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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. Data from the Deep Sea Drilling Project are modified in this 4-period, individualized activity focusing on use of fossil ranges in and correlating sea sediments. Students describe kinds of data obtained by the project, determine relative ages of sediment layers by using fossils and principle of supersition, correlate layers represented in diagrams (provided in booklets), and relate age of ocean crust to sea-floor spreading. (Author/JN)

CEEP™

CRUSTAL EVOLUTION EDUCATION PROJECT

Microfossils, Sediments And Sea-floor Spreading

TEACHER'S GUIDE

Catalog No. 34W1020

For use with Student Investigation 34W1120
Class time: four 45-minute periods

Developed by
THE NATIONAL ASSOCIATION OF GEOLOGY TEACHERS

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Microfossils, Sediments And Sea-floor Spreading

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 2[illegible] 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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Microfossils, Sediments And Sea-floor Spreading

INTRODUCTION

In this module students use modified data of the Deep Sea Drilling Project to study the use of fossil ranges in dating and correlating sediments. They find that the relative age of the ocean crust can be determined by dating the overlying sediments and that the crust gets progressively older outward from the Mid-Atlantic Ridge.

Until the last 20 years or so, very little was known about the ocean basins, their topography, sediments, or how they were formed. Even now we know less about the ocean basins than we know about the surface of the moon. Much has been learned recently as the result of a program called the Deep Sea Drilling Project. The first cruises of its research ship, the *Glomar Challenger*, to collect ocean basin data, were made in 1968. This project has provided much valuable data and material, including core samples of sea-floor sediment.

The section of a cruise between two places is called a **leg**. In these activities, you will be using data from Leg 2 of the Deep Sea Drilling Project. This leg is between New York and Dakar, Senegal (see Figure 1). On this cruise, the *Glomar Challenger* drilled into sea-bottom sediments at five different locations. These are labeled 8, 9, 10, 11 and 12 on Figure 1. You will use information from sites 8, 10, 11 and 12, only. It has been changed somewhat from the original data. This is necessary because the original data, although very detailed, are incomplete in some cases.

If you have already studied the theory of sea-floor spreading, try to answer the following questions. When you have finished, your teacher will discuss them with you. If you have not studied this theory, skip the questions and go on to PART A of this module.

If the theory of sea-floor spreading is correct, what information would you expect to find from Leg 2 concerning each of the following?

1. The cores at locations 10 and 11 (Figure 1) reached the basalt of the oceanic crust. Which core has the oldest sediment?

Site 10

2. How should the total thickness of the sediments on the ocean floor change under the *Glomar Challenger*, as the ship moved from the continental slope off North America to the axis, or crest, of the Mid-Atlantic Ridge?

The thickness of the sediments should decrease toward the ridge axis.

3. What changes in depth to the sea bottom should you expect beneath the *Glomar Challenger* as it moved from site 8 to a point above the ridge axis?

The ocean should be deepest at site 8 and shallowest above the ridge axis. The deepest area would be found close to the continental slope. As the *Glomar Challenger* moved toward the ridge, the depth would decrease beneath it.

PREREQUISITE STUDENT BACKGROUND

If the students already understand sea-floor spreading theory, they should be able to answer the questions in the INTRODUCTION.

Students are in essentially the same position as those scientists working on the Deep Sea Drilling Project. Before the project started, the theory had already been developed. The purpose of the project was to gather data that would either support or invalidate the theory. In answering these questions, the students are predicting the nature and distribution of deep sea sediments according to this theory.

If your students are not familiar with the theory of sea-floor spreading, they should not attempt to answer these questions. Instead, they should proceed directly to PART A of the activity. They will then have to develop an aspect of the theory of sea-floor spreading in order to explain the data that they will study.

Students should be acquainted with the common types of sedimentary and igneous rocks, and understand the principles of correlation and superposition. They should also understand what is meant by the range of a fossil species and be able to use the geologic time scale. Those students completing the EXTENSION need to understand the solubilities of silica and carbonate in sea water.

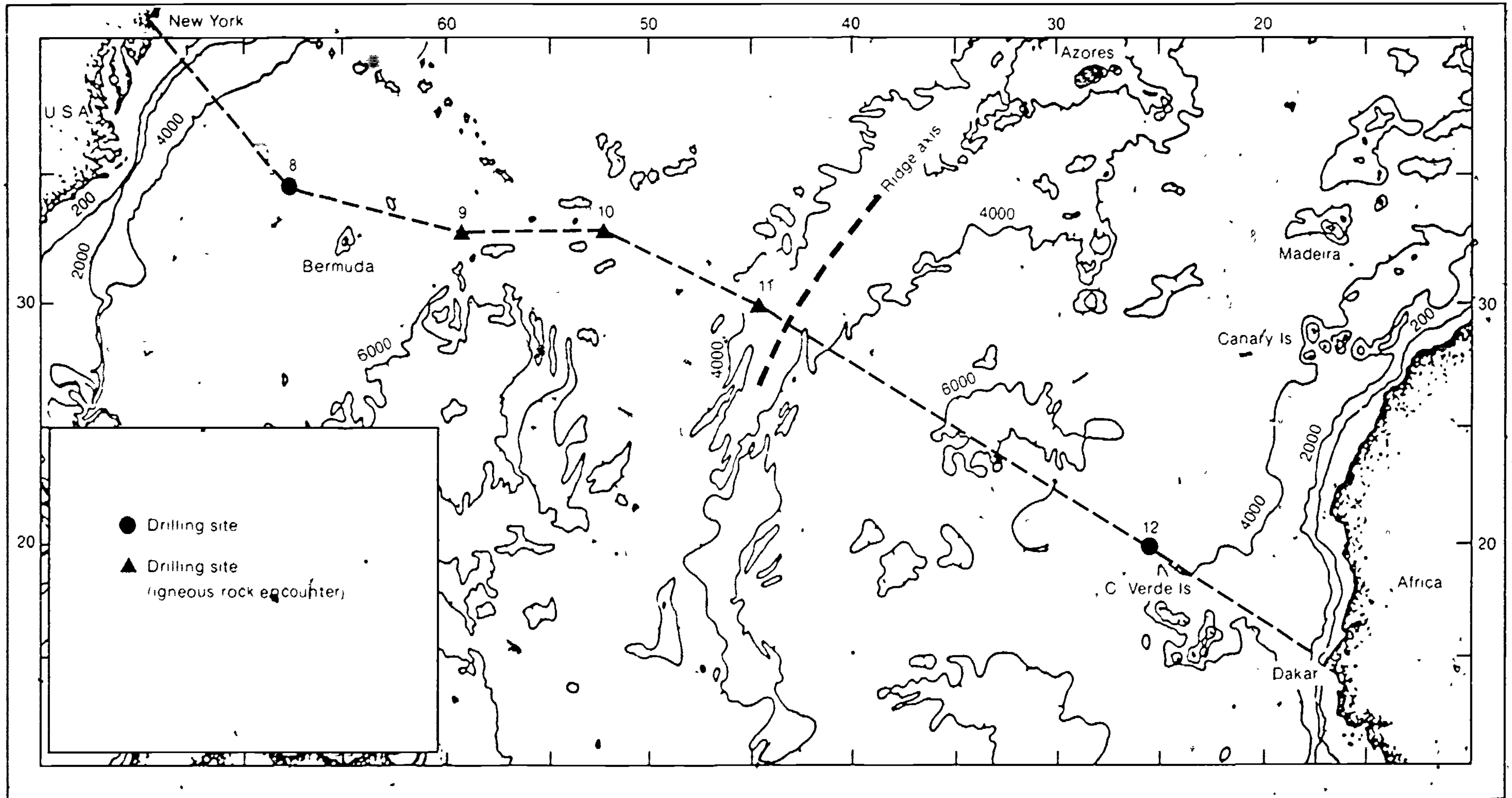

Figure 1 Map of the North Atlantic Ocean showing the sites drilled on Leg 2 Depth contours are in meters The line from New York to Dakar represents the path taken by the *Glomar Challenger* (Adapted from Volume II, Initial Reports of the Deep Sea Drilling Project)

OBJECTIVES

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

1. Describe the kinds of data obtained by the Deep Sea Drilling Project.
2. Determine the relative ages of sediment layers by using fossils and the principle of superposition.
3. Correlate the layers represented in the Core Diagrams
4. Relate the age of ocean crust to sea-floor spreading.

MATERIALS

Most of the materials needed by the students are included in the Student Investigation booklet and should be available according to instructions below.

One set for each group of 3 students:
- Reference Collection of Fossils (Worksheet 1)
- Fossils Found in Cores (Worksheet 2)
- Colored pencils and rulers

One set for each student:
- Key to Geologic Ages, Sediments and Rocks (Worksheet 3)
- Range Chart of Fossil Species (Worksheet 4)
- Core Diagrams (Worksheet 5)

BACKGROUND INFORMATION

The Deep Sea Drilling Project has produced a vast amount of data about the sediments of the ocean basins. The information resulting from these data has not only confirmed basic aspects of the plate tectonic theory, but has also led to a more complete understanding of the earth's climate and the factors that control it. In this respect, the project will have a direct effect on the lives of your students.

The data used in this activity are based upon those obtained by the project. They have been simplified, and the fossils are not necessarily those found in Leg 2. These modifications in the data will make them more understandable to students. You should emphasize, however, that the conclusions the students will reach are the same as those of the scientists who worked with these data.

SUGGESTED APPROACH

This activity is written in a step-by-step individualized format. For many students, it can be used in an independent study situation. However, the activity can be easily adapted for total class, laboratory-type teaching situations. You should present the introductory questions, objectives, and explanatory and summary information from the student activity in a pre-lab and post-lab group discussion.

In any case, you should be certain that this material is either read by or presented to the students and understood by them. It is important to the understanding of the OBJECTIVES of the activity.

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PROCEDURE

PART A. How are the relative ages of sediments in a core determined?

Students identify the fossils found in each of the cores and determine their ranges from their pictures in a Reference Collection. This identification is analogous to the procedure a paleontologist uses in determining the ranges of the fossils found in sediments. Students then determine the ages of the various intervals of sediment found in the cores.

Key words: leg, principle of superposition, species, index fossil, range

Time required: two 45-minute periods

Materials: Worksheets 1, 2, 3, 4, and 5; rulers, pencils and colored pencils

Sediments are deposited in layers. The **principle of superposition** states that when those layers remain undisturbed, the layer on the bottom was deposited first and is the oldest. The youngest is on top

1. Find your set of Core Diagrams (Worksheet 5). Look at the diagram of the core from site 8. There are letters at several places on the diagram List the letters in a column here, according to the ages of the sediments they mark Write "youngest" beside the top letter and "oldest" beside the bottom letter

D youngest
A
C
B
E oldest

The principle of superposition allows us to determine the youngest and oldest sediment within a single core How can you relate the age of a layer of sediment in one core to a layer in another core from a different location? A scientist working on the Deep Sea Drilling Project must do this to work out the history of the ocean basins Many sediments contain fossils Some of these are microscopic shells of tiny plants and animals that lived in the surface waters of the ocean When these organisms die, they fall to the ocean floor and become part of the sediments

Some **species** of plants or animals lived throughout wide areas during a relatively short period of geologic time. Their fossils are called **index fossils.** Many individuals of a species drifted far and wide across the ocean. Their fossil shells are found in a layer of sediment deposited over a large area of the ocean floor at the time that the species existed. When cores are taken from this layer of sediment at different locations, the same species of fossils may be found in several of the cores The sediments in which the fossils are found can then be matched between cores. The fossils must be a part of the sediment deposited at the same time in each of the areas where the cores were taken.

2. Examine the Reference Collection of Fossils (Worksheet 1). These pictures are of fossils from the groups called Foraminifera and Radiolaria. Instead of the actual species names of these organisms, each is labeled with an identification letter The **range** (the portion of geologic time during which a fossil lived) is given for each fossil (for example, Middle Paleocene to Late Oligocene for species E) Plot the range of each species on the Range Chart of Fossil Species (Worksheet 4) The range of species E has already been plotted Have your teacher check your graph when you finish

The range of each of the fossil species is to be plotted on the Range Chart of Fossil Species (Worksheet 4). Students will need to use this completed graph in the next part of the activity, so be certain that they have the ranges plotted correctly before they continue.

See Answer Sheet 4

3. Does any species represent a single time period (for example, Miocene) or only part of a time period? List these along with the part of geologic time in which they are found These species are index fossils

The following species can be used as index fossils for the time intervals indicated:

O, P = Pleistocene
N, D = Pliocene
L = Miocene
G = Oligocene
H = Eocene
C = Paleocene
B = Cretaceous

4. Using Fossils Found in Cores (Worksheet 2) identify each fossil as follows: The numbers on the fossils correspond to the layer in which they occur in the core. For example, fossil 1 was found near the top of the core from site 8. Fossil 2 was found in the layer immediately below it. To identify each of these fossils, compare them with the picture of each species in your Reference Collection of Fossils (Worksheet 1). Record the letter labeling the species in the space provided on the Core Diagrams. For example, fossil 1 would be identified as "A", fossil 2 as "I", etc.

See Answer Sheet 5.

5. Look at the first section (Worksheet 5), site 8. It contains fossils A, I and O. Using your Range Chart of Fossil Species (Worksheet 4), find the one geologic age when all these organisms lived at the same time. You should find this to be Pleistocene. Write **Pleistocene** on the line above **Age** on the core diagram. Now determine the ages of the other core diagrams at each site in the same manner.

See Answer Sheet 5.

6. Which fossils did you find most useful?

The students should list the same fossils found in question 3.

7. What do we call such fossils?

Index fossils

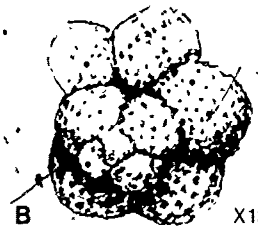
8. Find the Key to Geologic Ages, Sediments and Rocks (Worksheet 3). Color the small squares next to each geologic age with a different color. Next, color each section of the core diagrams (Worksheet 5) to match the color of the geologic ages in your key.

9. Notice that some sediments lack fossils, so you cannot be certain of their ages. Use the principle of superposition to estimate the ages of these sediments. Indicate on the cores the ages that you have determined by drawing diagonal lines of the appropriate color in each section of the core diagram.

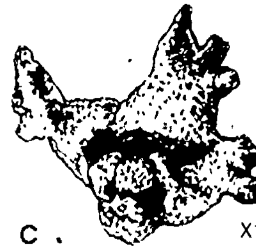
See Answer Sheet 5.

You have now used index fossils to determine the ages of sediments in cores in the same way that scientists do. These core diagrams will also be used in PART B of this activity.

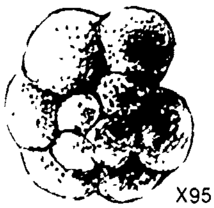
Reference Collection of Fossils—Foraminifera

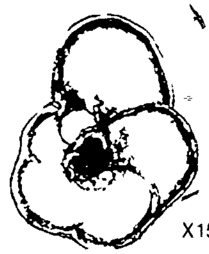

B X130
Cretaceous

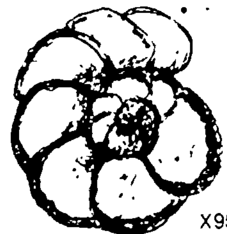

J X150
Early Oligocene—Middle Miocene


C X130
Paleocene


D X95
Pliocene

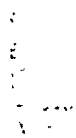

L X95
Miocene

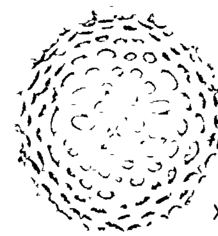

M X150
Early Pliocene—Middle Pleistocene


P X95
Pleistocene

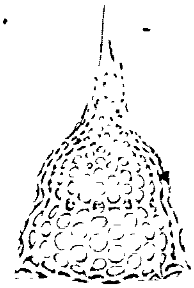
Reference Collection of Fossils—Radiolaria


A X300
Cretaceous-Pleistocene

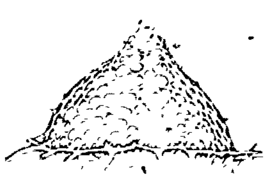

G X250
Oligocene


E X350
Middle Paleocene—Late Oligocene

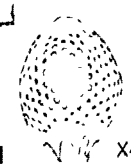

F X500
Early Oligocene—Middle Pliocene


H X450
Eocene


I X375
Eocene-Recent


K X500
Eocene-Miocene


O X375
Pleistocene

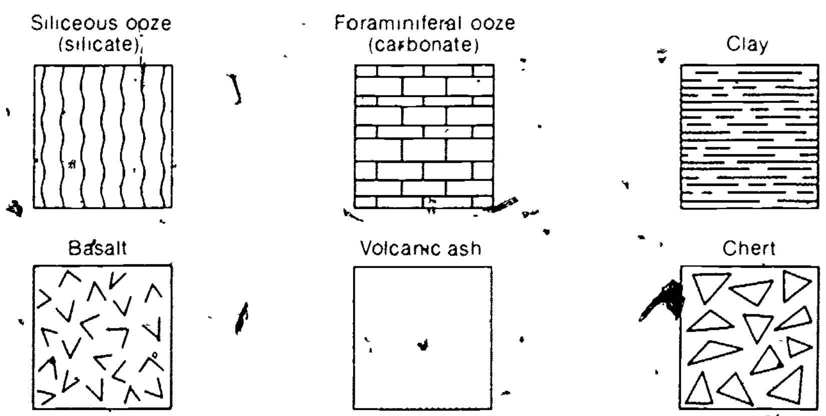

N X400
Pliocene

nswer Sheet 1 (PART A)

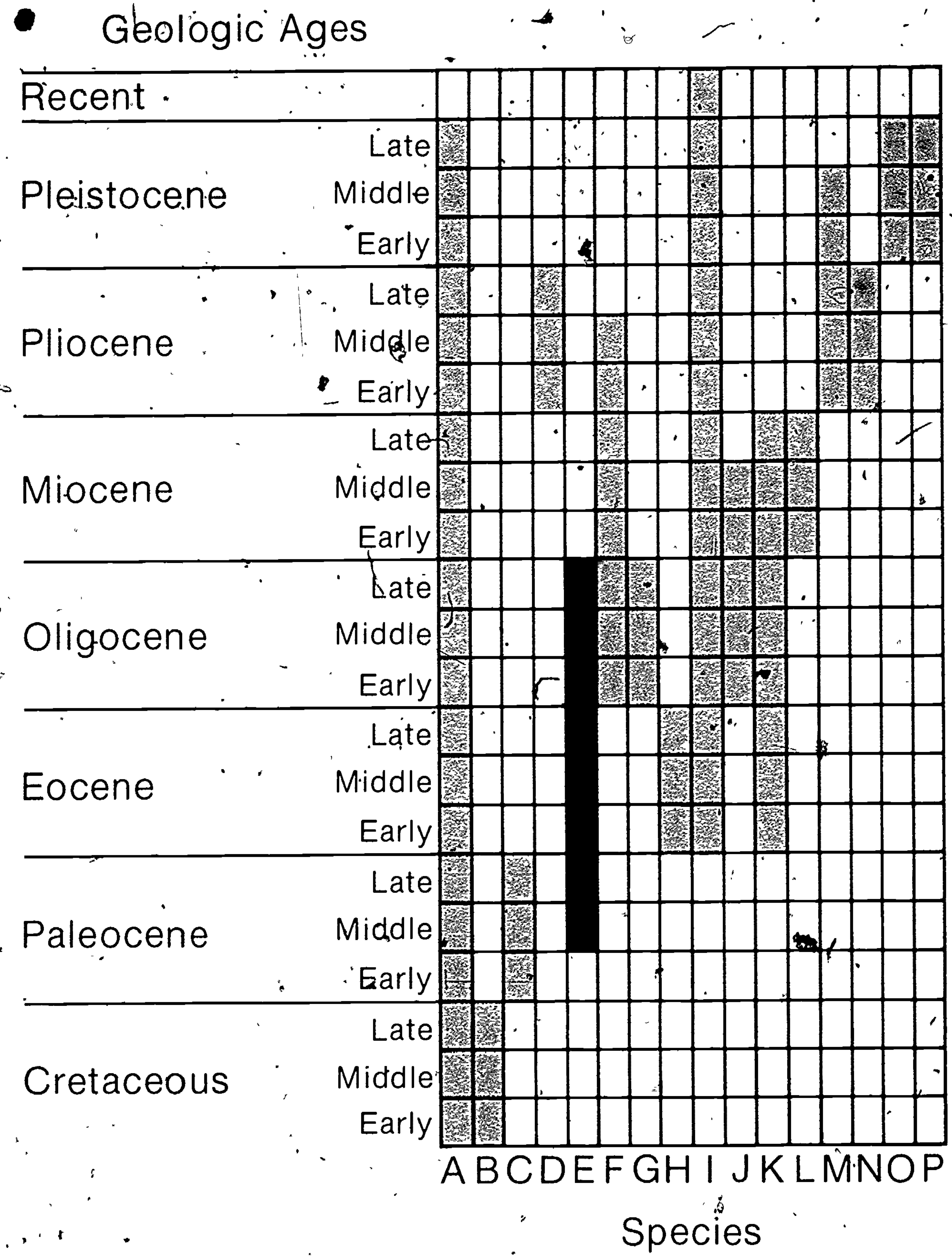
Key to Geologic Ages, Sediments and Rocks

Geologic ages	Color key
Recent—Pleistocene	
Pliocene	
Miocene	
Oligocene	
Eocene	
Paleocene	
Cretaceous	

Sediments And Rocks



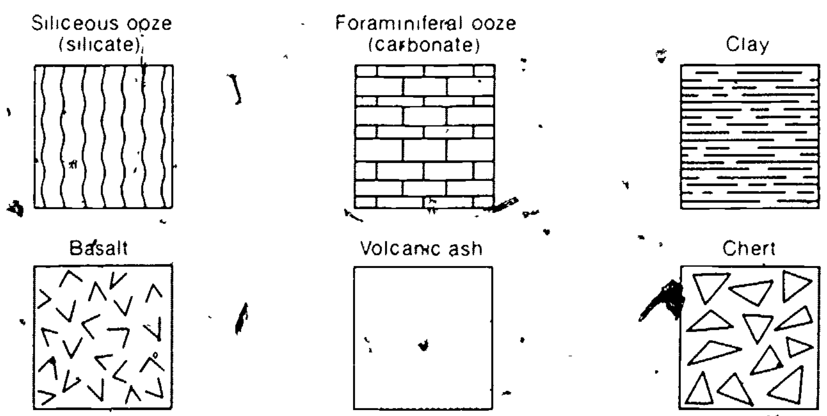
Range Chart of Fossil Species



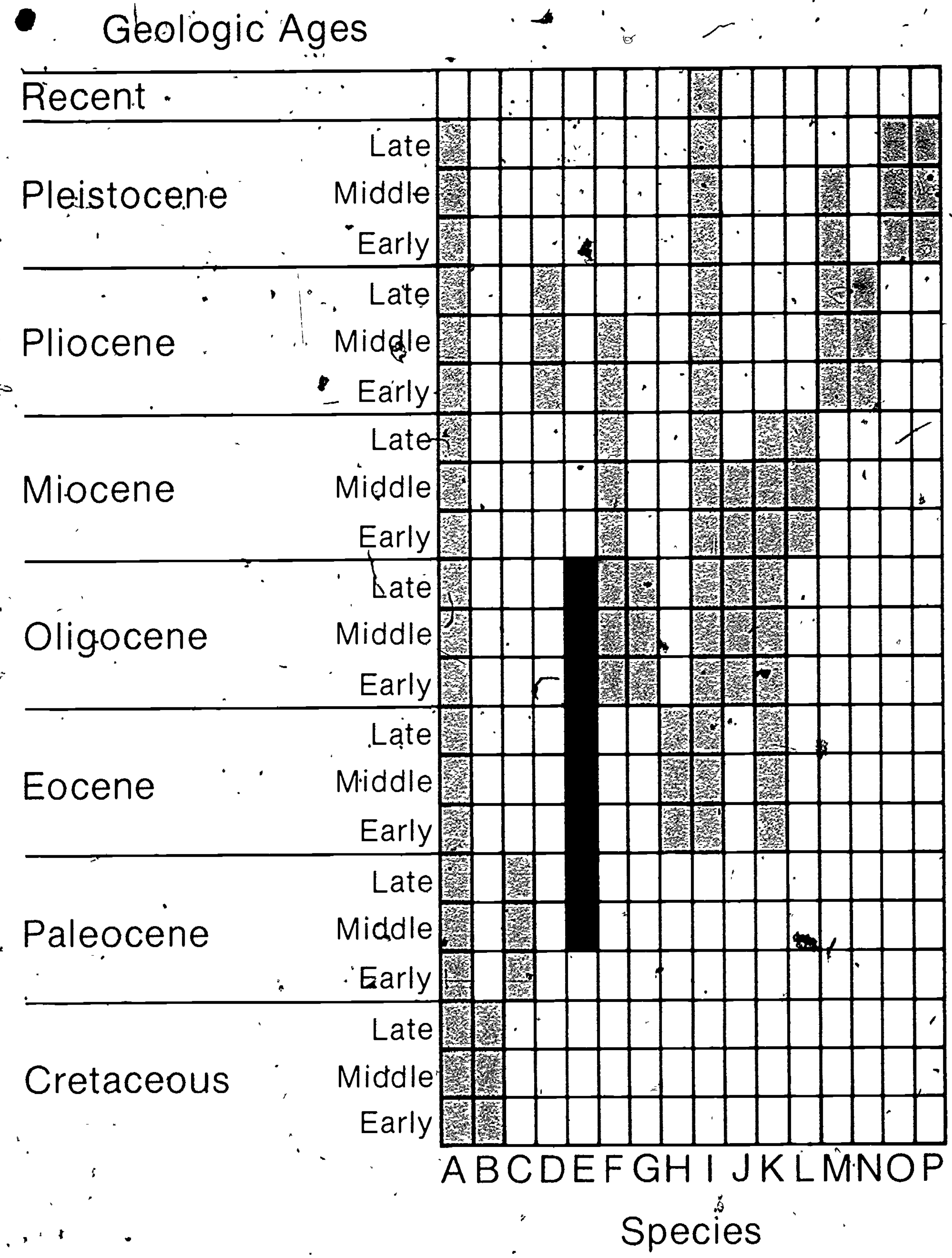
Key to Geologic Ages, Sediments and Rocks

Geologic ages	Color key
Recent—Pleistocene	
Pliocene	
Miocene	
Oligocene	
Eocene	
Paleocene	
Cretaceous	

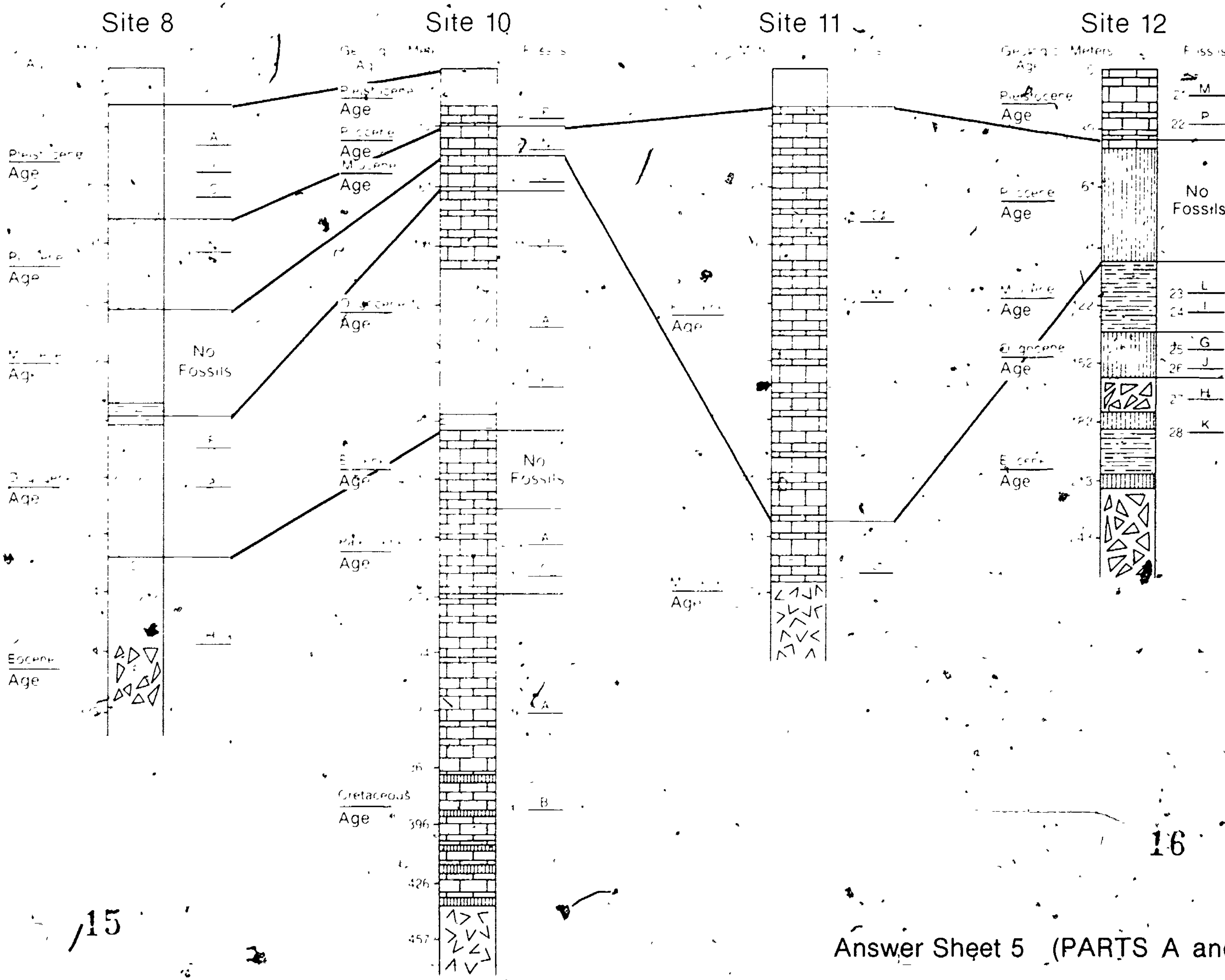
Sediments And Rocks



Range Chart of Fossil Species



Core Diagrams



Answer Sheet 5 (PARTS A and B)

PROCEDURE

PART B. How do the ages of sediments differ from core to core?

Students correlate layers between cores and determine the ages of the oldest sediments in each core. The result is information that confirms one aspect of the sea-floor spreading theory: the ocean floor becomes younger as the ridge is approached.

Key word: sea-floor spreading

Time required: one to two 45-minute periods

Materials: Worksheets 3 and 5, rulers and pencils

1. Using Worksheet 5 that you filled in for PART A, correlate by drawing lines between cores, marking the time boundaries from one core to the next. For example, connect the line in each core that represents the boundary between the Miocene and Pliocene. Have your teacher check your diagrams before you continue.

In correlating, the students will be connecting the base (or top) of each period from core to core. See Answer Sheet 5. Check your students' diagrams before they continue with the remaining questions.

For the remainder of these questions, refer to the Core Diagrams (Worksheet 5); the Key to Geologic Ages, Sediments and Rocks (Worksheet 3), the map (Figure 1), and the chart showing the topography of the Atlantic Ocean Basin (Figure 2).

2. At which sites did the *Glomar Challenger* drill through sediment to igneous rock?

Sites 9, 10 and 11

The igneous rock at these sites is basalt and probably is oceanic crust.

3. Which of the sites is closest to the ridge axis?

Site 11

Which is closest to the North American continental shelf?

Site 8

4. If the core at site 8 had been drilled deeper, would the deeper sediments be older or younger than those from the bottom of the core?

By applying the principle of superposition, students should reason that the deeper sediments would be older.

5. Keeping your last answer in mind, do the deepest sediments of sites 8 through 11 become younger or older as you move from the bottom of the continental margin to the ridge?

Younger

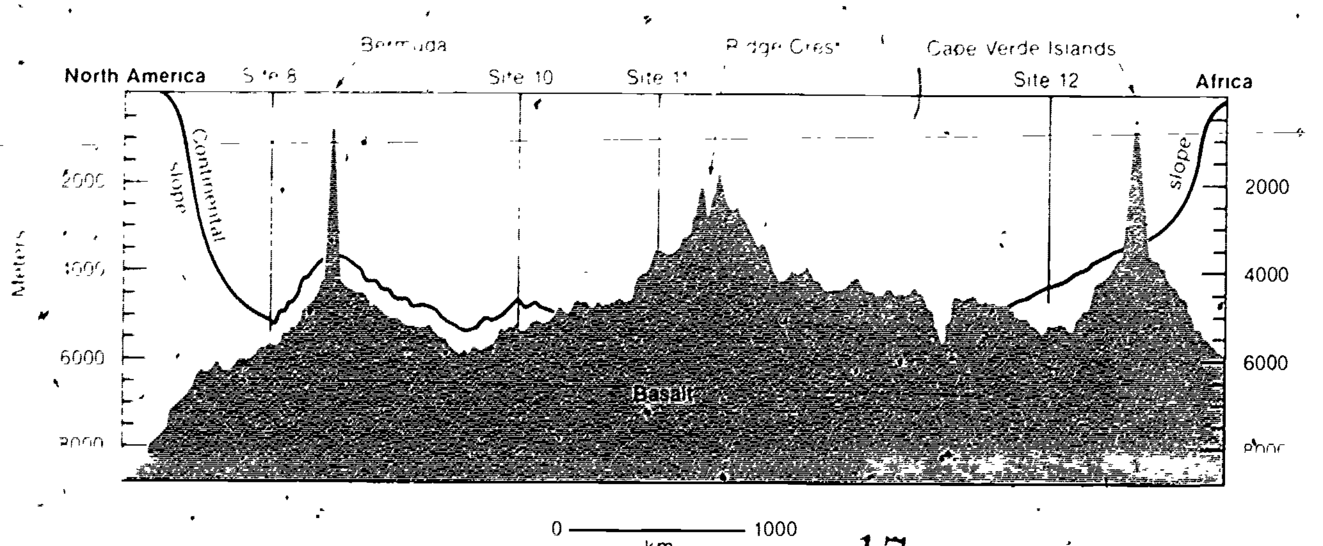


Figure 2 Topography of the Atlantic Ocean basin along the path of Leg 2. Vertical scale is greatly exaggerated (Adapted from Volume II, Initial Reports of the Deep Sea Drilling Project.)

6. What must happen to the age of the basaltic ocean crust from west to east (sites 8 to 11)? How can you explain the differences in ages?

The crust becomes younger. Students can infer this by applying the principle of superposition. That is, the bottom-most sediments become progressively younger toward the ridge, therefore it is likely that the crust also becomes younger toward the ridge. New basalt is rising at the ridges. As a result, the older basalt is pushed away on both sides of the ridge. Thus, the closer to the ridge, the younger the basalt.

7. What are the relative ages of bottom sediments at sites 11 and 12? Are these ages consistent with your answers to 5 and 6?

At site 11, which is closer to the ridge, the bottom sediments above the basalt are Miocene in age; at site 12, farther from the ridge, sediments are older; Eocene age. This is consistent with the ideas in questions 5 and 6.

8. What happens to the depth of the ocean waters from site 8 to site 11? From site 11 to 12? How can you explain these differences in depth?

The depth of the water becomes less as the ridge is approached from either side. Since basalt is rising at the ridge, it is warmer and less dense there than it is farther away from the ridge. Being less dense, it floats higher in the mantle, and thus the ocean in that area is shallower. This idea should be discussed with your class. It is unlikely that students will be able to answer this question, just from the information provided in the student activity. They will probably need some idea of isostasy.

9. Why should the sediment on both sides of the ridge be of similar age and represent similar depth of water?

Sea-floor spreading is occurring at a uniform rate on both sides of the ridge. Therefore, bottom-most sediments at a given distance on both sides will be the same age. Since the cooling rate and the increased density of basaltic crust will be uniform on both sides, so will the depth.

10. Are your observations in this activity consistent with the predictions you made in questions 1 through 3 in the INTRODUCTION?

The answer should be yes.

In the early 1960s, a scientist by the name of Harry Hess proposed an idea to explain how the ocean crust might form. He suggested that new crust was coming to the surface at the Mid-Atlantic Ridge, and that the older crust was being pushed away. As a result, the ocean basin was spreading away in both directions from the ridge. In other words, the basaltic ocean crust is older in both directions away from the ridge. The Deep Sea Drilling Project data used in this activity supports Hess's theory of **sea-floor spreading.**

SUMMARY QUESTIONS

1. What types of data has the Deep Sea Drilling Project recovered from the ocean floor?

Cores containing sediment and fossils; ocean depth measurements.

2. Why can the ranges of fossils be used to determine the age of a layer of sediment?

Certain fossils known as index fossils represent organisms that lived for brief periods of time. The sediments containing these fossils must have been deposited at the time that the organisms were alive.

3. How is it possible to correlate layers of sediment in one core with those in another?

The ages of sediments in a core can be determined by using index fossils. Layers of the same age in different cores can then be correlated.

4. How do the ages of the oldest sediment in cores from the Mid-Atlantic Ridge compare to those taken near Bermuda?

Younger

The Cape Verde Islands?

Younger

18

EXTENSIONS

What is the carbonate compensation depth?

The carbonate compensation depth is an important idea to geologists attempting to interpret information from deep sea cores. The carbonate compensation depth is the level at which temperature and pressure are such that all calcium carbonate is in solution. Below this depth, you would not expect calcareous muds (future limestones) to be deposited. Instead, only siliceous oozes would be found since silica is less soluble than calcium carbonate. You might want to introduce this portion of the activity by discussing what is meant by solubility, especially the solubility of gases, since it is carbon dioxide that determines the solubility of calcium carbonate.

Many microscopic plants and animals live in the ocean's surface waters When they die, their shells sink to the bottom of the ocean Because they are so small, it takes a very long time for them to reach the bottom These shells dissolve in sea water, and carbonate shells are more likely to dissolve than those made of silica The longer it takes for a carbonate shell to reach the bottom, the more likely it is to be totally dissolved In very deep water, carbonate shells are not preserved, only the silica shells are left They form a *siliceous ooze* on the bottom The depth at which little carbonate is preserved in the sediment is called the *carbonate compensation depth* This depth varies primarily with temperature of the water The colder the water the sooner carbonate will be dissolved and, therefore, the shallower the carbonate compensation depth Generally, the carbonate compensation depth will be at about the same depth everywhere at a given latitude.

The cores you have studied were obtained between latitudes 20° and 30° North The youngest sediments in these cores are Pleistocene We can assume that they were deposited under conditions similar to those of today. These sediments will therefore indicate the present level of the carbonate compensation depth. It should be the same for each of the areas represented by the cores.

1. Using Figure 2, determine the depth of the water at the **top** of each core taken at each site.

Site 8 **5250m**
Site 10 **4750m**
Site 11 **3500m**
Site 12 **4250m**

2. Using the Core Diagrams (Worksheet 5) and the Key to Geologic Ages, Sediments and Rocks (Worksheet 3), determine whether the fossils found at the **top** of each core are silica or carbonate.

Site 8 **silica**
Site 10 **carbonate**
Site 11 **carbonate**
Site 12 **carbonate**

3. Using Figure 2, determine the level of the carbonate compensation depth for this part of the Atlantic

About 5000 meters.

(Hint. the foraminiferal ooze is composed of carbonate sediment; the siliceous ooze and the chert are composed of silica)

By holding a ruler horizontally across Figure 2, the students should be able to estimate the depth at which these sediments were deposited. They lie at about the 5000 meter depth and slightly below the bottom of the core at site 12. Therefore, the carbonate compensation depth must be at about 5000 meters.

Most geologists believe that the basalt making up old crust is cooler and therefore more dense than that of relatively new crust If this is true, old crust should lie at a lower elevation in the ocean basins than new crust Therefore the ocean should be deeper over the old crust

4. Should the crust under site 8 be younger or older than that below site 11? What two lines of evidence support your conclusion?

The crust below site 8 should be older than that below site 11. No carbonates occur at site 8, so the ocean crust here must lie at a deeper level. Also Figure 2 shows the ocean is much deeper over site 8 than site 11.

5. The core at site 8 did not reach the basalt. If it had, what type of sediment (carbonate or silicate) would you expect to find resting on the basalt? Why?

The crust below site 8 must have been higher when it was relatively young, as is the crust below site 11. Therefore, at one time it would have been above the carbonate compensation depth, so you would expect to find some carbonate sediment in the oldest sediments.

REFERENCES

Matthews, S W., 1976, What's happening to our climate?. *National Geographic*, v. 150, no. 5 (Nov.), p. 576-615.

Peters, M.N.A , and others, 1970, *Initial reports of the Deep Sea Drilling Project*, v. II, Washington, D.C., National Science Foundation, U.S. Government Printing Office, 501 p.

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. OHS 4-6
0-89873-036-4

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CRUSTAL EVOLUTION EDUCATION PROJECT

NAME DATE

Student Investigation
Catalog No 34W1120

Microfossils, Sediments And Sea-floor Spreading

INTRODUCTION

Until the last 20 years or so, very little was known about the ocean basins, their topography, sediments, or how they were formed Even now we know less about the ocean basins than we know about the surface of the moon Much has been learned recently as the result of a program called the Deep Sea Drilling Project The first cruises of its research ship, the *Glomar Challenger*, to collect ocean basin data, were made in 1968 This project has provided much valuable data and material, including core samples of sea-floor sediment

The section of a cruise between two places is called a **leg.** In these activities, you will be using data from Leg 2 of the Deep Sea Drilling Project This leg is between New York and Dakar, Senegal (see Figure 1). On this cruise, the *Glomar Challenger* drilled into sea-bottom sediments at five different locations. These are labeled 8, 9, 10, 11 and 12 on Figure 1. You will use information from sites 8, 10, 11 and 12, only It has been changed somewhat from the original data This is necessary because the original data, although very detailed are incomplete in some cases

If you have already studied the theory of sea-floor spreading, try to answer the following questions. When you have finished, your teacher will discuss them with you. If you have not studied this theory, skip the questions and go on to PART A of this module.

If the theory of sea-floor spreading is correct, what information would you expect to find from Leg 2 concerning each of the following?

1. The cores at locations 10 and 11 (Figure 1) reached the basalt of the oceanic crust Which core has the oldest sediment?

2. How should the total thickness of the sediments on the ocean floor change under the *Glomar Challenger*, as the ship moved from the continental slope off North America to the axis, or crest, of the Mid-Atlantic Ridge?

3. What changes in depth to the sea bottom should you expect beneath the *Glomar Challenger* as it moved from site 8 to a point above the ridge axis?

22

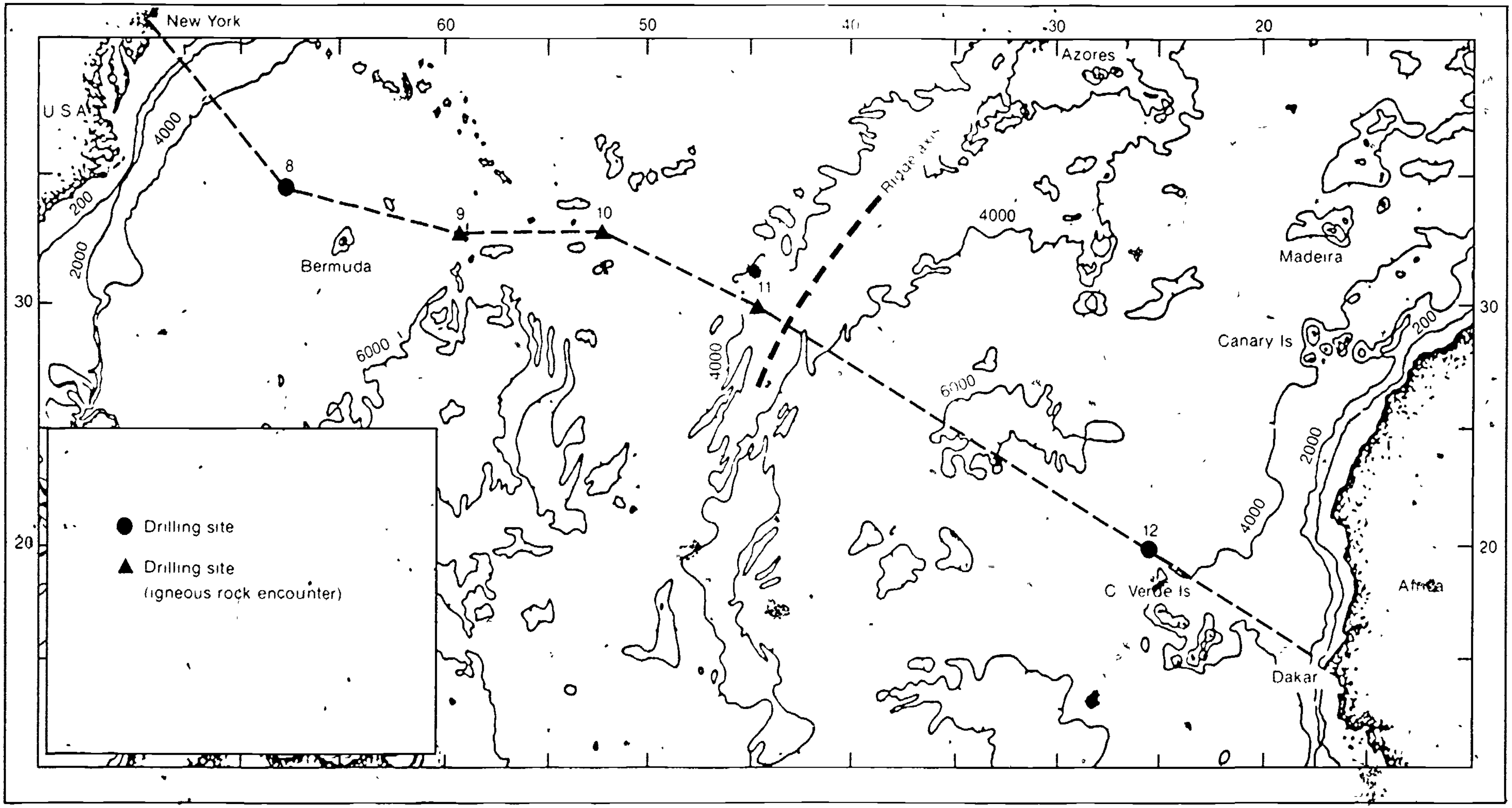


Figure 1 Map of the North Atlantic Ocean showing the sites drilled on Leg 2 Depth contours are in meters The line from New York to Dakar represents the path taken by the *Glomar Challenger.* (Adapted from Volume II, Initial Reports of the Deep Sea Drilling Project.)

OBJECTIVES

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

1. Describe the kinds of data obtained by the Deep Sea Drilling Project.
2. Determine the relative ages of sediment layers by using fossils and the principle of superposition.
3. Correlate the layers represented in the Core Diagrams.
4. Relate the age of ocean crust to sea-floor spreading.

PROCEDURE

PART A. How are the relative ages of sediments in a core determined?

Materials Worksheets 1, 2, 3, 4, and 5; rulers, pencils and colored pencils

Sediments are deposited in layers The **principle of superposition** states that when those layers remain undisturbed, the layer on the bottom was deposited first and is the oldest. The youngest is on top.

1. Find your set of Core Diagrams (Worksheet 5) Look at the diagram of the core from site 8. There are letters at several places on the diagram List the letters in a column here, according to the ages of the sediments they mark. Write "youngest" beside the top letter and "oldest" beside the bottom letter.

The principle of superposition allows us to determine the youngest and oldest sediment within a single core. How can you relate the age of a layer of sediment in one core to a layer in another core from a different location? A scientist working on the Deep Sea Drilling Project must do this to work out the history of the ocean basins. Many sediments contain fossils. Some of these are microscopic shells of tiny plants and animals that lived in the surface waters of the ocean. When these organisms die, they fall to the ocean floor and become part of the sediments.

Some **species** of plants or animals lived throughout wide areas during a relatively short period of geologic time. Their fossils are called **index fossils.** Many individuals of a species drifted far and wide across the ocean Their fossil shells are found in a layer of sediment deposited over a large area of the ocean floor at the time that the species existed When cores are taken from this layer of sediment at different locations, the same species of fossils may be found in several of the cores The sediments in which the fossils are found can then be matched between cores. The fossils must be a part of the sediment deposited at the same time in each of the areas where the cores were taken.

2. Examine the Reference Collection of Fossils (Worksheet 1) These pictures are of fossils from the groups called Foraminifera and Radiolaria Instead of the actual species names of these organisms, each is labeled with an identification letter The **range** (the portion of geologic time during which a fossil lived) is given for each fossil (for example, Middle Paleocene to Late Oligocene for species E) Plot the range of each species on the Range Chart of Fossil Species (Worksheet 4). The range of species E has already been plotted. Have your teacher check your graph when you finish

3. Does any species represent a single time period (for example, Miocene) or only part of a time period? List these along with the part of geologic time in which they are found. These species are index fossils.

4. Using Fossils Found in Cores (Worksheet 2) identify each fossil as follows: The numbers on the fossils correspond to the layer in which they occur in the core. For example, fossil 1 was found near the top of the core from site 8. Fossil 2 was found in the layer immediately below it. To identify each of these fossils, compare them with the picture of each species in your Reference Collection of Fossils (Worksheet 1). Record the letter labeling the species in the space provided on the Core Diagrams. For example, fossil 1 would be identified as "A", fossil 2 as "I", etc.

5. Look at the first section (Worksheet 5), site 8. It contains fossils A, I and O Using your Range-Chart of Fossil Species (Worksheet 4), find the one geologic age when all these organisms lived at the same time You should find this to be Pleistocene Write **Pleistocene** on the line above **Age** on the core diagram. Now determine the ages of the other core diagrams at each site in the same manner

6. Which fossils did you find most useful?

7. What do we call such fossils?

8. Find the Key to Geologic Ages, Sediments and Rocks (Worksheet 3). Color the small squares next to each geologic age with a different color. Next, color each section of the core diagrams (Worksheet 5) to match the color of the geologic ages in your key.

9. Notice that some sediments lack fossils, so you cannot be certain of their ages. Use the principle of superposition to estimate the ages of these sediments. Indicate on the cores the ages that you have determined by drawing diagonal lines of the appropriate color in each section of the core diagram.

You have now used index fossils to determine the ages of sediments in cores in the same / that scientists do. These core diagrams will) be used in PART B of this activity.

PROCEDURE

PART B. How do the ages of sediments differ from core to core?

Materials: Worksheets 3 and 5, rulers and pencils.

1. Using Worksheet 5 that you filled in for PART A, correlate by drawing lines between cores, marking the time boundaries from one core to the next. For example, connect the line in each core that represents the boundary between the Miocene and Pliocene. Have your teacher check your diagrams before you continue.

For the remainder of these questions, refer to the Core Diagrams (Worksheet 5), the Key to Geologic Ages, Sediments and Rocks (Worksheet 3); the map (Figure 1), and the chart showing the topography of the Atlantic Ocean Basin (Figure 2)

2. At which sites did the *Glomar Challenger* drill through sediment to igneous rock?

The igneous rock at these sites is basalt and probably is oceanic crust.

3. Which of the sites is closest to the ridge axis?

Which is closest to the North American continental shelf?

4. If the core at site 8 had been drilled deeper, would the deeper sediments be older or younger than those from the bottom of the core?

5. Keeping your last answer in mind, do the deepest sediments of sites 8 through 11 become younger or older as you move from the bottom of the continental margin to the ridge?

6. What must happen to the age of the basaltic ocean crust from west to east (sites 8 to 11)? How can you explain the differences in ages?

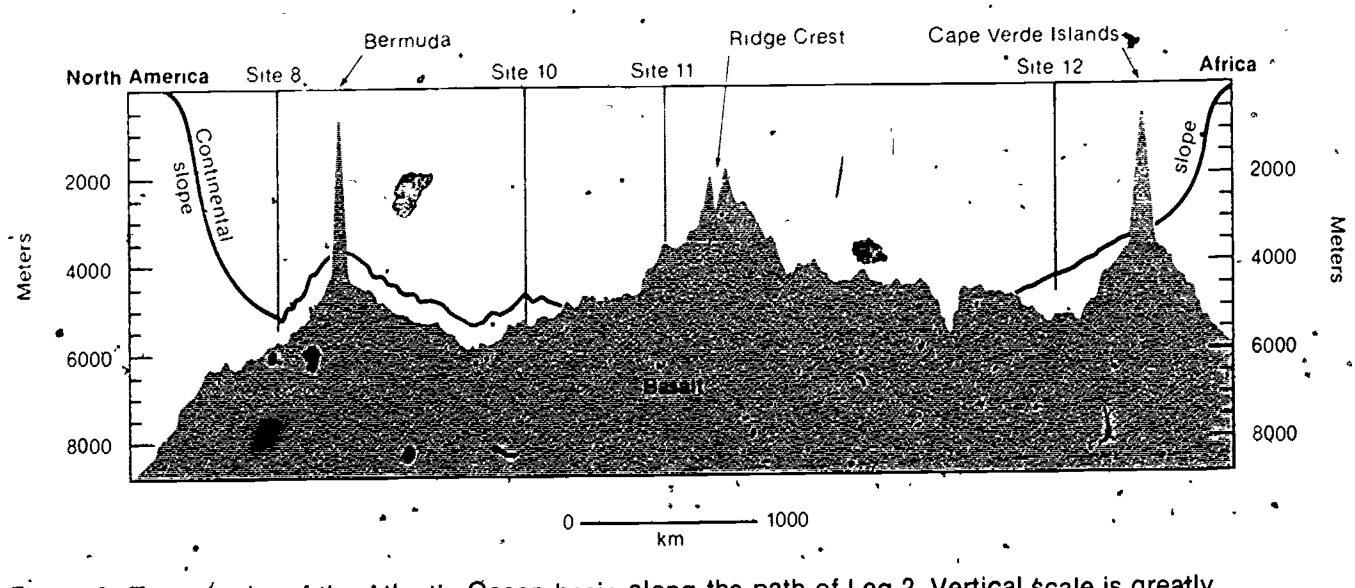
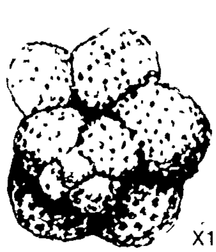
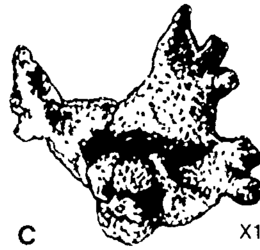


Figure 2. Topography of the Atlantic Ocean basin along the path of Leg 2. Vertical scale is greatly exaggerated. (Adapted from Volume II, Initial Reports of the Deep Sea Drilling Project.)

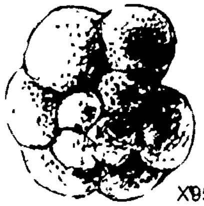
Reference Collection of Fossils—Foraminifera

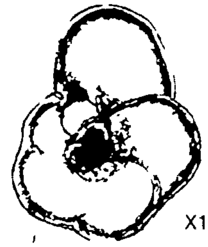

B X130
Cretaceous

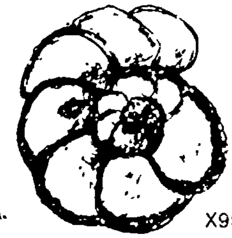

J X150
Early Oligocene—Middle Miocene


C X130
Paleocene


D X95
Pliocene

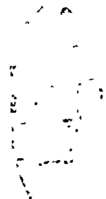

L X95
Miocene

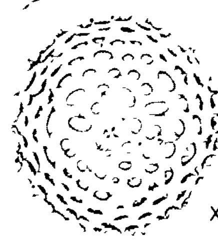

M X150
Early Pliocene—Middle Pleistocene

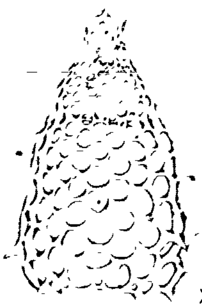

P X95
Pleistocene

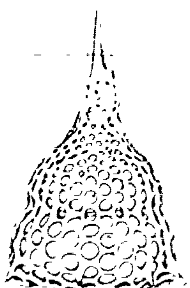
Reference Collection of Fossils—Radiolaria

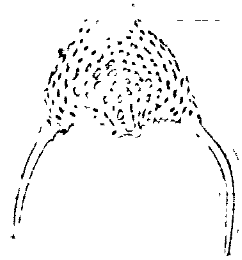

A X300
Cretaceous-Pleistocene

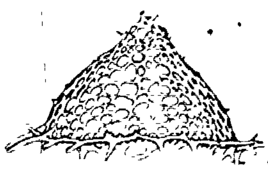

G X250
Oligocene

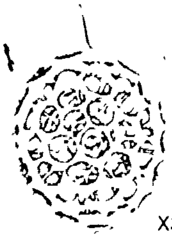

E X350
Middle Paleocene—Late Oligocene

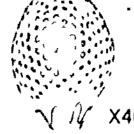

F X500
Early Oligocene—Middle Pliocene


H X450
Eocene


I X375
Eocene-Recent


K X500
Eocene-Miocene


O X375
Pleistocene


N X400
Pliocene

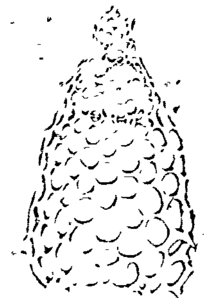
Fossils Found in Cores


1 ______


2 ______


3 ______


4 ______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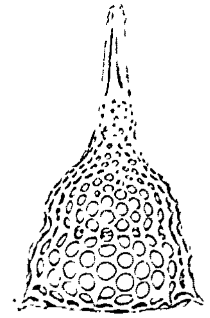
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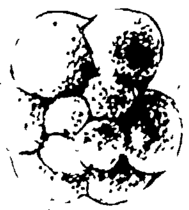
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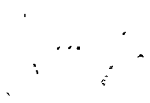
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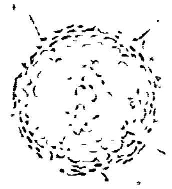
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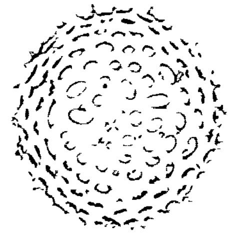
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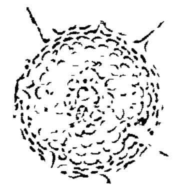
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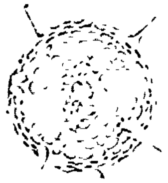
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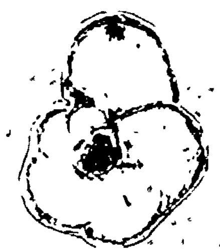
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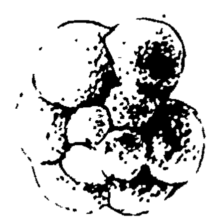
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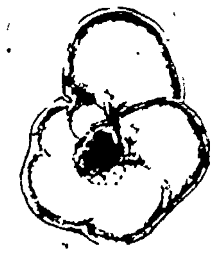
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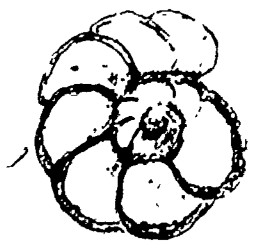
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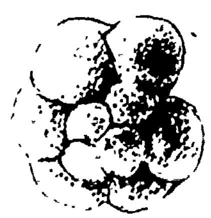
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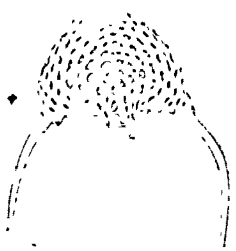
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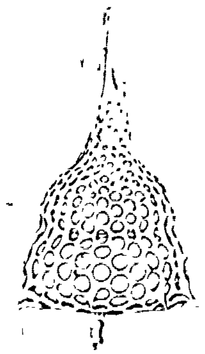
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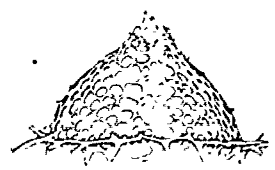
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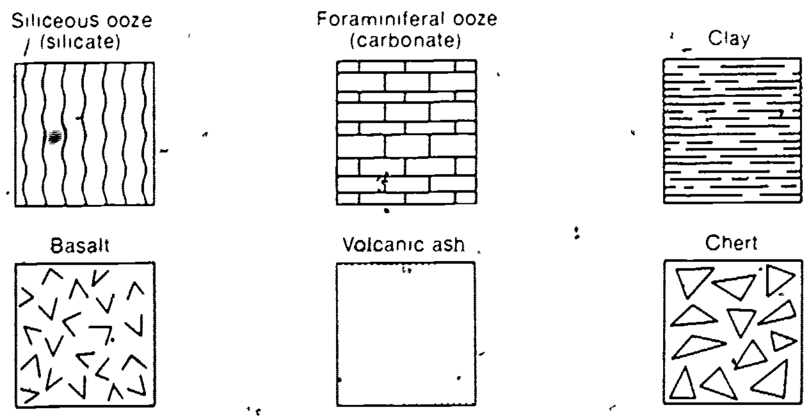
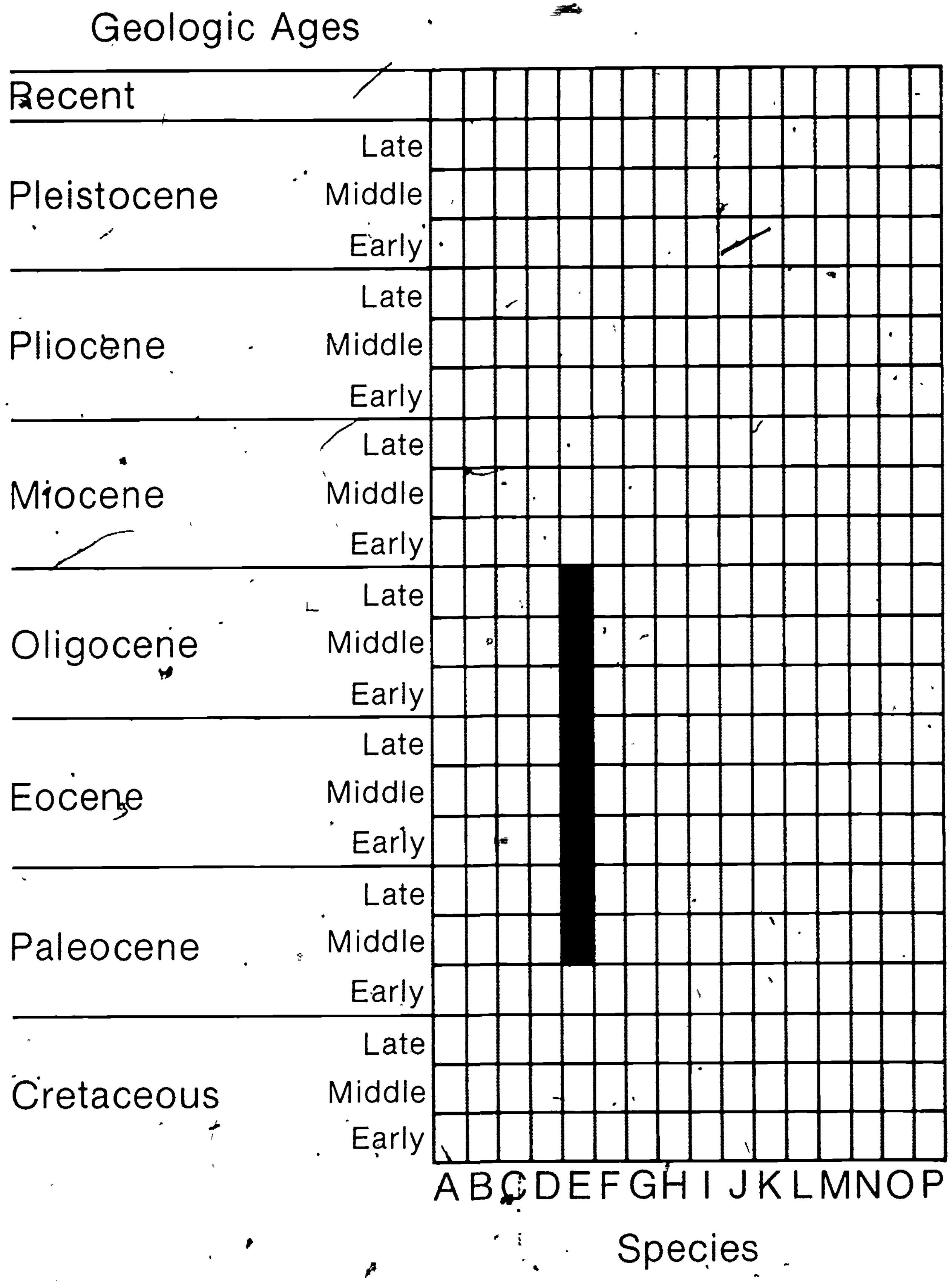
Key to Geologic Ages, Sediments and Rocks

Geologic ages	Color key
Recent—Pleistocene	
Pliocene	
Miocene	
Oligocene	
Eocene	
Paleocene	
Cretaceous	

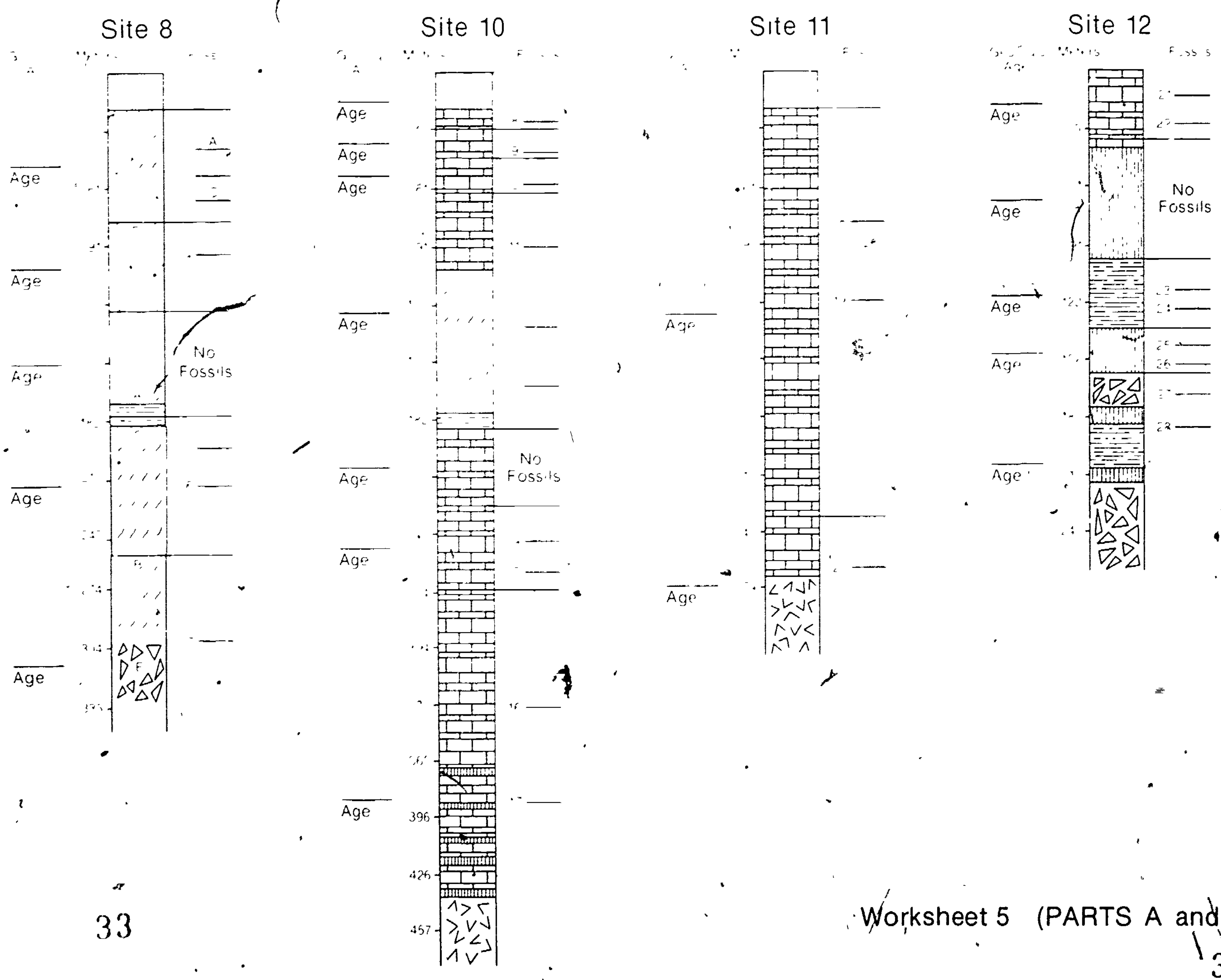
Sediments And Rocks



Range Chart of Fossil Species



Core Diagrams



Worksheet 5 (PARTS A and B)

7. What are the relative ages of bottom sediments at sites 11 and 12? Are these ages consistent with your answers to 5 and 6?

8. What happens to the depth of the ocean waters from site 8 to site 11? From site 11 to 12? How can you explain these differences in depth?

9. Why should the sediment on both sides of the ridge be of similar age and represent similar depth of water?

10. Are your observations in this activity consistent with the predictions you made in questions 1 through 3 in the INTRODUCTION?

In the early 1960s, a scientist by the name of Harry Hess proposed an idea to explain how the ocean crust might form. He suggested that new crust was coming to the surface at the Mid-Atlantic Ridge, and that the older crust was being pushed away. As a result, the ocean basin was spreading away in both directions from the ridge. In other words, the basaltic ocean crust is older in both directions away from the ridge. The Deep Sea Drilling Project data used in this activity supports Hess's theory of **sea-floor spreading.**

SUMMARY QUESTIONS

1. What types of data has the Deep Sea Drilling Project recovered from the ocean floor?

2. Why can the ranges of fossils be used to determine the age of a layer of sediment?

3. How is it possible to correlate layers of sediment in one core with those in another?

4. How do the ages of the oldest sediment in cores from the Mid-Atlantic Ridge compare to those taken near Bermuda?

The Cape Verde Islands?

EXTENSIONS

What is the carbonate compensation depth?

Many microscopic plants and animals live in the ocean's surface waters. When they die, their shells sink to the bottom of the ocean. Because they are so small, it takes a very long time for them to reach the bottom. These shells dissolve in sea water, and carbonate shells are more likely to dissolve than those made of silica. The longer it takes for a carbonate shell to reach the bottom, the more likely it is to be totally dissolved. In very deep water, carbonate shells are not preserved; only the silica shells are left. They form a *siliceous ooze* on the bottom. The depth at which little carbonate is preserved in the sediment is called the *carbonate compensation depth.* This depth varies primarily with temperature of the water. The colder the water the sooner carbonate will be dissolved and, therefore, the shallower the carbonate compensation depth. Generally, the carbonate compensation depth will be at about the same depth everywhere at a given latitude.

The cores you have studied were obtained between latitudes 20° and 30° North. The youngest sediments in these cores are Pleistocene. We can assume that they were deposited under conditions similar to those of today. These sediments will therefore indicate the present level of the carbonate compensation depth. It should be the same for each of the areas represented by the cores.

1. Using Figure 2, determine the depth of the water at the **top** of each core taken at each site

Site 8 ______

Site 10 ______

Site 11 ______

Site 12 ______

2. Using the Core Diagrams (Worksheet 5) and the Key to Geologic Ages, Sediments and Rocks (Worksheet 3), determine whether the fossils found at the **top** of each core are silica or carbonate.

Site 8 ______

Site 10 ______

Site 11 ______

Site 12 ______

3. Using Figure 2, determine the level of the carbonate compensation depth for this part of the Atlantic.

(Hint. the foraminiferal ooze is composed of carbonate sediment, the siliceous ooze and the chert are composed of silica.)

Most geologists believe that the basalt making up old crust is cooler and therefore more dense than that of relatively new crust. If this is true, old crust should lie at a lower elevation in the ocean basins than new crust. Therefore the ocean should be deeper over the old crust.

4. Should the crust under site 8 be younger or older than that below site 11? What two lines of evidence support your conclusion?

5. The core at site 8 did not reach the basalt. If it had, what type of sediment (carbonate or silicate) would you expect to find resting on the basalt? Why?

REFERENCE

Matthews, S.W., 1976, What's happening to our climate?. *National Geographic*, v. 150, no. 5 (Nov.), p. 576-615.