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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, suggesting two 45-minute class periods; (8) summary questions (with answers); (9) extension activities; and (10) list of references. Two activities focus on fossil evidence supporting continental drift. Students describe how paleontologists reconstruct animals from small bits of fossil evidence found in Antarctica, list fossils making best climate indicators (and explain why), describe climatic conditions in Antarctica 200-million years ago, and explain possible location of Antarctica in Cretaceous time based on fossil locations from several continents and where paleontologists might look for new fossil evidence. (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

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Tropics In Antarctica?

INTRODUCTION

This activity presents fossil evidence supporting continental drift. The fossils of reptiles and amphibians found in Antarctica helped convince many scientists of continental drift. Most students are able to understand that amphibians and reptiles require a warm, moist, tropical climate in which to live. If amphibian and reptile fossils are found in Antarctica as well as other continents where the climate is cold, those places must have been in different locations and had a different climate than they do today.

Early expeditions found very little fossil evidence. However, in 1969 a bone fragment found near Beardmore Glacier, Antarctica, by Dr. Edwin H. Colbert, started an extended research effort dealing with fossil vertebrates. Comprehensive research in many fields is being conducted by the United States, Russia, New Zealand, Japan, Argentina, China, South Africa, Norway and France.

PREREQUISITE STUDENT BACKGROUND

Most students have the basic background in earth science and biology to be able to complete the activity. Knowledge of basic bone shapes, size relationships, climatic and food requirements for the five classes of vertebrates is desirable for a good class discussion. Basic knowledge of geography and plotting by latitude and longitude is beneficial.

OBJECTIVES

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

1. Describe how paleontologists reconstruct animals from small bits of fossil evidence found in Antarctica
2. List the fossils that make the best climatic indicators and explain why.
3. Describe the climatic conditions in Antarctica 200 million years ago
4. Explain the possible location of Antarctica in Cretaceous time, based on fossil locations from several continents.
5. Explain where paleontologists might look for new fossil evidence to support the theory of continental drift.

The early understanding of global tectonics was based upon physical evidence of the rocks and the shape of the continents But what about biological evidence? Complete remains of ancient animals are scarce Usually only bones, teeth and shells are preserved However, many inferences can be made from incomplete remains Many animals can be identified from very few or very small parts

If you were looking for biological evidence of the climate of Antarctica, what type of fossils would you look for? What evidence would convince you that climatic conditions were different in Antarctica 200 million years ago?

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MATERIALS

Map, *The Physical World*, National Geographic Society, Educational Services, Department 79, Washington, D.C. 20036—one for each classroom.

Bones from several skeletons—for class demonstration. Be sure to have several bones that students may recognize easily and some that they will not. Cow bones and chicken bones will be the easiest to obtain.

Colored pencils

BACKGROUND INFORMATION

Most of the early evidence for continental drift was geologically based. The need for supporting biological evidence was necessary before the continental drift theory could be accepted. Fossil evidence usually can only be found in sedimentary rocks, therefore, only certain locations are suitable for field work. Climatic and terrain conditions in Antarctica must have discouraged many early explorers.

More and more fossil evidence continues to be collected in South America, Africa and Antarctica. Fossils give some idea of what animals were like many years ago. Animals may be identified from very few or very small parts. Climate is especially important in determining what kinds of plants and animals are present at a particular location. Fossils help us make interpretations about the type of climate during the Triassic Period. Reptiles and amphibians are particularly sensitive to climatic conditions due to their inability to regulate body temperature internally. Similar rock series are found on all three continents, and the fossil assemblages are similar on all three continents. Some gaps do exist, but it is expected that these gaps will be filled after more field research has been done.

SUGGESTED APPROACH

In PART A show different animal bones to the students. The intent is to demonstrate that our knowledge of living animals is helpful in predicting the animal from which a single bone came. Also, help the students recognize that some animals (cold-blooded ones in particular) are useful for interpreting past climatic conditions. A meaningful pre-activity discussion will "make" this lesson.

In PART B the students work together or individually on a worksheet type of activity. For this section you must hold a post-activity discussion. In this discussion emphasize the answers to the SUMMARY QUESTIONS.

PROCEDURE

PART A. How can we identify fossils?

Students will identify bones and tell from which animal the bones came.

Key words: vertebrate, *Lystrosaurus*, extant

Time required: one 45-minute period

Materials: bones from several skeletons

The students will look at several bones one at a time and try to hypothesize from what animal they came and which bones of the skeletons they are. As students answer which bone it is, ask why they are giving the answers they do. For instance, "What are the characteristics of a neck bone, leg bone, etc?" They may say that the size or shape is familiar or "I've seen it before." Encourage students to have several hypotheses for the first few bones. After the last bone has been shown and all students recognize it, see if the students can hypothesize what part of the skeleton is represented in Figure 1 and why they think so.

1. Look at the bones your teacher displays and try to identify 1) the animal or animals they came from, and 2) what bones they are You may have more than one hypothesis.

EVIDENCE	HYPOTHESIS Animals based on.		
a. What bone? ________	first bone.	1.	________ ________
		2.	________
		3	________
b. What bone? ________	second bone.	1.	________
		2	________
		3	________
c What bone? ________	third bone.	1	________

2. What was the basis of your hypotheses?

When you see a fossil bone of a kind you know and have seen many times before, the identification is easy. This is how paleontologists recognize fossils in the field.

Figure 1 is a right maxilla with a tusk, representing a small animal. Most students recognize that the bone fragment is part of a skull. However, it takes some imagination and willingness on the part of the student to accept a poor fit in order to place the bone fragment in the correct position (see Figure 2). The bone fragment is not a perfect fit because we do not have a complete skull of *Lystrosaurus* from Antarctica. Therefore, we compare the fragment and the fit to a *Lystrosaurus* skull from South Africa.

To answer questions 3 through 8, the students will have to look at the skull closely to see that it has no teeth except the tusks. In answering questions 4, 5, and 6, the students will have to make guesses. However, by selected questioning you can turn their guesses into good hypotheses.

The skull looks too large and heavy to be a bird, therefore, it must be a reptile or amphibian. The most common modern reptile with no teeth, and a similar mouth, is a turtle. Although *Lystrosaurus* and turtles are both reptiles, they are not closely related reptiles. Students may suggest that the bone fragment is from a mammal. Point out that this fragment was found in rocks of Triassic age and mammals of this size didn't appear on earth until many millions of years later.

The choice of food should be made based on the skull with no teeth. The question for the use of the tusk may be raised at this point. Some elementary classification can be explained here showing there are five classes of vertebrates. The environmental requirements of the five classes should be discussed, as follows: fish only in water; amphibians in water and on land; reptiles on land and in water; birds on land, in water and air; and mammals on land, in water and air. Fish, amphibians and reptiles are the most restricted as to climate. Reproduction, body temperature and food are three of the limitations that relate closely to climate. This section can be taken as far as time or knowledge allows.

The bone fragment in Figure 1 was found in 1969 in the general vicinity of the Beardmore Glacier, Antarctica, at a locality known as Coalsack Bluff. A team of research scientists led by Dr. Edwin H. Colbert went to Antarctica in 1969 and 1970 to try to find **vertebrate** fossil evidence to support the theory of continental drift. (Vertebrate animals are those with a spinal column.)

3. What part of the animal does the piece seem to come from?

The skull; the fossil piece has a tusk.

If you don't know, look at Figure 2. This is the actual size skull of ***Lystrosaurus***, a Triassic reptile.

Trace and cut out the fossil bone in Figure 1 and try to fit the piece in the proper location on the skull in Figure 2

4. How long do you think the animal would be, based upon the size of the skull?

The skull in the drawing is actual size. Most students will say "small dog" size.

5. What do you think ***Lystrosaurus*** would have eaten?

Since the skull has no teeth, the animal probably ate vegetation—like a turtle.

6. What might be a similar **extant** (still living) relative, based upon the skull?

A turtle

7. Which groups (classes) of animals are limited to certain environments?

a) amphibians
b) reptiles
c) fish

8. Why are these groups of animals limited to these places? (Base your answers on your knowledge of modern animals of the same type)

Amphibians, reptiles and fish are cold-blooded animals. This means they have no internal control of their body temperature. These animals have approximately the same temperature as their surroundings. Therefore, they are limited to a narrow "temperature-niche" in the environment.

Figure 1. Reproduction of the first vertebrate fossil bone found in Antarctica.

Figure 2. Fossil skull of *Lystrosaurus* found in South Africa.

The outline of the skull fragment from Figure 1 '- shown.

PROCEDURE

PART B: What animals were found in Antarctica? Where was Antarctica long ago?

Students will plot known fossil locations on the map, using longitude and latitude. The students will be asked to compare the present location of the continents with the locations during the Triassic Period.

Key words: none.

Time required: one 45-minute period

Materials. map, *The Physical World,* and colored pencils

Worksheet 1 shows the presumed positions of Laurasia and Gondwanaland in the early Triassic Period Table 1 is a list of fossil locations of several reptiles and amphibians that have been found to date Plot the locations on the map, using a different color and shape for each fauna.

Look at the locations of all the fossils.

1. What general "patterns" do you see in the locations of the fossils?

Lystrosaurus **and other Triassic dicynodonts are widely distributed.** ***Cynognathus*** **and rhytidostoids are confined to a narrow latitude zone south of the equator. There are more fossil locations south of the equator.**

Now, pretend you are a paleontologist. We know that ***Lystrosaurus*** (a reptile) lived in a certain kind of climate. We know where fossil evidence of ***Lystrosaurus*** has been found

2. Would you look for ***Lystrosaurus*** fossils in Australia? **Yes** in South America? **Yes**

3. On which other continents might you find fossils of ***Cynognathus***? **Africa** and **South America.**

4. What are some other possible locations (continents) of rhytidostoid amphibians? **South America** and **Australia**.

5. Which group of fossils is spread over the greatest area on the map?

Lystrosaurus

6. Which group of fossils is limited to the smallest area?

Cynognathus

7. What type of climate do you think existed in Antarctica during the Triassic Period, based on the fossils found there?

Warm, moist climate

Look at a world map and draw arrows on Worksheet 1 to show the direction the landmasses had to move to arrive at today's location.

Table 1.
Fossil locations

		Latitude	Longitude
LYSTROSAURUS	Reptile	60°S.	40°E.
		50°S	10°E.
		30°S	50°E.
		60°N.	90°E.
		60°N	80°E.
CYNOGNATHUS	Reptile	50°S	10°W.
		40°S.	10°E.
RHYTIDOSTOIDS	Amphibian	50°S	50°E
		40°S	20°E.
		20°S.	90°E
CHIROTHERIUM	Reptile	50°S.	20°E
		50°N	30°E.
OTHER TRIASSIC DICYNODONTS	Reptile	40°S.	5°W.
		35°S	20°E.
		20°S	60°E.
		60°N	90°E.
		50°N.	50°E.
		50°N	20°W.

When students are drawing the arrows to show possible movement of the continents, you may want to use the length of the arrow to show the relative distance moved, but this isn't necessary. Some students may raise the question for the location of today's tropics, 20° North and South latitude. This can lead to a very good discussion about the modifying effect the position and size of the landmasses have on climate (no polar ice caps, ocean currents, wind patterns, etc.) Most paleontologists agree the tropics could have extended to 60° North and South Latitude during the Triassic Period.

8. Which continents moved the most?

Antarctica, India

9. Which continents moved the least?

Africa, Asia

10. In general, were the continents getting closer together or moving farther apart?

Moving farther apart

11. Which continent's climate would have changed the most?

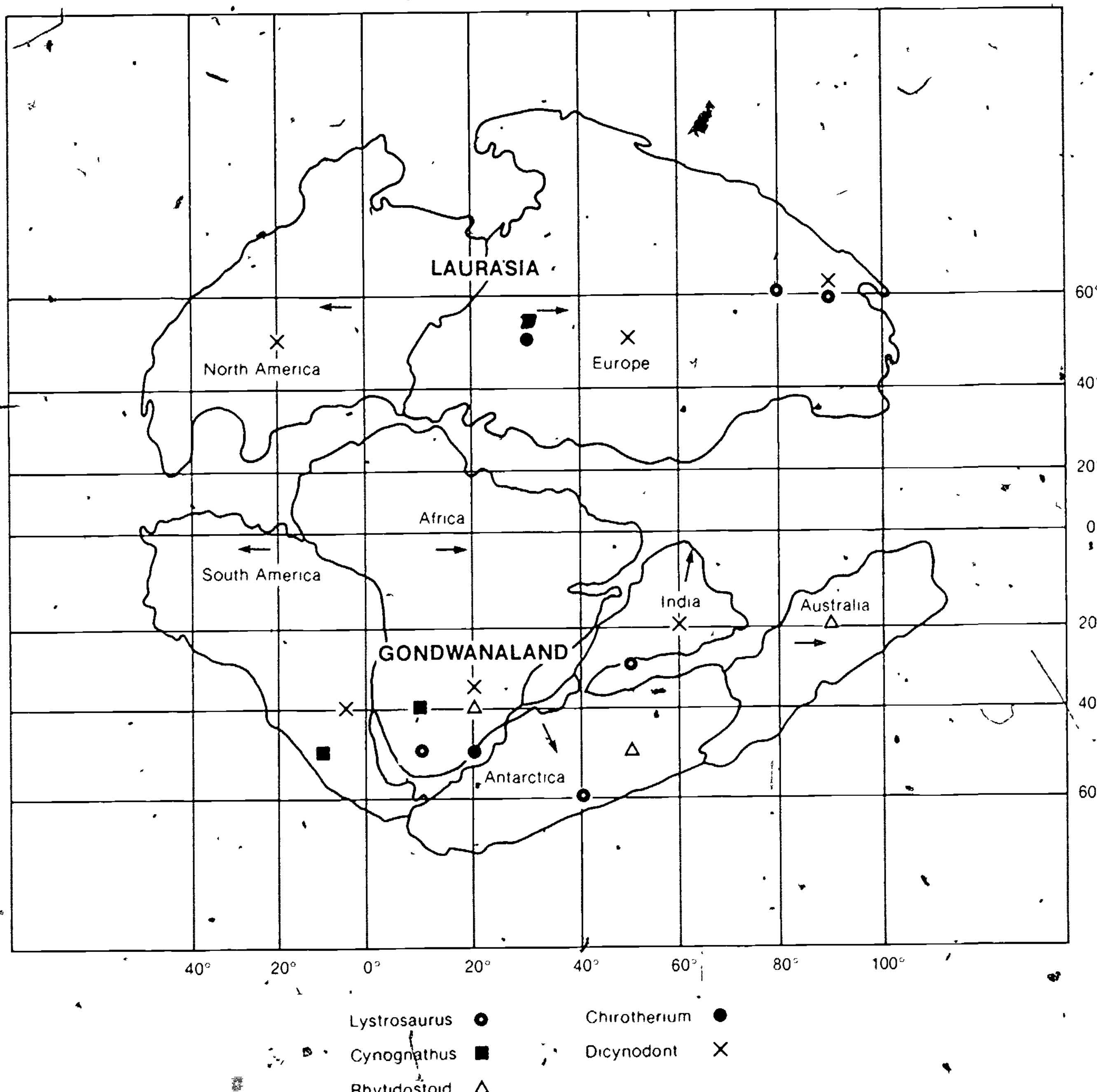
Antarctica

12. Which continent's climate would have changed the least?

South America or Africa

13. Judging from fossil evidence presented in this module, was the climate warmer and wetter at the South Pole before continental drift or was Antarctica closer to the equator?

Considering fossil evidence, we assume Antarctica was closer to the equator.


LAURASIA
North America
Europe
Africa
South America
India
Australia
GONDWANALAND
Antarctica
60°
40°
20°
0°
20°
40°
60°
40°
20°
0°
20°
40°
60°
80°
100°
Lystrosaurus
Cynognathus
Rhytidostoid
Chirotherium
Dicynodont

SUMMARY QUESTIONS

1. How can plant and animal fossils prove anything about continental drift?

The fossils of plants and animals provide clues to the environment in which they lived. If the environment where they are found is different from that in which they could live, we assume that the continents drifted. This is a simpler assumption than to say the climate changed in that location.

2. When we "go back" to the life of 200 million years ago, why do we think of reptiles and amphibians instead of mammals?

Mammals did not develop until later in geologic time.

3. Could *Lystrosaurus* move from one continent to another if the continents were separated by the ocean? Why or why not?

No. *Lystrosaurus* was not capable of moving long distances in ocean water.

4. If you were the leader of the next expedition, where would you look, and what would you look for, as further evidence of continental drift?

All of the fossils identified in this activity could become the target of search on the other continents. However, the southern hemisphere continents would be the best places to look. The researchers would try to find fossil assemblages that match on each continent.

REFERENCES

Colbert, E.H , 1971, Tetrapods and continents *The Quarterly Review of Biology*, v. 46, p 250-269 .

Colbert, E H , 1974, ***Lystrosaurus*** from Antarctica, *American Museum Novitates*, no 2535 (Mar. 4), p 14-43.

Colbert, E H., 1976, Fossils and the drifting continents. *Fossils*, v. 1, no. 1 (May), p. 5-22.

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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CRUSTAL EVOLUTION EDUCATION PROJECT

NAME DATE

Student Investigation
Catalog No 34W1128

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4. Explain the possible location of Antarctica in Cretaceous time, based on fossil locations from several continents.
5. Explain where paleontologists might look for new fossil evidence to support the theory of continental drift.

PROCEDURE

PART A: How can we identify fossils?

Materials: bones from several skeletons

1. Look at the bones your teacher displays and try to identify 1) the animal or animals they came from, and 2) what bones they are. You may have more than one hypothesis.

EVIDENCE	HYPOTHESIS Animals based on:		
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		3.	________
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3. What part of the animal does the piece seem to come from?

If you don't know, look at Figure 2. This is the actual size skull of *Lystrosaurus* a Triassic reptile

Trace and cut out the fossil bone in Figure 1 and try to fit the piece in the proper location on the skull in Figure 2.

4. How long do you think the animal would be, based upon the size of the skull?

5. What do you think *Lystrosaurus* would have eaten?

6. What might be a similar **extant** (still living) relative, based upon the skull?

7. Which groups (classes) of animals are limited to certain environments?

8. Why are these groups of animals limited to these places? (Base your answers on your knowledge of modern animals of the same type.)

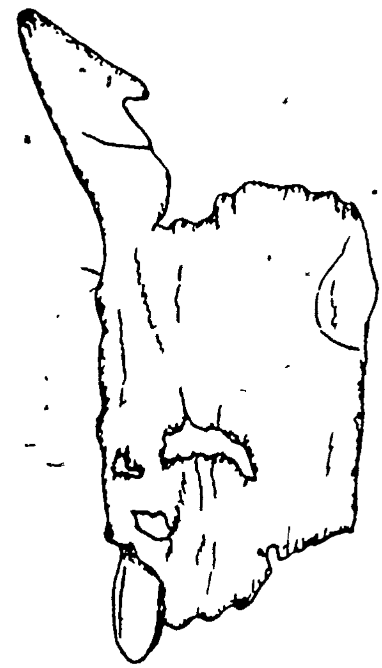

Figure 1. Reproduction of the first vertebrate fossil bone found in Antarctica

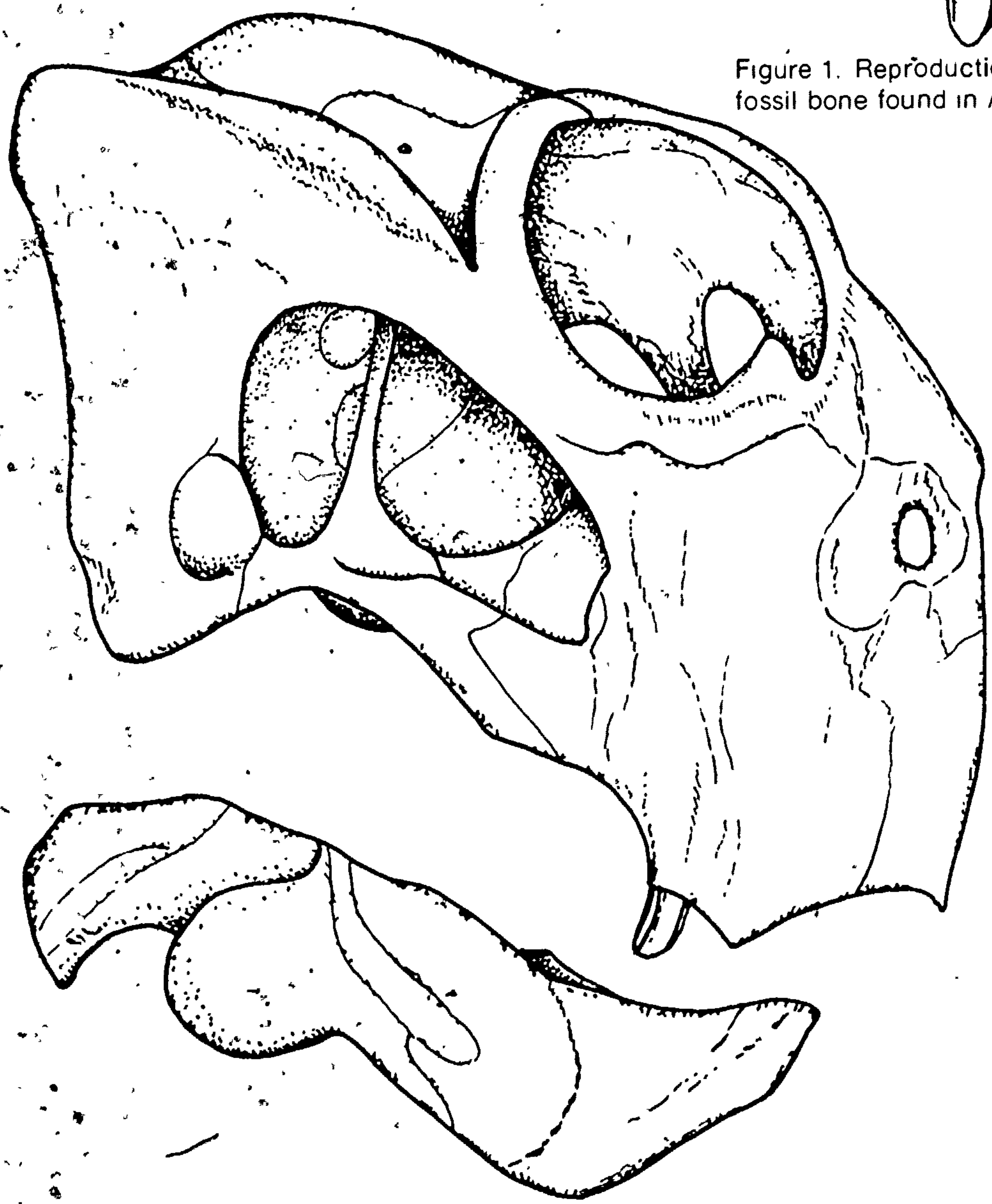

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Figure 2. Fossil skull of ***Lystrosaurus*** found in South Africa.

PROCEDURE

PART B. What animals were found in Antarctica? Where was Antarctica long ago?

Materials map, *The Physical World*, and colored pencils

Worksheet 1 shows the presumed positions of Laurasia and Gondwanaland in the early Triassic Period. Table 1 is a list of fossil locations of several reptiles and amphibians that have been found to date. Plot the locations on the map, using a different color and shape for each fauna

Look at the locations of all the fossils

1. What general "patterns" do you see in the locations of the fossils?

Now, pretend you are a paleontologist. We know that ***Lystrosaurus*** (a reptile) lived in a certain kind of climate. We know where fossil evidence of ***Lystrosaurus*** has been found

2. Would you look for ***Lystrosaurus*** fossils in Australia? _____ in South America? _____

3. On which other continents might you find fossils of ***Cynognathus?*** ______________ and ______________

4. What are some other possible locations (continents) of rhytidostoid amphibians? ______________ and ______________

5. Which group of fossils is spread over the greatest area on the map?

6. Which group of fossils is limited to the smallest area?

7. What type of climate do you think existed in Antarctica during the Triassic Period, based on the fossils found there?

Table 1.
Fossil locations

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		20°S	60°E
		60°N	90°E
		50°N	50°E
		50°N	20°W.

Look at a world map and draw arrows on Worksheet 1 to show the direction the landmasses had to move to arrive at today's location.

8. Which continents moved the most?

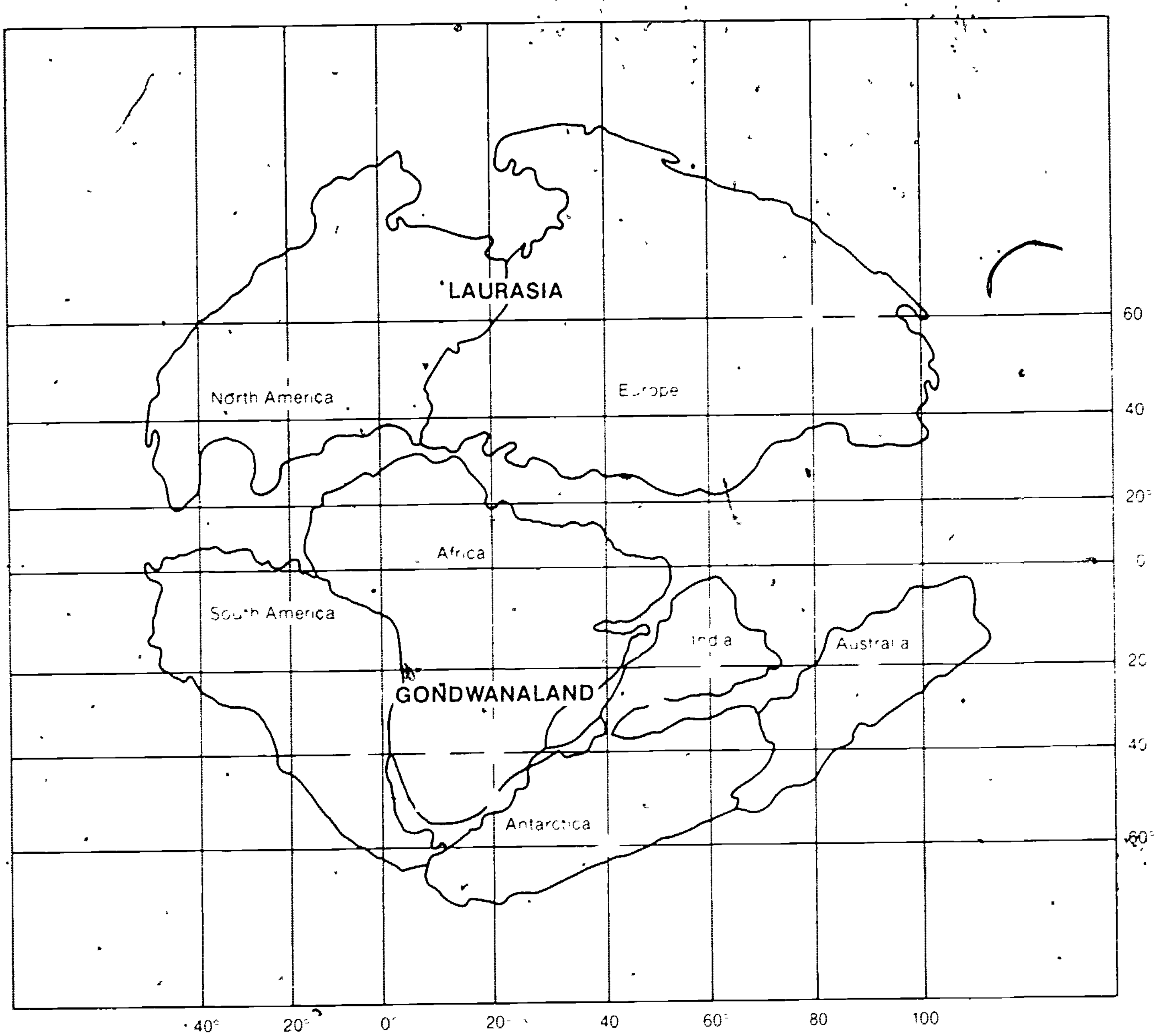
9. Which continents moved the least?

10. In general, were the continents getting closer together or moving farther apart?

11. Which continent's climate would have changed the most?

12. Which continent's climate would have changed the least?

13. Judging from fossil evidence presented in this module, was the climate warmer and wetter at the South Pole before continental drift or was Antarctica closer to the equator?



Worksheet 1 (PART B)

SUMMARY QUESTIONS

1. How can plant and animal fossils prove anything about continental drift?

2. When we "go back" to the life of 200 million years ago, why do we think of reptiles and amphibians instead of mammals?

3. Could *Lystrosaurus* move from one continent to another if the continents were separated by the ocean? Why or why not?

4. If you were the leader of the next expedition, where would you look, and what would you look for, as further evidence of continental drift?

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