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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, recommending two-three 45-minute class periods required; (8) summary questions (with answers); (9) extension activities; and (10) list of references. Best used after concepts of continental drift, sea-floor spreading, and plate tectonics are introduced, students study rocks found in areas thought to be former portions of the proto-continent of Gondwanaland, learning what rocks reveal about the environment, correlating rock units using fossil evidence, using superposition principle to find relative ages of rock units, and describing evidence supporting theory that continents were once joined. (Author/JN)

NAGT Crustal Evolution Education Project

Edward C. Stoever, Jr., Project Director

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

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

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

About CEEP Modules...

Most CEEP modules consist of two booklets a Teacher's Guide and a Student Investigation The Teacher's Guide contains all the information and illustrations in the Student Investigation plus sections printed in color intended only for the teacher as well as answers to the questions that are included in the Student Investigation

In some modules there are illustrations that appear only in the Teacher's Guide and these are designated by figure letters instead of the number sequence used in the Student Investigation

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

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

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

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Fossils As Clues To Ancient Continents

INTRODUCTION

In 1915, German meteorologist Alfred Wegener based his theory of continental drift on evidence in rocks from several continents. The ancient climates indicated by the rocks were quite different from the climates that prevail in these present-day continents or countries. For example, evidence was found for glaciation in India during Permian time.

In these activities, students study rocks found in areas thought to be former portions of the proto-continent of Gondwanaland. They learn what rocks can reveal about the environment. By using fossil symbols, they correlate rock columns and find that environments during the Paleozoic and early Mesozoic were similar in four now widely separated areas. They learn how the distribution of certain fossils contributes to the concept of continental drift.

In the early 1900s, a famous English explorer, Captain Robert Scott, made a surprising discovery when exploring the cold and forbidding continent of Antarctica. Captain Scott describes the discovery in his diary in this entry for February 8, 1912.

> "We found ourselves under perpendicular cliffs of Beacon sandstone, weathering rapidly and carrying veritable coal seams From the last, Wilson, with his sharp eyes, has picked several plant impressions, the best a piece of coal with beautifully traced leaves in layers, also some excellently preserved impressions of thick stems, showing cellular structure "

This was written upon Scott's return from the South Pole The coal seams and plant fossils had been found at the base of Mount Bowers, at the head of the Beardmore Glacier

Geologists generally suppose that coal is formed in temperate or tropical regions How could it have formed in Antarctica, which is now almost entirely covered by glacial ice?

PREREQUISITE STUDENT BACKGROUND

This module is best used after the concepts of continental drift, sea-floor spreading and plate tectonics have been introduced. Students should be familiar with the major rock types, the geologic time scale and the principles of superposition and correlation. They should also be able to identify the continents on an outline map of the world. In introducing the activity, you should discuss *uniformitarianism* and its role in deciphering the earth's geologic history.

OBJECTIVES

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

1. Tell how rocks indicate the environment in which they were formed.
2. Use superposition to find the relative ages of rock units.
3. Use fossils to correlate rock units.
4. Describe evidence which supports the theory that certain continents were once joined.

MATERIALS

Colored pencils

Geologic time scale (such as found in your earth science text or reference books) and a political world map would be helpful.

Each student group should have a set of six rocks: basaltic lava, marine sandstone, fluvial sandstone, shale, tillite, and coal. The fluvial sandstone should be poorly sorted, relative to the marine sandstone. The tillite will be the most difficult to obtain. However, you could substitute the cemented till found in many places in the Midwest. Otherwise, a conglomerate with some angular grains can be used.

BACKGROUND INFORMATION

The data for the stratigraphic columns and the correlations provided in this teacher guide were generalized from the article cited below. The authors of the activity added data on *Lystrosaurus*. This information is highly generalized and simplified so that it will be more understandable to students. Despite this, students will be able to infer the same correlations agreed upon by the scientists.

Grindley, G.W., 1963, The geology of the Queen Alexandra Range, Beardmore Glacier, Ross Dependency, Antarctica; with notes on the correlation of Gondwana sequences. *New Zealand Journal of Geology and Geophysics*, v. 6, (June), p. 307-347.

SUGGESTED APPROACH

This activity is written in a step-by-step, individualized format. Many students can use it in an independent study situation. However, you can easily adapt it for total-class, laboratory-type teaching situations. The introductory questions, objectives, and the explanatory and summary information could be presented in pre-lab and post-lab group discussions. In either case, students can work in teams of two.

PROCEDURE

PART A: What can we learn from rocks about past environments?

Students learn about the past environments of four areas by studying the characteristics of their rocks. You should emphasize the principle of uniformitarianism (that we judge the past by the present.)

Key words: fluvial, marine, tillite

Time required: one 45-minute period

Materials: six different rocks

A geologist is a scientist who studies rocks to learn about the history of the earth. Your teacher will provide you with six rocks that have been identified and described by geologists.

1. Identify each of your rocks. You or your group will have one of each of the following:

Basaltic lava was formed from molten rock that erupted from volcanoes or from long cracks in the earth's crust. It is dark and so fine-grained that you will not be able to see individual grains. It may have round holes formed by gases released from the molten rock and then trapped in the lava as it hardened.

Marine sandstone was formed from sediments deposited in a sea or ocean. Usually it will contain only quartz grains. Individual grains will all be of about the same size. Any fossils it may contain usually will be of plants or animals that lived in salt water.

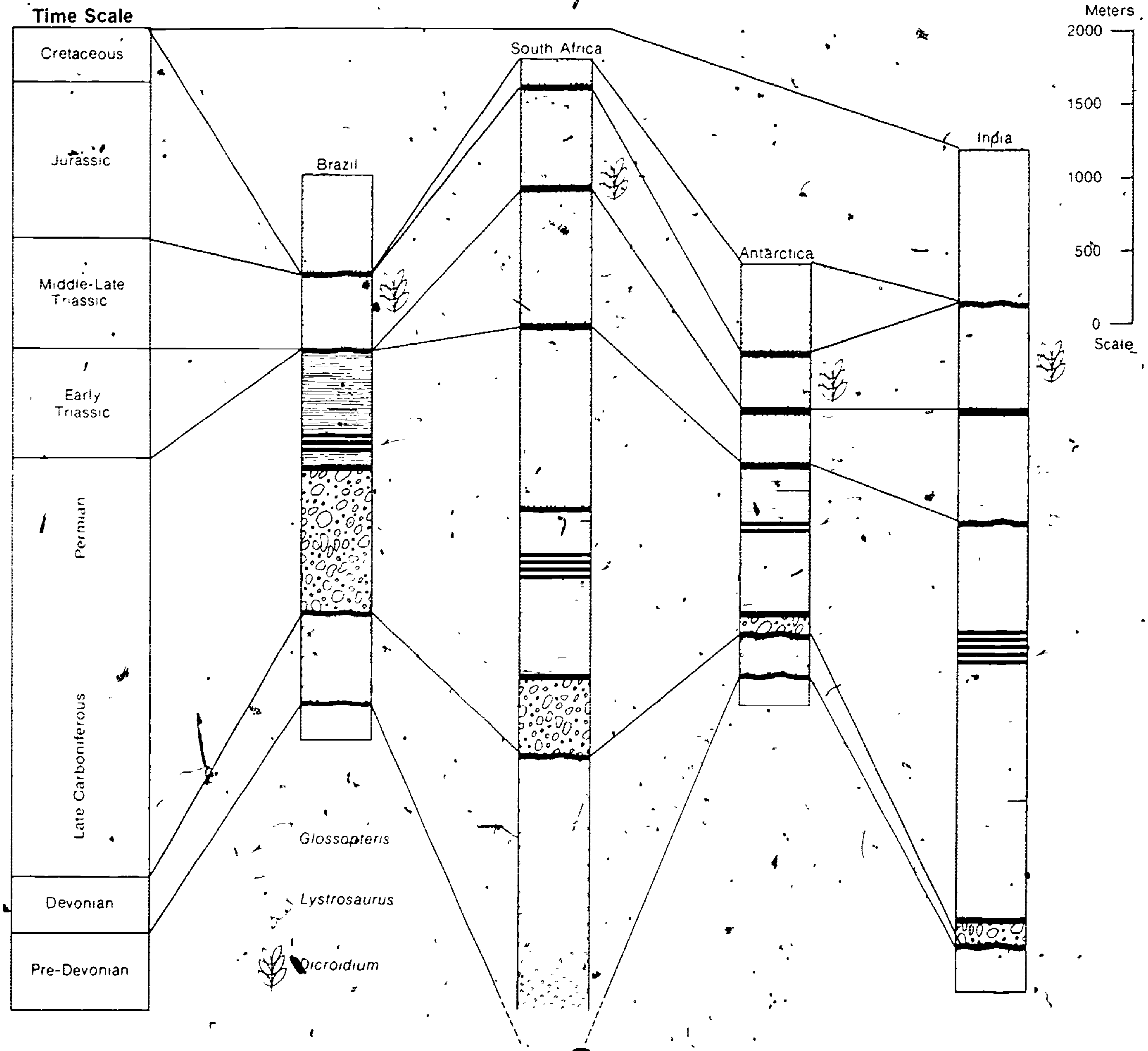
Fluvial sandstone was formed from sediments deposited in the bed of a stream. It may have minerals other than quartz, and the mineral grains will be of various sizes. If there are any fossils, they will be of plants or animals from on land or in fresh water.

Shale is a very fine-grained rock formed from clay or mud. It will show some layering.

Tillite is a rock formed from sediment deposited by a glacier. These rocks may have a wide variety of grain sizes and minerals. Many of the grains will be somewhat angular.

Coal is formed from the remains of trees and other plants that grew in swamps. Coal will be black, brittle, and not very hard. It may have fossilized leaves and plant stems.

Answer Sheet 1 (PARTS A and B)



2. After you have identified all six rocks, place each one on Worksheet 3 on the correct symbol representing that rock. **Have your teacher check your rock identification before you continue with the activity.** Notice that each of the symbols on Worksheet 3 is used in the rock column chart on Worksheet 1. Remember what each symbol means and also the kinds of conditions under which each type of sediment or rock material was deposited.

The purpose of this step is for students to become familiar with the symbols used for certain rock types on Worksheet 1 and with the idea that rocks can reveal to the geologist the environments in which they began to form.

3. Apply the principle of superposition to the South Africa rock column on Worksheet 1 Which rock layer is the oldest? marine sandstone Which layer is the youngest? basalt

4. What was the environment of Antarctica like when the marine sandstone sediment was being deposited?

Shallow seas must have covered Antarctica when the marine sandstone sediment was deposited.

What was the environment like when the coal material was being deposited?

Coal is generally thought to indicate a moist climate with the remains of luxuriant vegetation accumulating in swamps.

5. Does the present environment in Antarctica differ from either of those you describe in question 4 above? Yes If so, how does it differ?

Today Antarctica is cold, arid and largely covered by glaciers.

Could coal be forming in Antarctica today? **No**

6. Locate India on the world map. What type of climate do you think India has today?

You may need to discuss this with your students. Inform them that India has a climate that is warm throughout the year, with heavy rains during the monsoon season.

7. Now examine the rock column from India. Could rocks similar to those represented by the rock columns be forming in India today? **Yes** Which ones?

All of them could form, except tillite.

Could tillite be forming today in India?

The one rock that is definitely not forming in India today is tillite. Glaciers would be found only in the Himalayas. The rocks in this rock column were found farther south and over an extensive area. They imply that almost the entire country was covered by ice. A similar environment is not possible in India today because of its proximity to the equator.

8. You have observed that both India and Antarctica have rocks that were formed in environments that were much different from the environments in those two places today List as many explanations as you can, to account for this situation

The major idea that the students should understand now is that at another time the environments in both continents were quite different from today. Some students may suggest that the continents have moved in or out of polar regions to account for the widespread glaciation.

9. Examine the rock columns from all four areas. List each similar order of rock layers that you can find

All have tillite, shale, coal, fluvial sandstone and basalt in that order from bottom to top.

10. One similarity that you will have noticed is the presence of basalt at the top of each of the rock columns How is basalt formed?

Basalt is an igneous rock formed from magma. The basalts represented in these columns consist of lava flows.

11. Can you tell whether the basalt in each of the areas was formed at the same time? **No**. Explain

How about the coal? **No** Explain.

With the available information, students cannot determine if the basalts were formed at the same time or if the coals were formed at the same time. More information is needed. This point should be emphasized. Because similar rocks were formed in similar environments does not necessarily mean the rocks are the same age.

PROCEDURE

PART B: How old are the rocks?

Students date the rocks in the rock columns by using fossils. They then correlate the rock units and find that the four areas had similar environments at each time interval, up until the end of the Triassic Period, when the environments began to differ.

Key words: correlation, *Glossopteris*, *Lystrosaurus*, *Dicroidium*, radiometric dating, Gondwanaland

Time required: one 45-minute period

Materials colored pencils, political map of the world

You found out in step 11, PART A, that you really could not tell from the information provided, whether layers of similar rock types from different areas were formed at the same time. If you could find out the ages of these rocks, then you could determine whether the same environment existed in all four areas at the same time. You could also learn whether the environment changed in the same way in each of the four areas. This would certainly tell us something interesting about the history of the areas.

To determine the age of a sedimentary rock, we must find fossils. Certain fossil species are always the same age wherever they occur. All rocks containing these fossils are the same age even if found in different places and even if they are different kinds of rocks. Matching the ages of rocks is known as **correlation.**

The plant fossils found by Scott's expedition have been identified by geologists as ***Glossopteris.*** These plants have been found in coal seams in many places around the world. *Glossopteris* is of Permian age.

Figure 1. Leaf of the *Glossopteris* plant, which lived during the Permian age, 270 million years ago. (Redrawn from Hurley, P.M., 1968, Scientific American)

1. The rock columns are from four different areas. Antarctica, India, Brazil and South Africa. Write the names of these areas in their proper places on the outline map of the world (Worksheet 2).

See Answer Sheet 2

2. Color in each time period in the Time Scale, on the left edge of the rock columns chart (Worksheet 1), with a different color. (These six distinctive colors will then be used later to mark the same ages on the four rock columns.) Color in the beds containing the *Glossopteris* fossils with the color you used for Late Carboniferous or Permian on the Time Scale. Place a "G" on your world map (Worksheet 2) where *Glossopteris* has been found, next to the names of the four areas located in step 1.

See Answer Sheet 2

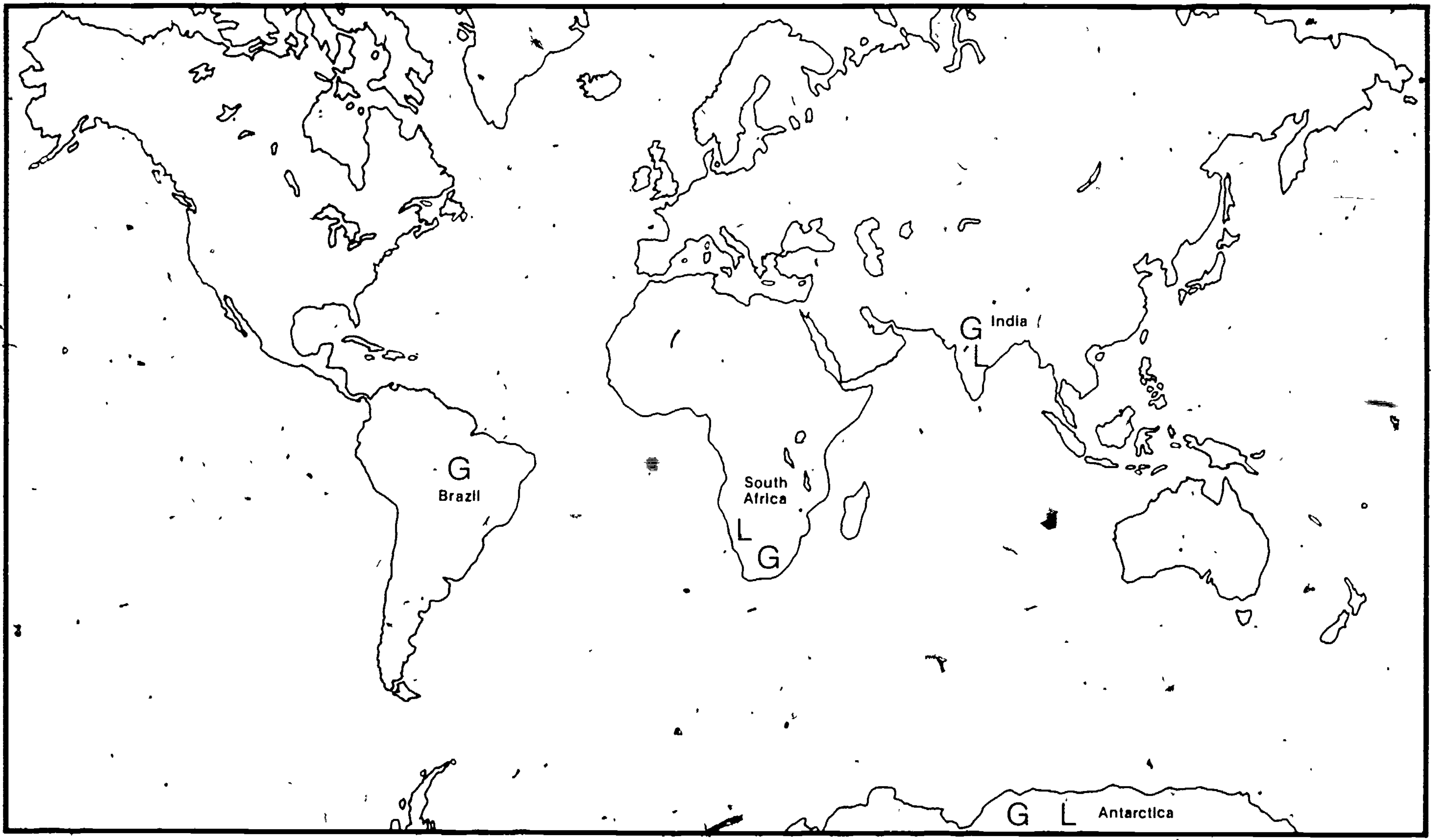
Have the students all use the same color code scheme.

3. How can you explain the presence of *Glossopteris* in four such widely separated areas?

Supporters of continental drift have used the presence of *Glossopteris* as evidence of the former contiguity of the four areas. They argue that the plant could not have migrated over such extensive areas of the ocean. Opponents, however, suggest that seeds could have been carried by ocean currents or maybe the wind. This type of migration accounts for the presence of the native flora and fauna of volcanic islands such as the Hawaiian Islands. You will need to help your students arrive at explanations for the presence of *Glossopteris*.

4. Fossilized pollen found in the tillites indicates that they are either Late Carboniferous or Early Permian. Color in the tillites with the color you used for that age in the Time Scale.

The students will be using the same color as in step 2. This is because the age ranges of the pollen and that of the *Glossopteris* overlap during Lower Permian. Therefore, for the purpose of this activity, they are "lumped" together.



Answer Sheet 2 (PART B)

In 1967, a geologist with the Ohio State University Institute of Polar Studies found a jaw fragment belonging to an ancient amphibian, not far from where Scott's party found the coal seams and the *Glossopteris* fossils. A team from the Institute of Polar Studies, encouraged by this find, returned to the same area in 1969 with a specialist in identifying fossil amphibians and reptiles. On the first day of the expedition, the team's leader, David Elliot, climbed a bluff near the base camp. He found an ancient stream channel containing bones and teeth. Edwin H. Colbert, the specialist in amphibian and reptile fossils, identified a jaw-bone he found there later as being that of ***Lystrosaurus***, a reptile previously found in India and South Africa in rocks of Early Triassic age. It was a land reptile, not adapted for swimming long distances.

5. In the rock columns, color those sediments containing *Lystrosaurus* with the color you used in the Time Scale indicating their age.

6. Place an "L" on Worksheet 2 beside the names of those areas where *Lystrosaurus* has been found. How can you explain the presence of a reptile, like *Lystrosaurus*, in such widely separated areas?

It is very difficult to argue that a land reptile, such as *Lystrosaurus*, could have migrated across the oceans to populate such widespread areas. When *Lystrosaurus* was found in Antarctica along with four other species of land reptiles, most paleontologists became convinced that continental drift was a viable theory.

7. Certain shells found in the marine sandstones of Brazil, South Africa and Antarctica have been determined to be of Devonian age. Color in these portions of the rock columns with the appropriate color. ***Dicroidium*** is a plant fossil restricted to the Late Triassic. Color in the portions of the rock columns containing *Dicroidium*.

The age of igneous rock, such as the basalt at the top of each of the rock columns, can be determined through a process called **radiometric dating.** In this procedure, the amounts of certain radioactive elements in the rock are measured.

8. The basalts in Brazil and India are of Cretaceous age. In South Africa and Antarctica they are from the Jurassic Period. Color the basalt in the rock columns with the colors you used for these ages in the Time Scale.

9. Now correlate the rock units for each area. Draw lines between the columns indicating the rock boundaries between each of the ages. The line dividing the "basement" rock (pre-Devonian) from the Devonian has already been drawn in for you. The Early Triassic layers of Brazil and South Africa have also been correlated. **Have your teacher check your correlations before you continue.**

It is essential that you check each of the correlations before students continue with the activity. You may want to collect and evaluate them. Hold a class discussion regarding how to correlate the rock columns correctly before allowing students to continue. See Answer Sheet 1. You could make an overhead transparency of Answer Sheet 1 to project during post-activity discussion.

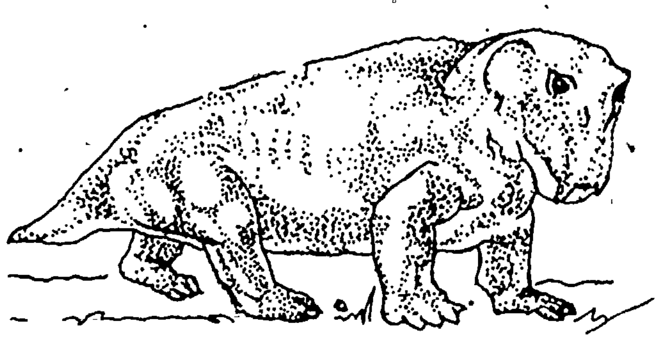


Figure 2. *Lystrosaurus* was a reptile that lived in India and South Africa during the Early Triassic age. (Redrawn with permission, courtesy of Edwin H. Colbert)

10. During what age were glaciers present in all four areas?

At the beginning of Late Carboniferous-Permian. Fossilized pollen indicates that glaciation ended in Early Permian.

11. When were three of the areas covered by the sea?

Brazil, South Africa and Antarctica were covered by the sea during the Devonian Period.

12. During what age did all four areas have extensive swamps?

Late Carboniferous-Permian. The presence of *Glossopteris* indicates a Permian age for the swamps.

13. How can you explain that in the past the environments of these four areas, as indicated by their rocks, were very similar when today their environments are so different?

Students should conclude that the evidence they have been studying suggests that these four areas were part of a single continent from at least Devonian through Jurassic.

In this activity you have studied some of the evidence that leads geologists to believe that at one time India, Antarctica, Africa, Australia and South America were all part of one supercontinent called **Gondwanaland.**

14. From your study of plant and animal fossils, determine the most recent time that Gondwanaland could have been a single continent

***Dicroidium* is present in all four areas in Middle to Late Triassic. Therefore, the continents were probably together through the Triassic.**

15. When did extensive volcanic activity first occur in Gondwanaland?

Lava flows occurred during the Jurassic Period in South Africa and Antarctica.

16. When do you think Gondwanaland began to break up?

Students might conclude that the extensive volcanic activity indicated by the basalt at the top of each column was caused by the breakup of Gondwanaland. If so, it must have started to break up during the Jurassic, with India and Brazil breaking loose in the Cretaceous. Hold a post-lab discussion emphasizing the meaning of the correlations that the students have completed. The major purpose of the activity is to present evidence of the former unity of the four areas. The information provided by the rocks and fossils is important evidence bearing upon plate tectonic theory.

SUMMARY QUESTIONS

1. How do geologists determine the type of environment that existed in an area during the past?

Geologists determine the environment of an area from the types of rocks and fossils that are found there.

2. A geologist found several layers of sediment exposed in a river bank. Which was the oldest layer? the youngest?

Using the principle of superposition, the geologist would determine that the lowest bed was the oldest and the highest bed was the youngest.

3. What is meant by correlation of rock layers?

Geologists can determine the age of a layer on the basis of its fossils or by radiometric dating. They then can match (correlate) layers in different areas where they contain fossils of the same age.

4. Describe the evidence for the former existence of the continent Gondwanaland.

Fossils and rocks found in the four different areas indicate that at one time the areas were joined together.

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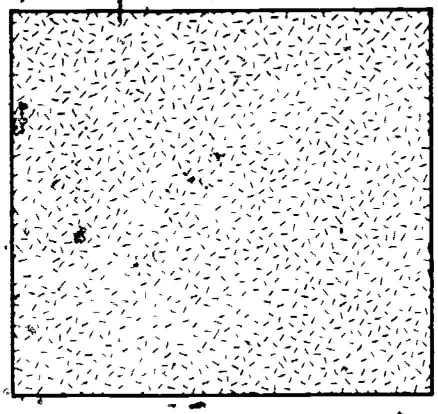
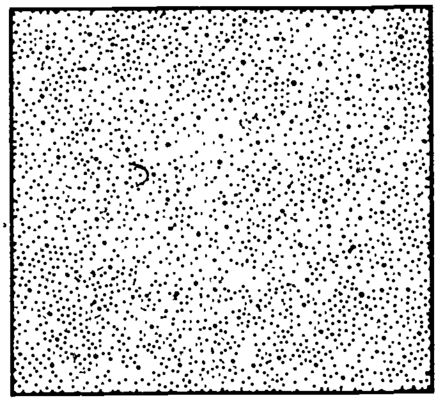
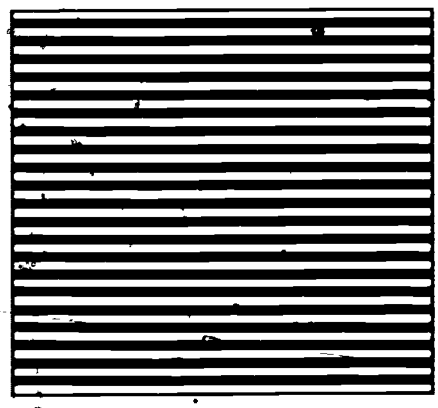
Lear, J., 1970, The bones of Coalsack Bluff. *Saturday Review,* v. 53, no 6 (Feb. 7), p. 47–51.



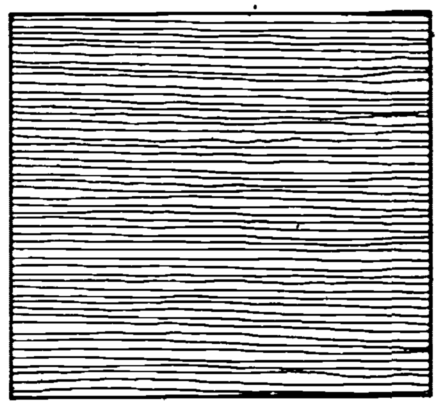
Basaltic lava



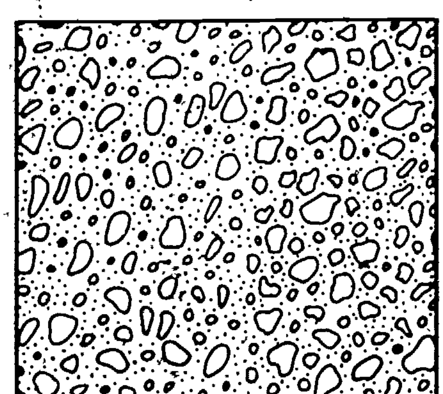
Fluvial sandstone



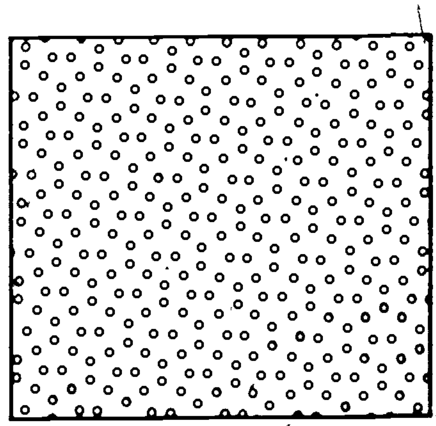
Coal seams



Shale



Tillite



Marine sandstone

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

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CRUSTAL EVOLUTION EDUCATION PROJECT

NAME DATE

Student Investigation
Catalog No 34W1108

Fossils As Clues To Ancient Continents

INTRODUCTION

In the early 1900s, a famous English explorer, Captain Robert Scott, made a surprising discovery when exploring the cold and forbidding continent of Antarctica Captain Scott describes the discovery in his diary in this entry for February 8, 1912

> "We found ourselves under perpendicular cliffs of Beacon sandstone, weathering rapidly and carrying veritable coal seams From the last, Wilson, with his sharp eyes, has picked several plant impressions, the best a piece of coal with beautifully traced leaves in layers, also some excellently preserved impressions of thick stems, showing cellular structure . ."

OBJECTIVES

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

1. Tell how rocks indicate the environment in which they were formed.
2. Use superposition to find the relative ages of rock units
3. Use fossils to correlate rock units.
4. Describe evidence which supports the theory that certain continents were once joined.

This was written upon Scott's return from the South Pole The coal seams and plant fossils had been found at the base of Mount Bowers, at the head of the Beardmore Glacier

Geologists generally suppose that coal is formed in temperate or tropical regions How could it have formed in Antarctica, which is now almost entirely covered by glacial ice?

SE 038 123

PROCEDURE

PART A What can we learn from rocks about past environments?

Materials. six different rocks

A geologist is a scientist who studies rocks to learn about the history of the earth Your teacher will provide you with six rocks that have been identified and described by geologists

1. Identify each of your rocks You or your group will have one of each of the following

Basaltic lava was formed from molten rock that erupted from volcanoes or from long cracks in the earth's crust It is dark and so fine-grained that you will not be able to see individual grains. It may have round holes formed by gases released from the molten rock and then trapped in the lava as it hardened.

Marine sandstone was formed from sediments deposited in a sea or ocean Usually it will contain only quartz grains Individual grains will all be of about the same size. Any fossils it may contain usually will be of plants or animals that lived in salt water

Fluvial sandstone was formed from sediments deposited in the bed of a stream It may have minerals other than quartz, and the mineral grains will be of various sizes If there are any fossils, they will be of plants or animals from on land or in fresh water

Shale is a very fine-grained rock formed from clay or mud. It will show some layering.

Tillite is a rock formed from sediment deposited by a glacier These rocks may have a wide variety of grain sizes and minerals Many of the grains will be somewhat angular

Coal is formed from the remains of trees and other plants that grew in swamps Coal will be black, brittle, and not very hard It may have fossilized leaves and plant stems.

2. After you have identified all six rocks, place each one on Worksheet 3 on the correct symbol representing that rock. **Have your teacher check your rock identification before you continue with the activity.** Notice that each of the symbols on Worksheet 3 is used in the rock column chart on Worksheet 1. Remember what each symbol means and also the kinds of conditions under which each type of sediment or rock material was deposited.

3. Apply the principle of superposition to the South Africa rock column on Worksheet 1 Which rock layer is the oldest? ________________

Which layer is the youngest? ________________

4. What was the environment of Antarctica like when the marine sandstone sediment was ~~being~~ deposited?

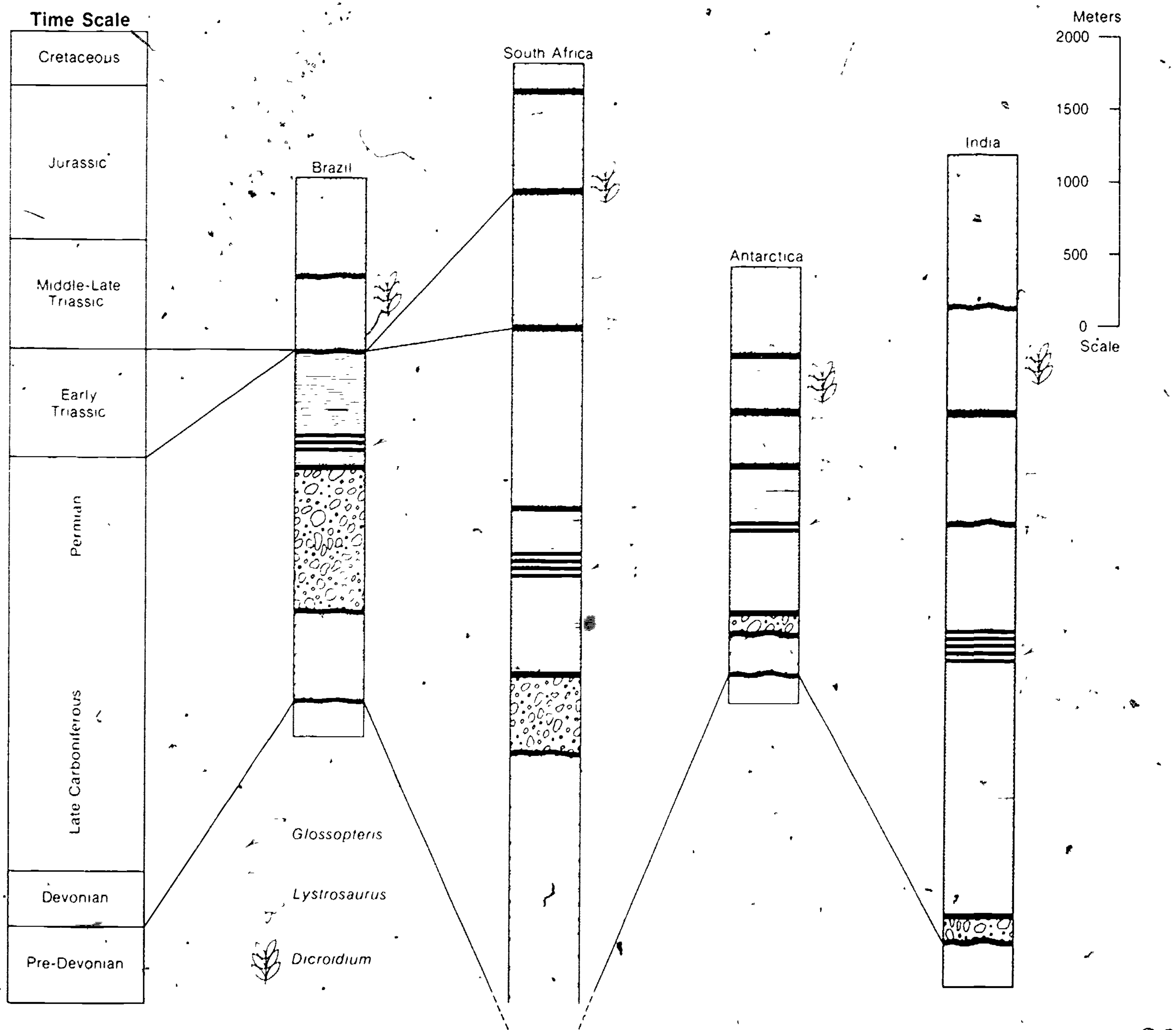
What was the environment like when the coal material was being deposited?

5. Does the present environment in Antarctica differ from either of those you describe in question 4 above? ____ If so, how does it differ?

Could coal be forming in Antarctica today? ____

6. Locate India on the world map What type of climate do you think India has today?

Worksheet 1 (PARTS A and B)



7. Now examine the rock column from India. Could rocks similar to those represented by the rock columns be forming in India today? ____ Which ones?

Could tillite be forming today in India?

8. You have observed that both India and Antarctica have rocks that were formed in environments that were much different from the environments in those two places today List as many explanations as you can, to account for this situation

9. Examine the rock columns from all four areas. List each similar order of rock layers that you can find.

10. One similarity that you will have noticed is the presence of basalt at the top of each of the rock columns How is basalt formed?

11. Can you tell whether the basalt in each of the areas was formed at the same time? ____ Explain.

How about the coal? ____ Explain

PROCEDURE

PART B. How old are the rocks?

Materials colored pencils, political map of the world

You found out in step 11, PART A, that you really could not tell from the information provided, whether layers of similar rock types from different areas were formed at the same time. If you could find out the ages of these rocks, then you could determine whether the same environment existed in all four areas at the same time You could also learn whether the environment changed in the same way in each of the four areas. This would certainly tell us something interesting about the history of the areas.

To determine the age of a sedimentary rock, we must find fossils Certain fossil species are always the same age wherever they occur. All rocks containing these fossils are the same age even if found in different places and even if they are different kinds of rocks. Matching the ages of rocks is known as **correlation.**

The plant fossils found by Scott's expedition have been identified by geologists as ***Glossopteris.*** These plants have been found in coal seams in many places around the world *Glossopteris* is of Permian age

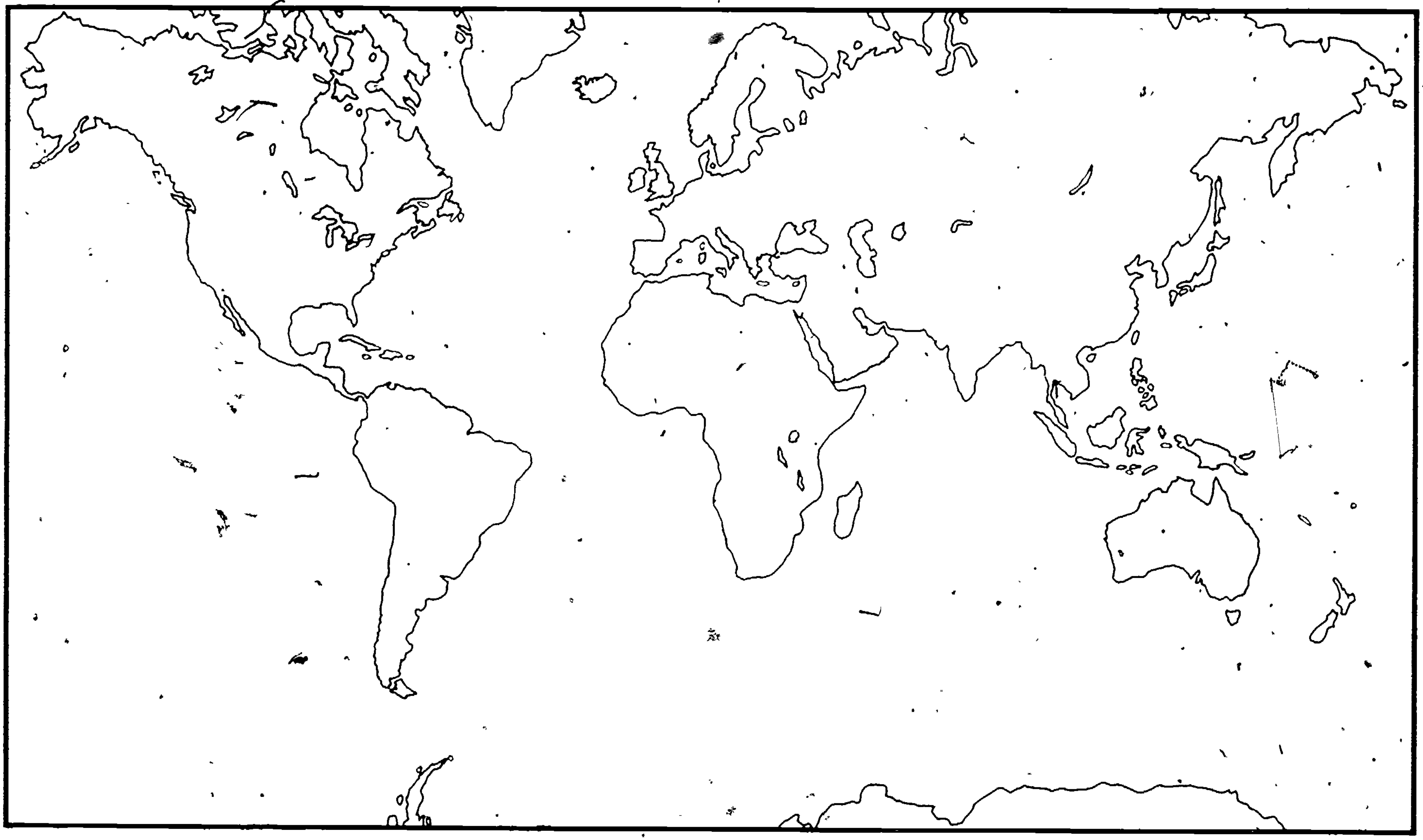
1. The rock columns are from four different areas Antarctica, India, Brazil and South Africa. Write the names of these areas in their proper places on the outline map of the world (Worksheet 2).

2. Color in each time period in the Time Scale, on the left edge of the rock columns chart (Worksheet 1), with a different color (These six distinctive colors will then be used later to mark the same ages on the four rock columns.) Color in the beds containing the *Glossopteris* fossils with the color you used for Late Carboniferous or Permian on the Time Scale. Place a "G" on your world map (Worksheet 2) where *Glossopteris* has been found, next to the names of the four areas located in step 1.

3. How can you explain the presence of *Glossopteris* in four such widely separated areas?

4. Fossilized pollen found in the tillites indicates that they are either Late Carboniferous or Early Permian Color in the tillites with the color you used for that age in the Time Scale

Figure 1. Leaf of the *Glossopteris* plant, which lived during the Permian age, 270 million years ago. (Redrawn from Hurley, P.M., 1968, Scientific American)



Worksheet 2 (PART B)

In 1967, a geologist with the Ohio State University Institute of Polar Studies found a jaw fragment belonging to an ancient amphibian, not far from where Scott's party found the coal seams and the *Glossopteris* fossils. A team from the Institute of Polar Studies, encouraged by this find, returned to the same area in 1969 with a specialist in identifying fossil amphibians and reptiles. On the first day of the expedition, the team's leader, David Elliot, climbed a bluff near the base camp. He found an ancient stream channel containing bones and teeth. Edwin H. Colbert, the specialist in amphibian and reptile fossils, identified a jaw-bone he found there later as being that of ***Lystrosaurus,*** a reptile previously found in India and South Africa in rocks of Early Triassic age. It was a land reptile, not adapted for swimming long distances.

5. In the rock columns, color those sediments containing *Lystrosaurus* with the color you used in the Time Scale indicating their age

6. Place an "L" on Worksheet 2 beside the names of those areas where *Lystrosaurus* has been found How can you explain the presence of a reptile, like *Lystrosaurus*, in such widely separated areas?

7. Certain shells found in the marine sandstones of Brazil, South Africa and Antarctica have been determined to be of Devonian age Color in these portions of the rock columns with the appropriate color ***Dicroidium*** is a plant fossil restricted to the Late Triassic. Color in the portions of the rock columns containing *Dicroidium*.

The age of igneous rock, such as the basalt at the top of each of the rock columns, can be determined through a process called **radiometric dating.** In this procedure, the amounts of certain radioactive elements in the rock are measured

8. The basalts in Brazil and India are of Cretaceous age. In South Africa and Antarctica they are from the Jurassic Period. Color the basalts in the rock columns with the colors you used for these ages in the Time Scale.

9. Now correlate the rock units for each area. Draw lines between the columns indicating the rock boundaries between each of the ages. The line dividing the "basement" rock (pre-Devonian) from the Devonian has already been drawn in for you The Early Triassic layers of Brazil and South Africa have also been correlated **Have your teacher check your correlations before you continue.**

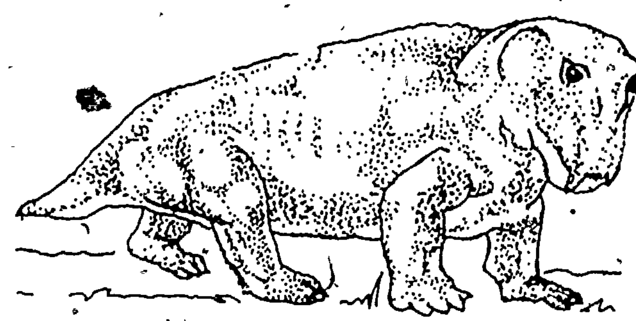


Figure 2. *Lystrosaurus* was a reptile that lived in India and South Africa during the Early Triassic age. (Redrawn with permission, courtesy of Edwin H. Colbert)

10. During what age were glaciers present in all four areas?

11. When were three of the areas covered by the sea?

12. During what age did all four areas have extensive swamps?

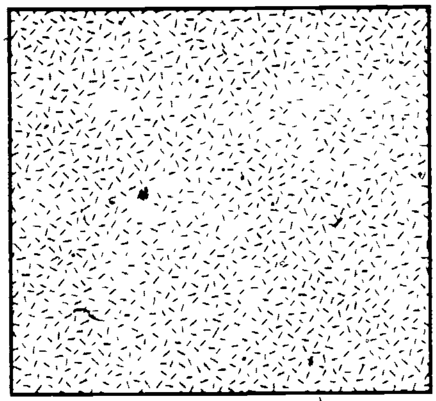
13. How can you explain that in the past the environments of these four areas, as indicated by their rocks, were very similar when today their environments are so different?

In this activity you have studied some of the evidence that leads geologists to believe that at one time India, Antarctica, Africa, Australia and South America were all part of one supercontinent called **Gondwanaland.**

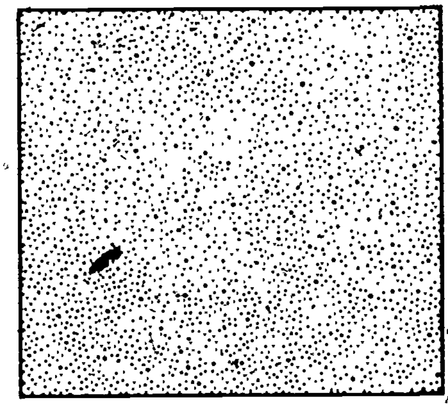
14. From your study of plant and animal fossils, determine the most recent time that Gondwanaland could have been a single continent.

15. When did extensive volcanic activity first occur in Gondwanaland?

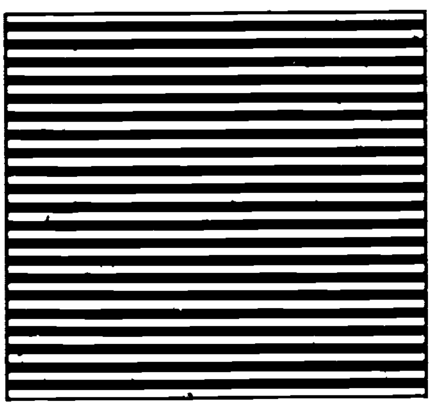
16. When do you think Gondwanaland began to break up?



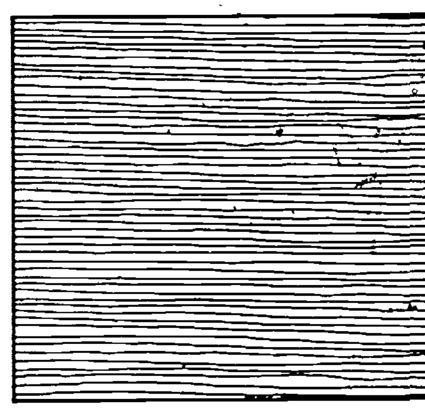
Basaltic lava



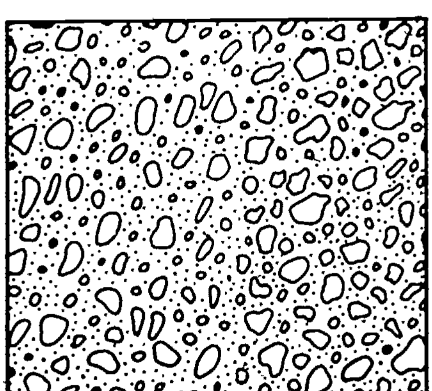
Fluvial sandstone



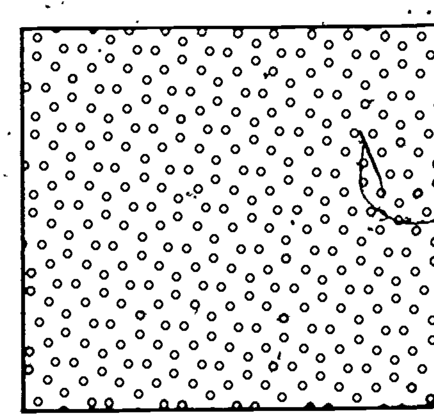
Coal seams



Shale



Tillite



Marine sandstone

SUMMARY QUESTIONS

1. How do geologists determine the type of environment that existed in an area during the past?

2. A geologist found several layers of sediment exposed in a river bank Which was the oldest layer? the youngest?

3. What is meant by correlation of rock layers?

4. Describe the evidence for the former existence of the continent Gondwanaland

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