volume of the ocean ridge continues to increase until the fourth step. From here on it would remain constant. Sea level too increases until the fourth step. It will also remain constant as long as the rate of sea-floor spreading remains the same.

14. When you used a slower rate of spreading (step 3), what happened to the mid-ocean ridge? to sea level?

With the slowing down of sea-floor spreading, the volume of the mid-ocean ridge shrinks. Sea level, therefore, begins to fall.

15. Why does sea level reach a point where it no longer changes? Did you find that this occurred during both fast and slow rates of spreading?

Sea level reaches a point of no change when the volume of the mid-ocean ridge *no longer changes*, that is, when the development of new crust *equals* that lost by destruction and/or cooling.

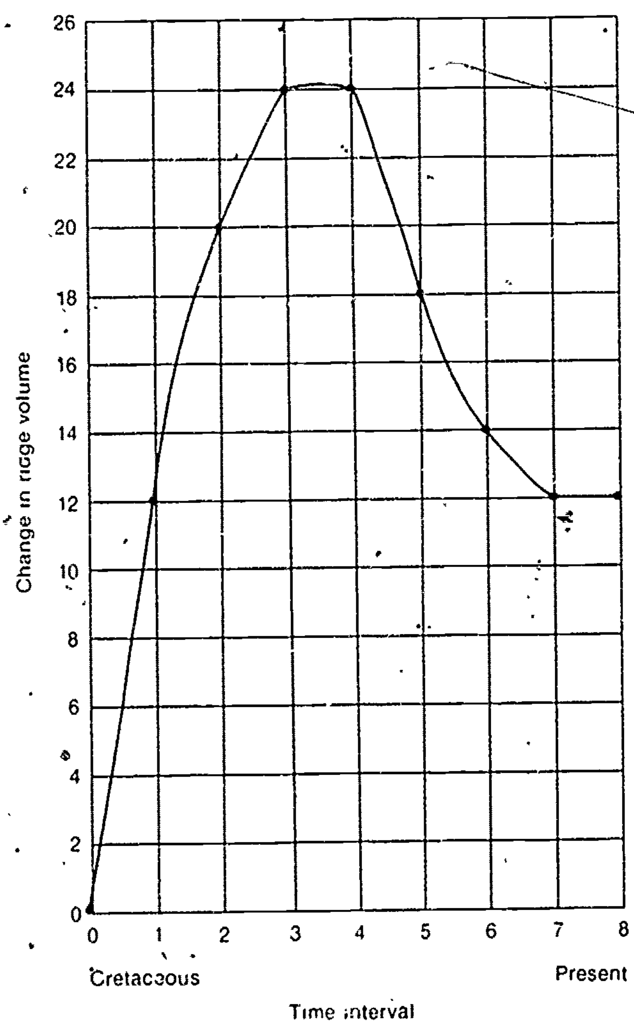
16. Describe the relationships between rate of sea-floor spreading, volume of ridge, and sea level.

Changes in the rate of sea-floor spreading will change the volume of the ocean crust and simultaneously, sea level. If the rate increases, so will the volume of the crust. Sea level will then rise. If the rate decreases, crust volume will shrink, and sea level will fall. After a time at the new sea-floor spreading rate, the ridge volume will remain constant and so will sea level. Since students used only two spreading rates, they may not come to these conclusions by themselves. You may have to discuss these relationships with them.

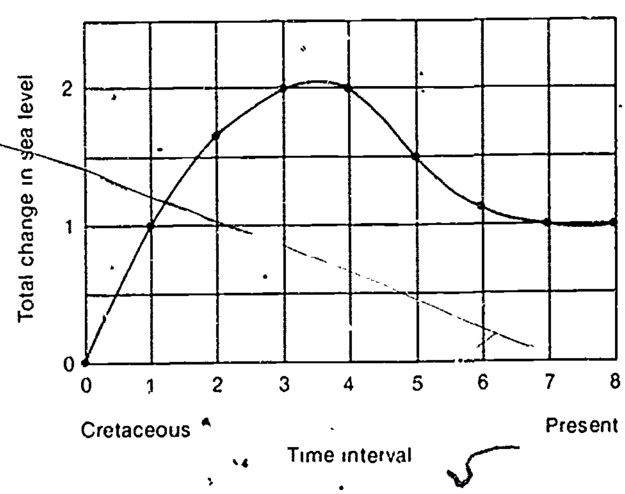
Data Table

Column 1 Time interval	Column 2 Total blocks added, both sides of ridge	Column 3 Total blocks removed, both sides of ridge	Column 4 Change in ridge volume (Col. 2 minus Col. 3 =)	Column 5 Total volume since spreading began	Column 6 Change in sea level from previous time interval $\left(\frac{\text{Col. 4}}{12} = \right)$	Column 7 Total change in sea level since spreading began
0	0	0	0	0	0	0
1	12	0	12	12	1	1
2	12	4	8	20	$\frac{2}{3}$	$1\frac{2}{3}$
3	12	8	4	24	$\frac{1}{3}$	2
4	12	12	0	24	0	2
5	6	12	-6	18	$-\frac{1}{2}$	$1\frac{1}{2}$
6	6	10	-4	14	$-\frac{1}{3}$	$1\frac{1}{6}$
7	6	8	-2	12	$-\frac{1}{6}$	1
8	6	6	0	12	0	1

Data from column 5



Data from column 7



Answer Sheet 3 (PART B)

The model you built in step 1 represents the ocean before the beginning of the Cretaceous. Little or no spreading was taking place. Sea-floor spreading started during the Cretaceous (step 2) and continued at a high rate through time interval 4. After that it slowed.

17. What can you say about changes in sea level during the Cretaceous and up to Present time?

Sea level increased rather rapidly during the Cretaceous, and then stabilized for awhile. Later it began to fall, but never as low as it was previous to the Cretaceous.

18. As sea level rose during the Cretaceous, where did the water go? What evidence do we have today as to where the water went?

The water flooded what are now continental areas. Cretaceous marine rocks extend far inland up into the mid-continent of North America, for example.

19. Why has sea level gone down since Cretaceous time? What evidence do we have that sea level is now lower?

Sea level has probably gone down because of a slowing of the spreading rate. The fact that Cretaceous rocks are extensively exposed on the continents is evidence that sea level has gone down.

You have been dealing with a model that greatly simplifies the idea of sea-floor spreading and its effect on sea level. One of the simplifications is that it treats the ocean basins as closed containers with high vertical walls. This, of course, is not true. On the real earth, the ocean basins are bounded by continents. The sides of continents slope gently toward their interior. As sea level rises, water goes up very slowly and the area of the ocean expands into the interior of the continents. Figure 1 indicates the probable extent of Cretaceous seas onto the continents. You may be living in an area once covered by those seas.

SUMMARY QUESTIONS

1. What is the relationship between the temperature of a substance, the volume it occupies and its density?

As temperature increases, so does the volume of a substance. Density will decrease.

2. How does the rate of sea-floor spreading affect sea level?

A change in rate will cause a change in sea level. If the rate increases, sea level will rise; if the rate decreases, sea level will fall.

3. What has happened to sea level since early in Cretaceous until the Present?

Sea level rose dramatically during the Cretaceous. The ocean covered a large area of present land surface. Sea level has now subsided, but is still higher than it was at the beginning of the Cretaceous.

REFERENCES

Hays, J.D. and Pitman, W.C. III, 1973, Lithospheric plate motion, sea level changes and climatic and ecological consequences. *Nature*, v. 246, no. 5427 (Nov. 2), p. 18-22.

Langseth, M., Le Pechon, S. and Ewing, W., 1966, Crustal structure of mid-ocean ridges, 5, Heat flow through the Atlantic Ocean floor and convection currents. *Journal of Geophysical Research*, v. 71, no. 22 (Nov. 15), p. 5321-5354.

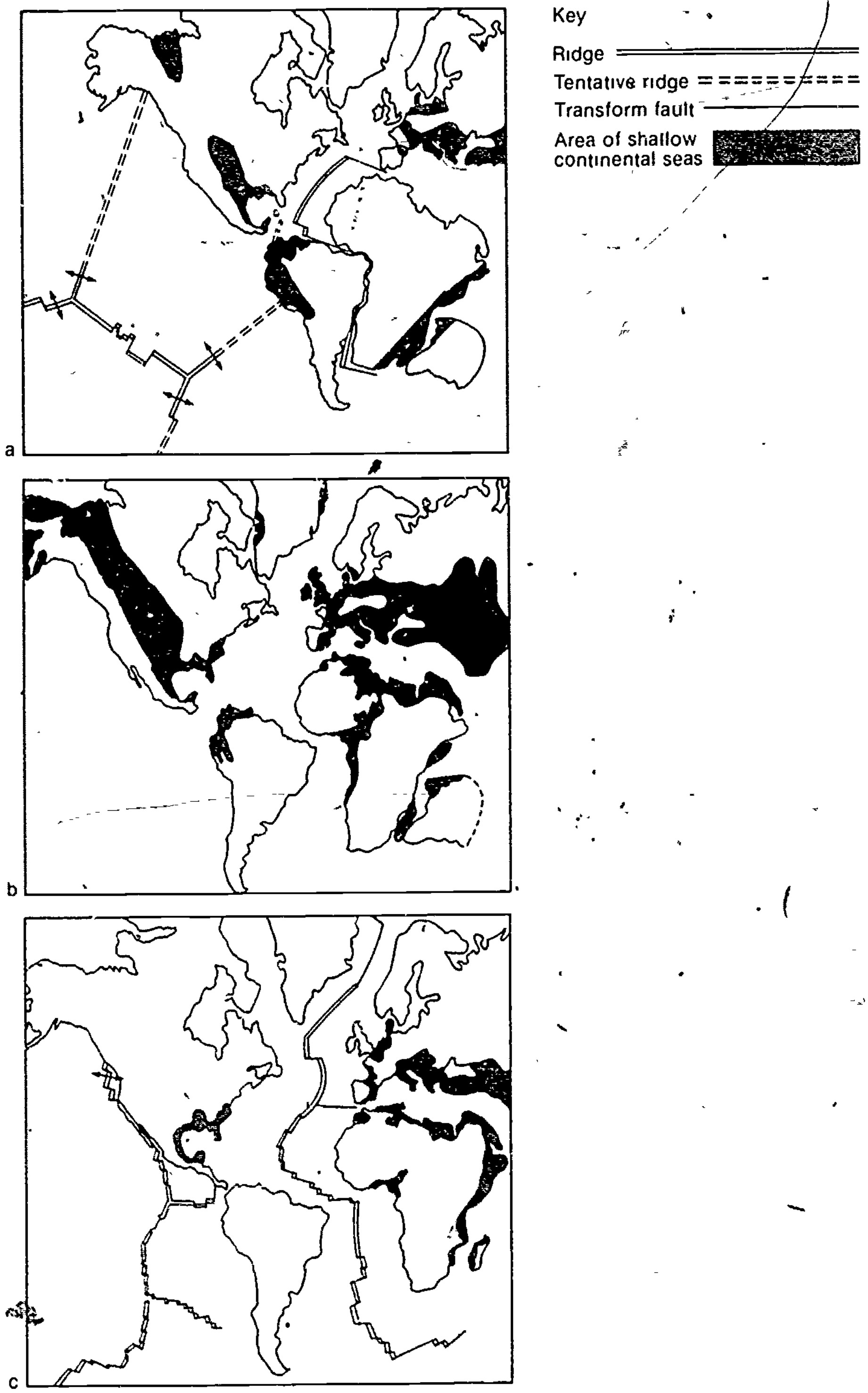


Figure 1. The extent of the seas for three geological epochs:
a. Middle Cretaceous (94 to 100 million years ago)
b. Upper Cretaceous (70 to 85 million years ago)
c. Eocene (40 to 50 million years ago)
The approximate positions of the mid-ocean ridge axes are shown in a and c. (From Hays and Pitman, 1973.)

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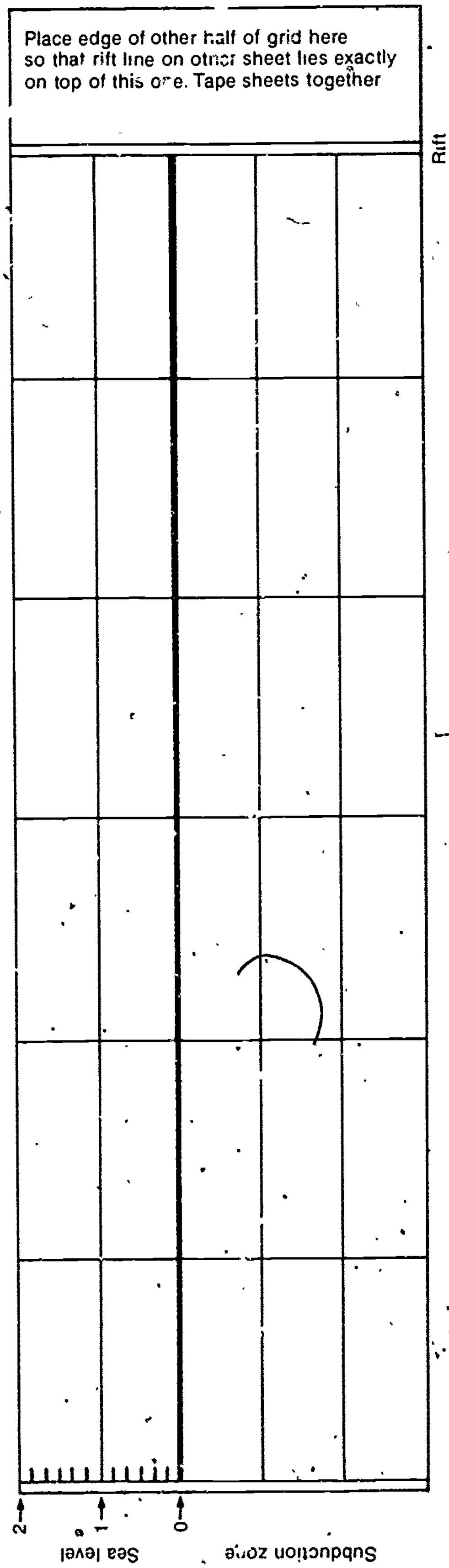

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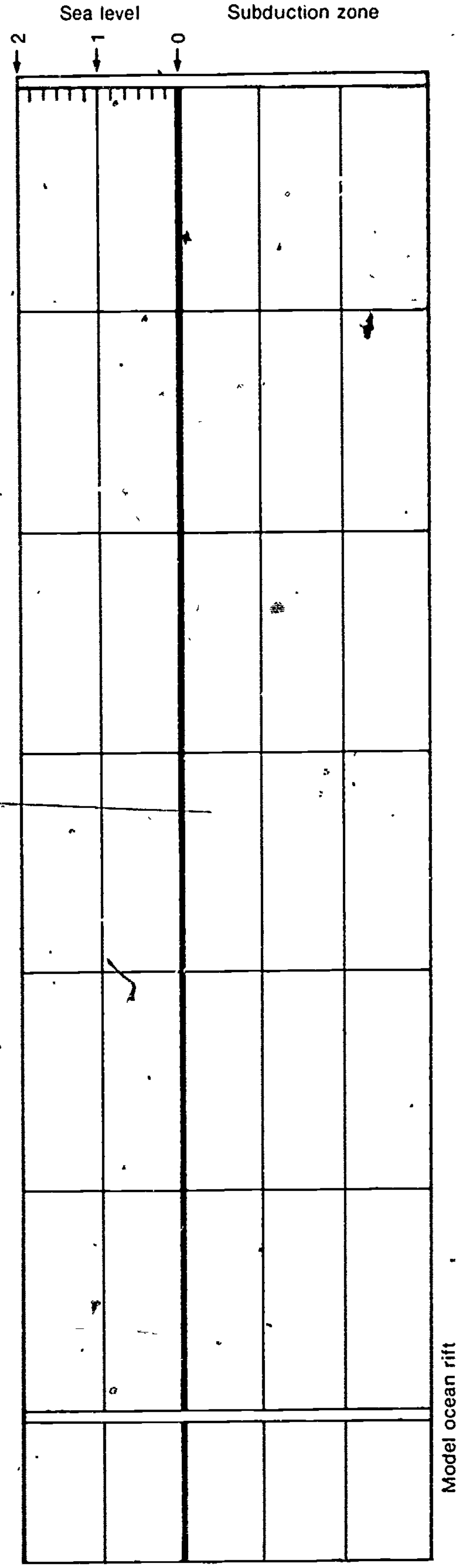
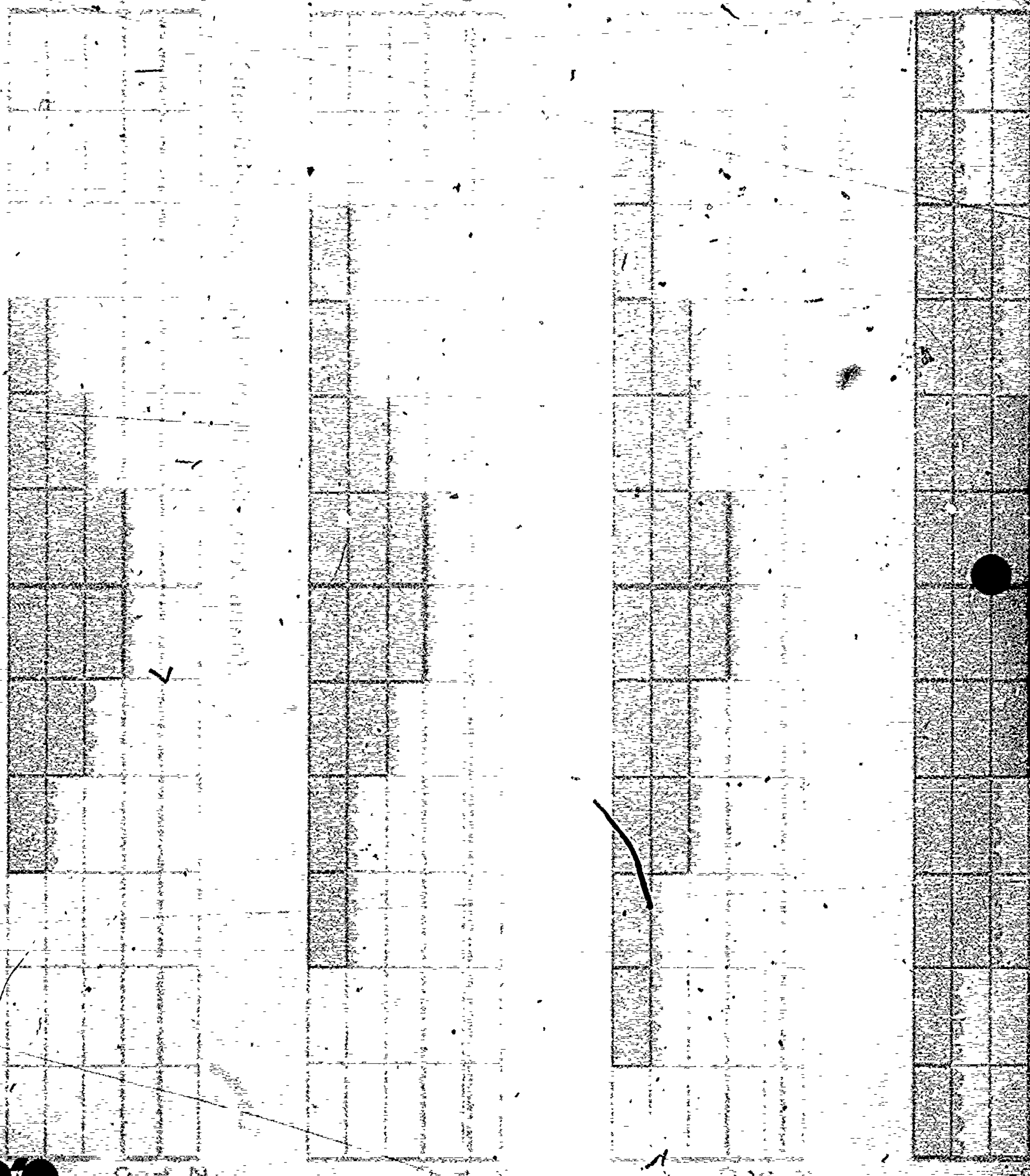


Worksheet 2 (PART B)

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. OH7 [illegible]

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CRUSTAL EVOLUTION EDUCATION PROJECT

NAME DATE

Student Investigation

Catalog No. 34W1133

Why Does Sea Level Change?

INTRODUCTION

Geologists have found evidence that sea level has not always been the same. In fact, many geologists believe that it may have changed by as much as 300 meters in the past 200 million years. At one time large areas of what is now the United States were under sea water. The sea extended as far north as the Dakotas. Even the Appalachian mountain area might have been covered by the sea. What could have caused such a great rise in sea level? Then, why did sea level go back down?

OBJECTIVES

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

1. Describe the relationship between the temperature and the volume of a rock.
2. Describe how the rate of sea-floor spreading affects the volume of the mid-ocean ridge.
3. Predict the effect of a change in the rate of sea-floor spreading upon sea level.

SE 038 145

PROCEDURE

PART A: What is the relationship between the temperature and the volume of a rock?

Materials: map, *Atlantic Ocean Floor*

Answer the following questions from your previous study of science or from the demonstrations your teacher may conduct.

1. What happens to the liquid in a thermometer when you put the thermometer in hot water? In cold water?

2. You may have seen a hot-air balloon. Can you explain how it is able to rise? What will cause it to descend?

3. The metal lid on a glass jar can often be loosened by placing it in hot water. Why does this work?

4. What property do these liquids, gases and solids have in common?

5. What would happen to rocks in the earth's crust if they were heated? cooled?

We have learned that a given mass of material takes up more volume when warm than when cool. Does this also apply to the ocean's crust? Examine the map, *Atlantic Ocean Floor*, and answer the following questions:

6. Locate the Mid-Atlantic Ridge and the Sierra Leone Rise. Is the crust in those areas young or old? How do you know?

7. Locate the Hatteras Plain and the Sierra Leone Basin. Is the crust in those areas young or old? How do you know?

8. Locate the areas identified in 6 and 7 above on the profile on Worksheet 1. Where would you expect the temperatures of the crust to be high? low? Why?

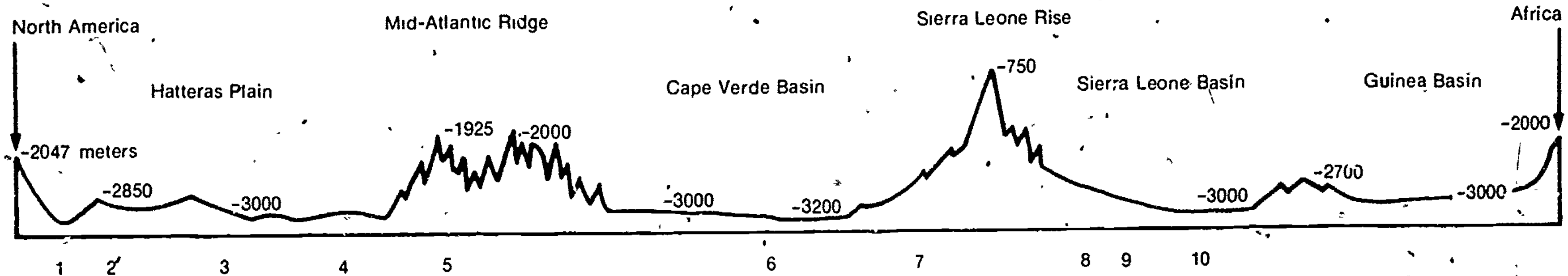
9. Plot the heat flow values on the profile on Worksheet 1. Were your conclusions in question 8 correct?

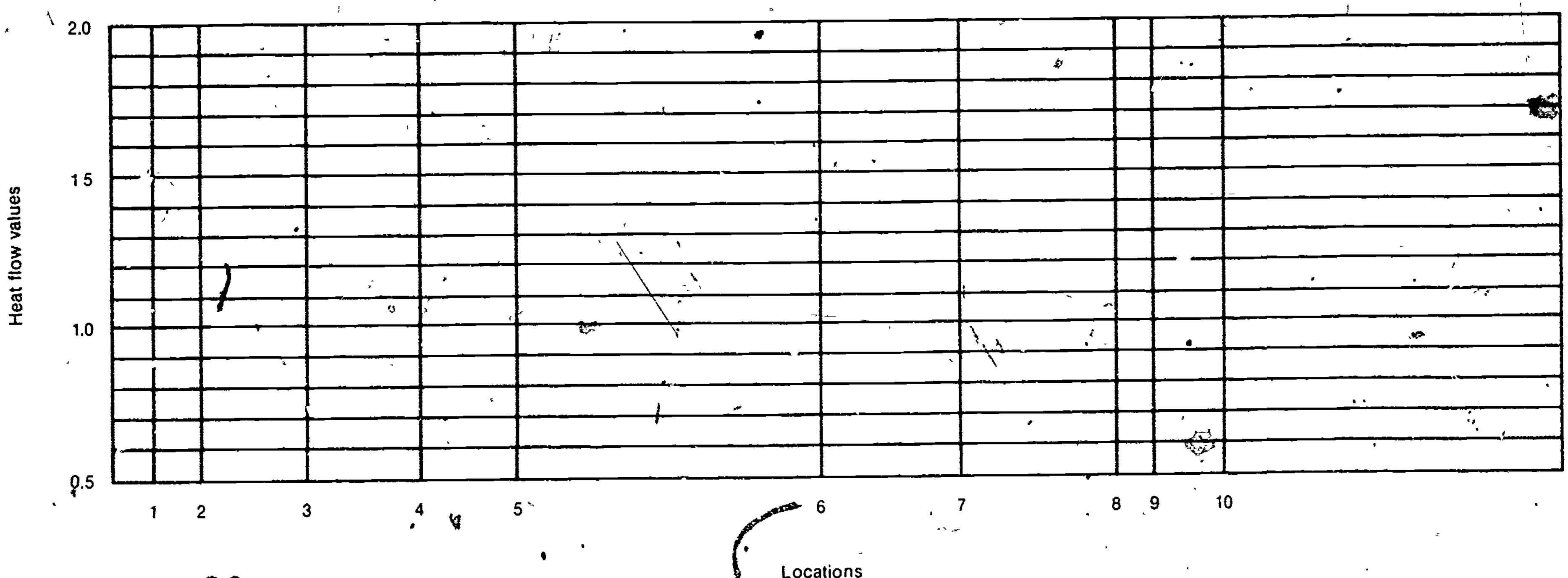
Scientists can actually take the temperature of ocean crust. They can do this by measuring what is called **heat flow**, which is heat that is given off by the crust. The higher the heat flow, the higher the temperature of the crust. Table 1 contains some actual measurements of heat flow in the Atlantic Ocean Basin. These measurements are in **microcalories** per square centimeter per second. A **calorie** is the amount of heat it takes to raise the temperature of one gram of water one degree Celsius. A microcalorie is one thousandth of a calorie. These measurements, then, are of very small differences in rock temperature.

Table 1.
Heat flow data for use with Worksheet 1.
(Langseth, Le Pechon and Ewing, 1966)

Location	*Heat flow*
1	0.9
2	1.0
3	1.0
4	1.4
5	1.6
6	0.8
7	1.8
8	1.6
9	1.4
10	1.0

Profile of the Atlantic Ocean Floor





Worksheet 1 (PART A)

PROCEDURE

PART B: How could changes in the rate of sea-floor spreading influence sea level?

Materials. set of 36 blocks for model ocean on Worksheet 2, transparent tape, scissors, colored pencils.

Scientists suggest that big changes in sea level are caused by changes in the volume of the mid-ocean ridge. Its volume can be decreased by the destruction of parts of the ridge or by the decrease in the rate of sea-floor spreading. The volume of the ridge can be increased by the formation of new ridges or by increasing the rate of sea-floor spreading.

In this activity you will be using a model ocean consisting of a paper grid (Worksheet 2) and blocks. You will investigate the effect of a change in the rate of sea-floor spreading upon the volume of the mid-ocean ridges and the height of sea level. Notice that the grid is ruled into rectangles the same size as the blocks. Also notice that subduction zones, a mid-ocean rift and sea level are indicated on the grid. This model is of all the world's ocean basins combined. In other words, the ridge represents all places where new crust originates and the ends of the paper represent subduction zones where crust is destroyed. The blocks will represent the crust. You will collect data on the effect of two changes of rate of sea-floor spreading upon your model ocean.

1. Cut out and tape together the two sections of the paper grid on Worksheet 2. Follow the instructions right on the grid. The bottom of the grid represents the ocean floor during a period when sea-floor spreading was not taking place. Notice that there is no ridge present. This is time interval 0. Sea level is now at 0.

2. Build four stacks of blocks, each stack three blocks high. Lay the stacks down on the grid on Worksheet 2, two stacks on each side of the rift. You have started an episode of sea-floor spreading. This is time interval 1. The four columns represent the mid-ocean ridge.

In this activity the rate of sea-floor spreading is represented by the number of stacks you use. Four stacks of blocks would represent a faster spreading rate than two stacks.

3. Count the number of blocks added at the rift. Record the number in column 2 of Worksheet 3. As you continue this activity, some blocks will be removed, by going into subduction zones (off the grid). Also, the ridge will cool and shrink down. Therefore blocks will be removed, to represent shrinkage. The total number of blocks removed is recorded in column 3. (In step 2 above, total blocks removed = 0.)

4. Determine the difference between the number of blocks added (column 2) and the number removed (column 3). In the **first** time interval this is equal to 12, which is the total number of blocks added. Record this in column 4.

5. Determine the change in sea level by dividing the number in column 4 by 12, which is the total number of block lengths across the grid. Enter this number in column 6. This will give the change in sea level in units of block height. In this case it is **one**.

6. Using the data from column 6, draw a line across the grid (Worksheet 2) to represent the new sea level. Use a colored pencil. Each new sea level should be drawn in a different color.

7. Repeat all of the procedures above until there is no change in sea level. Remember to do the same thing on both sides of the ridge at each step throughout the PROCEDURE. The old crust (blocks) must be pushed away from the rift (to the right and left) so that there is room to insert the new crust (blocks). Remember that at each time interval, you must first insert new material only at the rift and then you remove one block from each stack of all old parts of the crust. This represents shrinkage due to the cooling of the older rock. Add the number of blocks removed due to shrinkage to the number of any blocks subducted off the ends of the grid, and record the total in column 3.

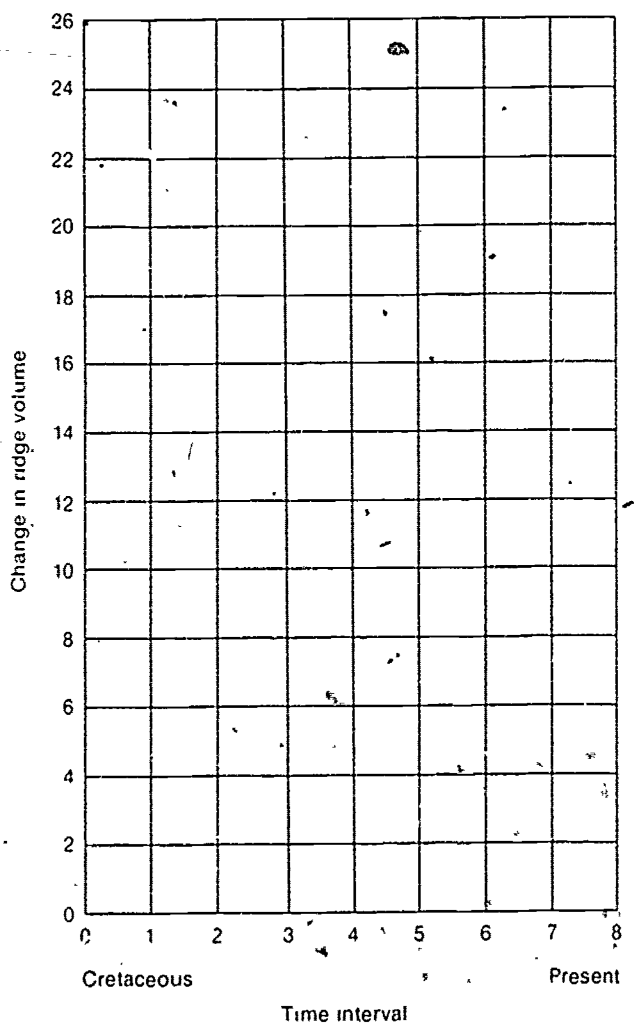
8. Now add "new crust" at the slow rate (two stacks of three blocks each; one stack on each side of the rift) and record your results until once again there is no change in sea level.

9. Complete column 5 by adding the data from column 4. (Add each new ridge volume to the previous ridge volumes.)

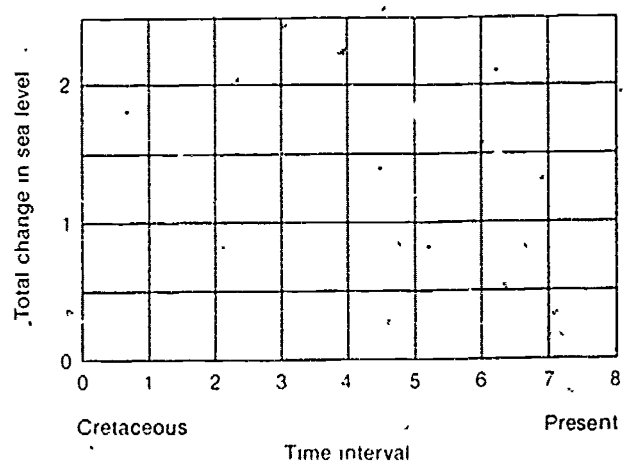
Data Table

Column 1 Time interval	Column 2 Total blocks added, both sides of ridge	Column 3 Total blocks removed, both sides of ridge	Column 4 Change in ridge volume (Col. 2 minus Col. 3 =)	Column 5 Total volume since spreading began	Column 6 Change in sea level from previous time interval $\left(\frac{\text{Col. 4}}{12} = \right)$	Column 7 Total change in sea level since spreading began
0	0	0	0	0	0	0
1						
2						
3						
4						
5						
6						
7						
8						

Data from column 5



Data from column 7



10. On the graph on Worksheet 3 marked Change in Ridge Volume, plot the data you recorded in column 5. The resulting curve represents changes in the volume of the mid-ocean ridge.

11. On the graph on Worksheet 3 marked Total Change in Sea Level, plot the data you recorded in column 7. The resulting curve represents changes in sea level.

12. Examine the two graphs. What happened to the volume of the mid-ocean ridge and to sea level at the first introduction of new crust (time interval 1)? What do you think caused this?

13. As you continued with the high rate of sea-floor spreading, what happened to the volume of the ocean ridge? sea level?

14. When you used a slower rate of spreading (step 3), what happened to the mid-ocean ridge? to sea level?

15. Why does sea level reach a point where it no longer changes? Did you find that this occurred during both fast and slow rates of spreading?

16. Describe the relationships between rate of sea-floor spreading, volume of ridge, and sea level.

The model you built in step 1 represents the ocean before the beginning of the Cretaceous. Little or no spreading was taking place. Sea-floor spreading started during the Cretaceous (step 2) and continued at a high rate through time interval 4. After that it slowed.

17. What can you say about changes in sea level during the Cretaceous and up to Present time?

18. As sea level rose during the Cretaceous, where did the water go? What evidence do we have today as to where the water went?

19. Why has sea level gone down since Cretaceous time? What evidence do we have that sea level is now lower?

You have been dealing with a model that greatly simplifies the idea of sea-floor spreading and its effect on sea level. One of the simplifications is that it treats the ocean basins as closed containers with high vertical walls. This, of course, is not true. On the real earth, the ocean basins are bounded by continents. The sides of continents slope gently toward their interior. As sea level rises, water goes up very slowly and the area of the ocean expands into the interior of the continents. Figure 1 indicates the probable extent of Cretaceous seas onto the continents. You may be living in an area once covered by those seas.

SUMMARY QUESTIONS

1. What is the relationship between the temperature of a substance, the volume it occupies and its density?

2. How does the rate of sea-floor spreading affect sea level?

3. What has happened to sea level since early in Cretaceous until the Present?

REFERENCE

Hays, J.D. and Pitman, W.C. III, 1973, Lithospheric plate motion, sea level changes and climatic and ecological consequences. *Nature*, v. 246, no. 5427 (Nov. 2), p. 18-22.

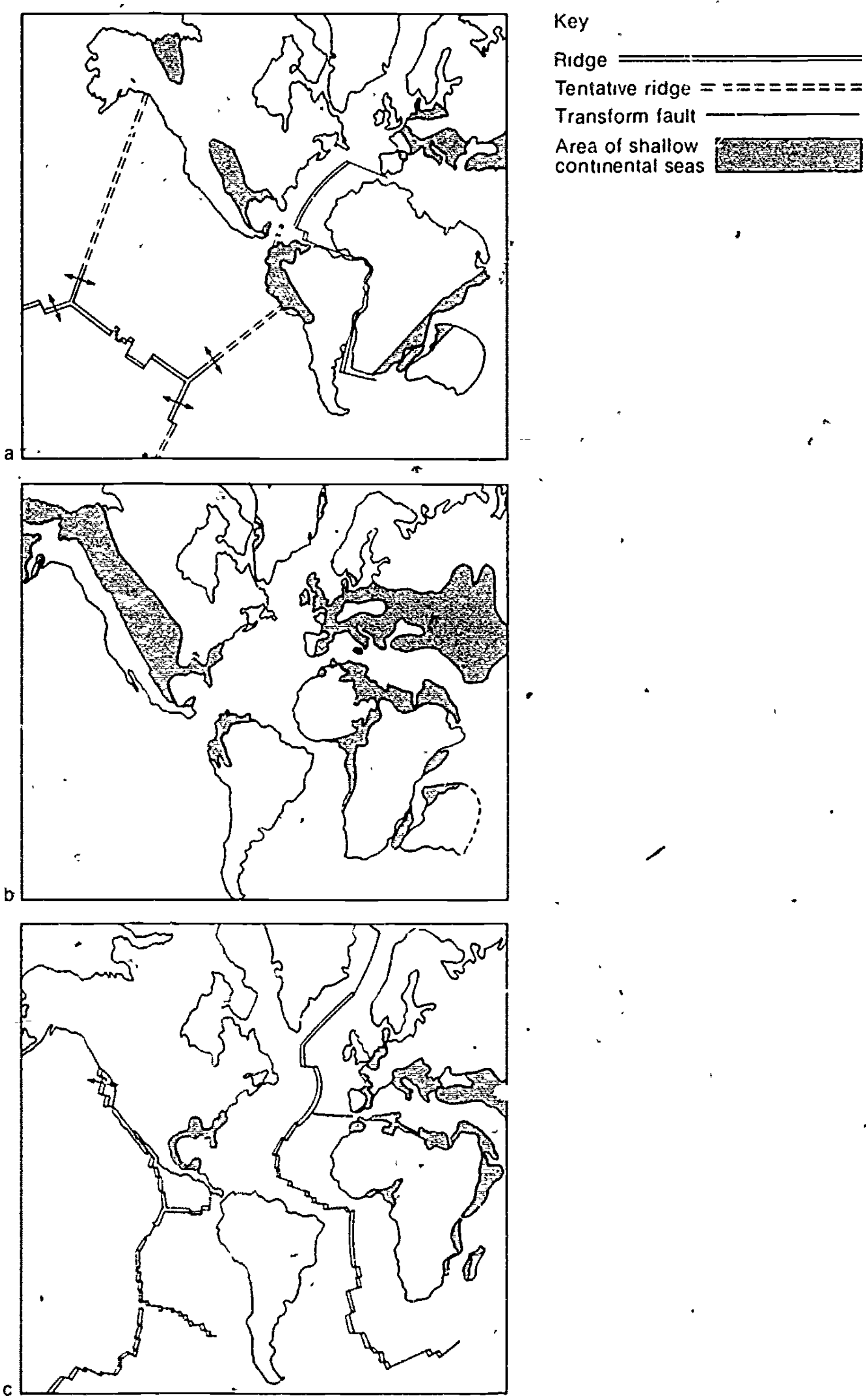
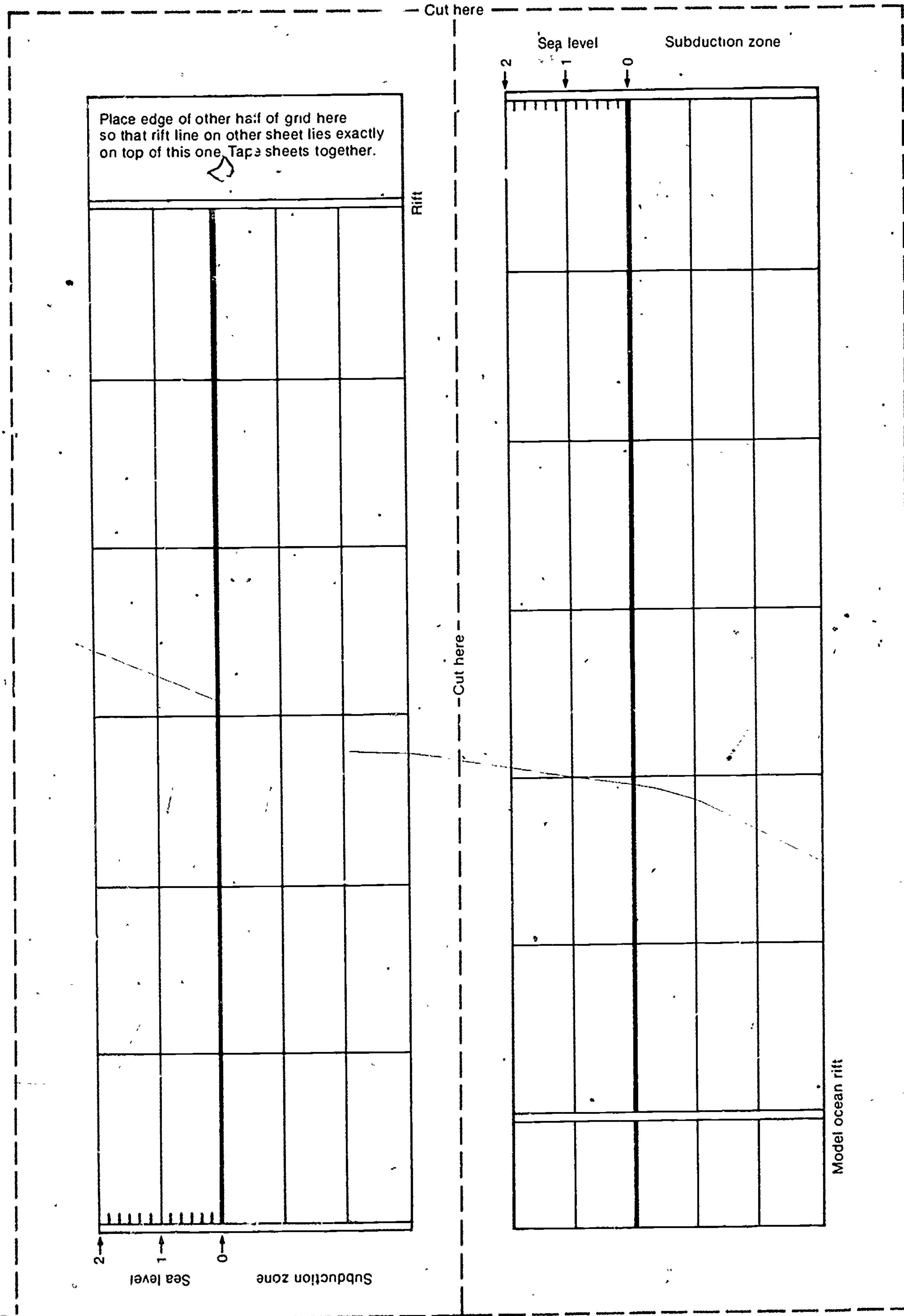


Figure 1. The extent of the seas for three geological epochs:
a. Middle Cretaceous (94 to 100 million years ago)
b. Upper Cretaceous (70 to 85 million years ago)
c. Eocene (40 to 50 million years ago)
The approximate positions of the mid-ocean ridge axes are shown in a and c. (From Hays and Pitman, 1973.)



Worksheet 2 (PART B)