CRUSTAL
EVOLUTION
EDUCATION
PROJECT

Imaginary Continents: A Geological Puzzle

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TEACHER'S GUIDE

Catalog No. 34W1015

For use with Student Investigation 34W1115
Class time: two 45-minute periods

Developed by
THE NATIONAL ASSOCIATION OF GEOLOGY TEACHERS

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NAGT Crustal Evolution Education Project

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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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Imaginary Continents: A Geological Puzzle

INTRODUCTION

This module suggests to the student that knowing the ages of rock types on two separated land masses is a clue to their having once been joined together. The student is then provided with a graph showing four radioactive decay curves. From this graph, the student calculates the ages of six rock units.

The puzzle can now be solved by cutting out the continents and trying to see if the continental coastlines match. Most students find that the continents do not fit very well. They then follow the hint and solve the puzzle by bringing the "X" rock units together.

Experience has shown that the students enjoy this activity and are intrigued by the idea that sea-floor spreading took place as the continents moved apart. In fact, they will reconstruct the motion several times after they solve the puzzle.

Imagine you are looking at the earth from a spaceship. Does it look like South America and Africa were once joined together? Would knowing the ages of the rocks on the two continents help you to decide?

Geologists have been trying to find out if these continents were joined together long ago. They are making many comparisons including evidence from fossils, glacial features, and rock ages. In this activity you will be comparing the ages of rocks on two imaginary continents. Suppose you are a geologist. Were the imaginary continents once one giant continent? As in other puzzles, the solution may surprise you!

PREREQUISITE STUDENT BACKGROUND

Although it is not necessary in carrying out this activity to know how graphs of radioactive decay are produced, it is suggested that some background on this subject be provided before the activity is initiated.

OBJECTIVES

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

1. Find the age of a rock by using a radioactive decay curve.
2. Decide whether or not two imaginary continents might have been joined at one time.
3. Estimate the unknown ages of rock units by inference.

MATERIALS

Scissors

BACKGROUND INFORMATION

The information that follows will be helpful in explaining to your students how radioactive decay curves are formed. The idea that a geologist can take some rocks and, by using scientific equipment, determine their ages, may be new to some students.

The technical part of this activity is concerned with the radioactive decay process and how it is used in the dating of rocks.

When a mineral containing radioactive material forms, a "clock" is started as the products of radioactive decay begin to accumulate in the mineral. Radioactive decay is a spontaneous process that occurs in the nuclei of atoms. It involves the release of various forms of radiation, as a result of which both the mass and the atomic number of the original element change to produce other elements (daughter elements).

The stages in the radioactive decay of ^{238}U, shown in Figure A, will help to illustrate the changes that take place in several stages of decay.

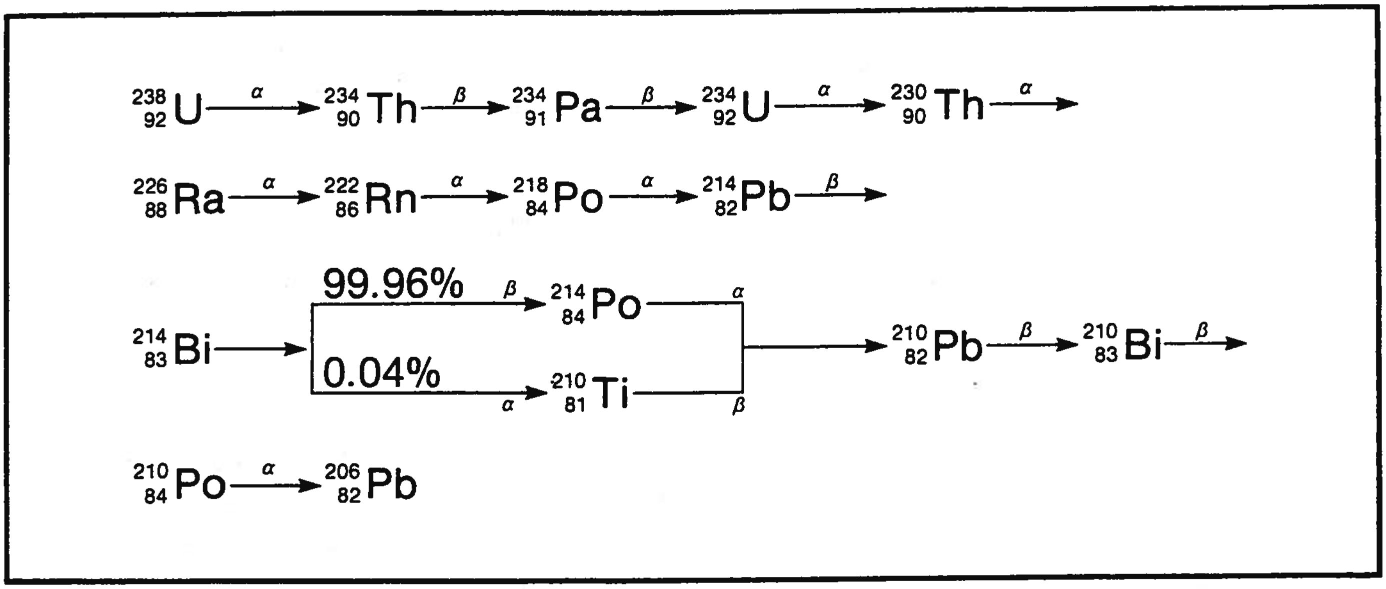


Figure A. Stages in the radioactive decay of Uranium-238.
Source: AGI, 1967, *Investigating the earth,* 1st ed., TE #2, Boston, Houghton Mifflin Co., p. 473.

Another way of expressing the radioactive process is shown in Figure B. Notice that ^{238}U decreases with time and that ^{206}Pb (the daughter element) increases with time. At any one moment, the sum of the percentages of each element remaining equals 100 percent of the original radioactive material.

In Figure B the time in "half-lives" is indicated along the horizontal axis. Since the scientists can measure the half-lives of many different radioactive elements, the time can be reported in years—as you see on the radioactive decay curve in the student activity.

When dating rocks containing uranium, both isotopes are usually used to determine the age of the rocks. The ages always agree unless some of the isotopes have escaped.

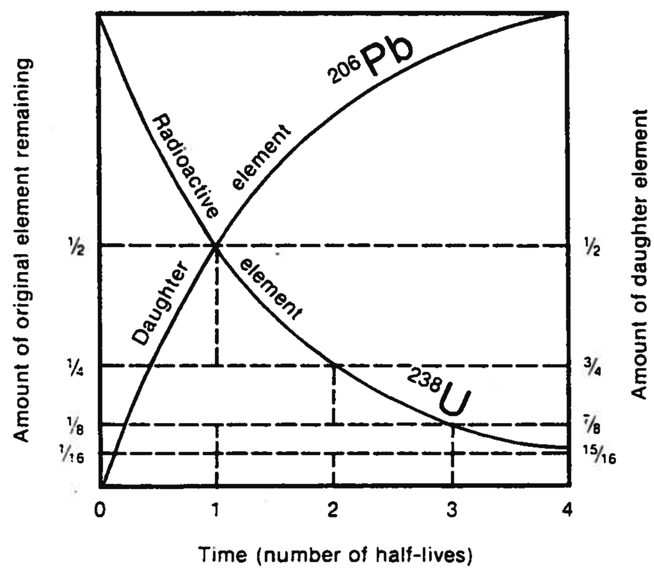


Figure B. Rate of radioactive decay.

SUGGESTED APPROACH

Prior to presenting this activity to the students, explain the principles of radioactive decay and the radioactive decay graph. Be sure they can obtain the data they need for this activity from the radioactive decay curve.

Pre-lab (5 minutes): You might point out on a globe that it looks like South America and Africa were once joined. Ask the class, "If they were joined, would the rock units on each continent be the same age?" Then lead into the activity and let the students work individually or in groups of two.

During the laboratory walk around the class to answer any questions of procedure.

Post-lab (10 minutes): Review the students' answers to the questions and the values they determined for the rock ages. Ask the students to explain what happened after the two continents separated. (Answer: Sea-floor spreading took place and split the continent of Bewarland.) Conclude the post-lab with a statement that finding the ages of rock units to be the same is good evidence that the landmasses were once joined together. However, additional evidence is required if we want to be sure that drift occurred.

Note: You should keep in mind that this activity is developed in vastly simplified form. Geologists generally agree that radiometric dates are not as definitive as other evidence, e.g., rock types, geologic structure, and fossil collections. Remind your students that positive correlation between continents requires multiple lines of evidence.

PROCEDURE

In this activity, the student will determine the ages of six rock units from a graph containing four radioactive decay curves. Using this data, they fit imaginary continents together.

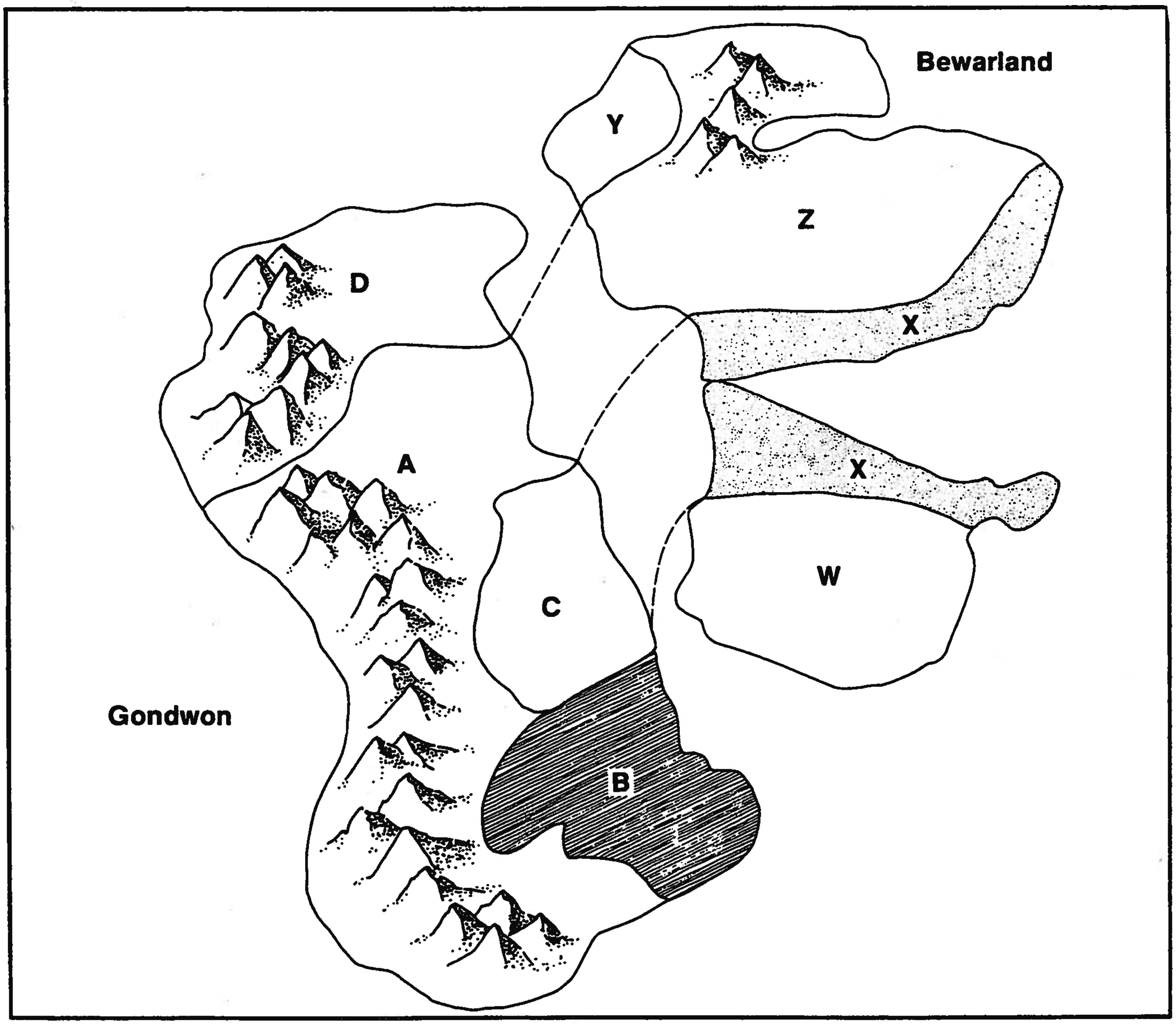
Key word: radioactive decay (You will need to explain this concept since it is not defined in the module.)

Time required: one 45-minute period or longer

1. Look at the shape of the imaginary continents on the Worksheet. Do they look like they would fit together in any way? ________

Students may answer yes or no.

2. Determine the ages of the different rock units by completing Table 1. You can find the age of each rock unit by using the graph in Figure 1 as explained by your teacher.



Answer Sheet

Hint!

Everyone knows that when a puzzle is solved the pieces should fit together perfectly or almost perfectly. Think about this puzzle a minute and then cut completely around each continent. Each continent should be **one complete piece.** You now have two pieces of paper. What can you do with Bewarland and rock type X in order to make the continents fit together?

Move rock type X until the edges touch each other.

What you have just done is similar to one of the methods which scientists use to suggest that continental positions may have been different in the past.

3. Using the age of the rocks recorded in Table 1, draw dashed lines between the continents on the Worksheet to match rocks of similar age. Be sure to draw your dashed lines from the rock boundary lines of one continent to the rock boundary lines of the other.

Note: Rock ages support the joining of continents if (1) rocks of the same type in corresponding parts of the two continents are about the same age, and (2) there are many, many rock samples of known age to compare. If the rock types are not the same age, then the continents were probably not joined.

Could the continents have been one big continent based on the ages of corresponding rock types? ________

Most students should write yes.

4. To see if the continents fit, cut along the sides that you think fit together. See if the shorelines match.

CAUTION: When cutting out the continent Bewarland, students should not cut through the notch. The activity works better if the continent Bewarland is not cut in half.

Could the continents have fit together at one time? ________

Most students will write no.

If you answered no, or don't know, ask your teacher for a hint.

The hint (see above) is reproduced on the reverse side of the student Worksheet.

5. Rock units D and W were not analyzed. What are their probable ages?

Rock Unit D **0.3×10^9** years
Rock Unit W **1.4×10^9** years

Table 1.
Ages of the rock units

Rock Unit	*Radioactive Element*	*% of Original Mass Remaining*	*Age of Rock*
A	^{238}U	60	3.3 x 10^9 years
B	^{235}U	25	1.4 x 10^9 years
C	^{87}Rb	97.5	2.3 x 10^9 years
X	^{235}U	12.5	2.1 x 10^9 years
Y	^{238}U	95	0.3 x 10^9 years
Z	^{232}Th	87.5	3.25 x 10^9 years

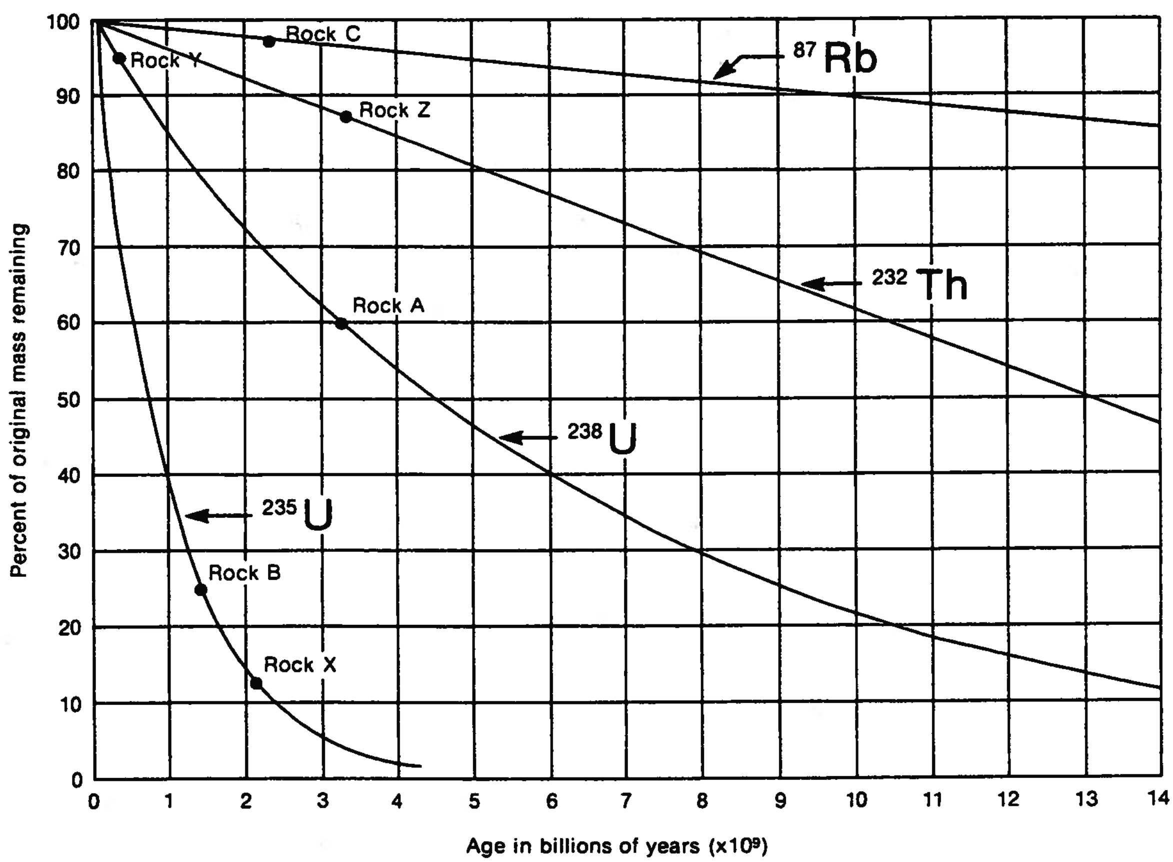


Figure 1. Graph of radioactive decay curve.

SUMMARY QUESTIONS

1. What other kinds of evidence might support the idea that two continents were once joined?

Additional evidence could include:

a. the fossils found in each continent
b. geological features
c. ages of other types of rocks

2. Why is it important for scientists to compare corresponding rock types as well as corresponding rock ages when matching rocks on different continents?

Corresponding rock types must be compared because knowing that the ages of the rocks are the same is not enough. The ages must "correspond" to the geometric fit of the rock types. Otherwise any two or more continents could be joined because they all have rocks of similar ages.

EXTENSION

Read the article by P.M. Hurley in *Scientific American*, listed in the REFERENCES, and compare his findings with what you have learned in this activity. (The article was also reprinted in *Continents Adrift*, 1972, W.H. Freeman and Co.) Do you think that Africa and South America were once combined into one large continent?

REFERENCES

AGI, 1978, *Investigating the earth,* 3d ed., TE, Boston, Houghton Mifflin Co., p. 306–308

Eicher, D.L., 1976, *Geologic time.* Englewood Cliffs, N.J., Prentice-Hall, Inc., 150 p.

Hurley, P.M., 1968, The confirmation of continental drift. *Scientific American,* v. 218, no. 4 (Apr.), p. 63–64.

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