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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 three 45-minute class periods; (8) summary questions (with answers); (9) extension activities; and (10) list of references. Activities in this module focus on investigating magnetic characteristics of a sea-floor model in the vicinity of a wide-ocean ridge. The model affords concrete, manipulative experience with the interpretive notions of mirror image (normal and reverse) magnetic patterns, with the amount and rate of sea-floor spreading, and the opportunity to suggest possible ways in which the magnetic pattern could have been formed. (Author/JN)

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CRUSTAL EVOLUTION EDUCATION PROJECT

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A Sea-floor Mystery: Mapping Polarity Reversals

TEACHER'S GUIDE

Catalog No. 34W1001

For use with Student Investigation 34W1101
Class time: three 45-minute periods

Developed by
THE NATIONAL ASSOCIATION OF GEOLOGY TEACHERS

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A Sea-floor Mystery: Mapping Polarity Reversals

SE 038 132

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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A Sea-floor Mystery: Mapping Polarity Reversals

INTRODUCTION

This is a module in which students will investigate magnetic characteristics of a sea-floor model of the vicinity of a mid-ocean ridge. The model enables students to have a concrete, manipulative experience with the interpretive notions of mirror image (normal and reverse) magnetic patterns, the amount and rate of sea-floor spreading, and the opportunity to suggest possible ways in which the magnetic pattern could have been formed.

One interesting find that scientists have made in recent years is that the earth's magnetic field has two favored positions One position is as it exists today, with the **north** magnetic pole near the **north** geographic pole (See Figure 1a) The other is exactly the reverse, with the **north** magnetic pole near the **south** geographic pole. (See Figure 1b) The **magnetic polarity** (the geographic directions of the north and south magnetic poles) appears to have reversed positions many times in the past

PREREQUISITE STUDENT BACKGROUND

Basic understandings of the earth's magnetic field, the response of a compass within that field and the idea of magnetic reversal are necessary before beginning this activity. In addition, students should be familiar with the topography of the ocean floor, specifically the mid-ocean ridge system.

OBJECTIVES

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

1. Describe the magnetic pattern that was found on the sea-floor model
2. Identify the areas on the model that have normal magnetism and the areas that have reverse magnetism
3. Compare the magnetic pattern on one side of the model mid-ocean ridge with that on the opposite side of the ridge
4. Suggest some possible ways in which the striped magnetic pattern could have been formed
5. Calculate the amount of sea-floor spreading that has occurred in the past 3 million years
6. Calculate the rate of sea-floor spreading that has occurred in the past 3 million years

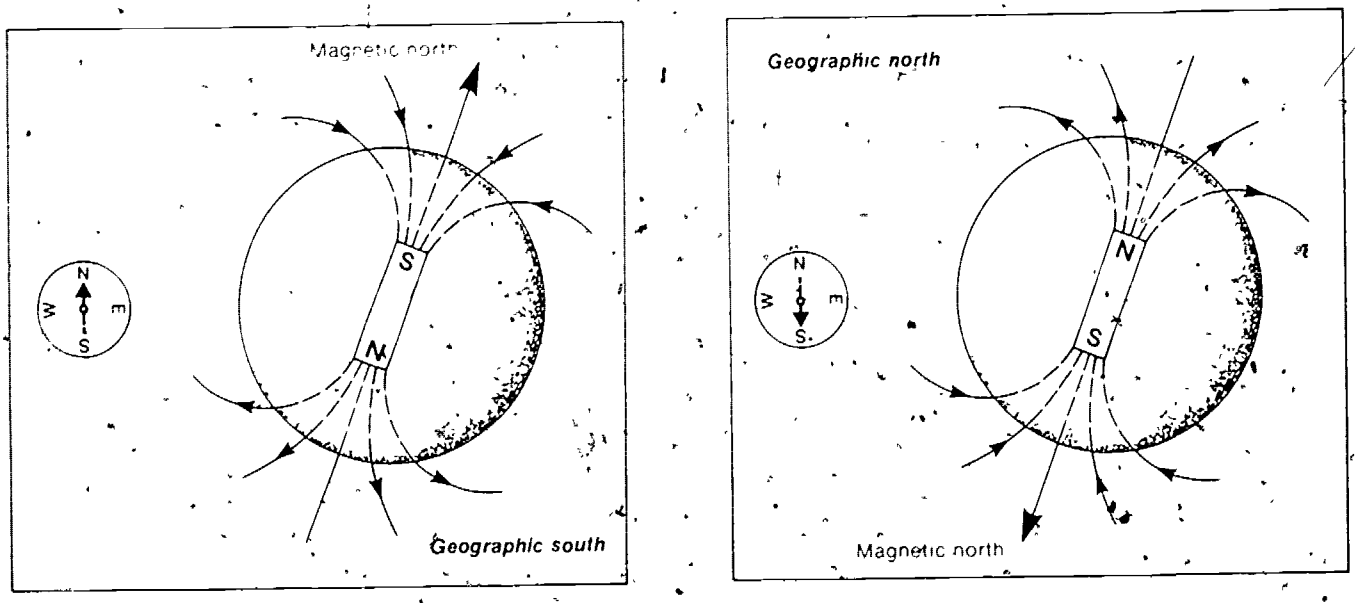

Figure 1 .Magnetic polarity of the earth.

a. Normal magnetic polarity—earth's magnetic field as it occurs today.

b Reverse magnetic polarity—earth's magnetic field as it has occurred at a number of times in the past.

MATERIALS

One set for each group:

- Corrugated cardboard, 18cm x 34cm
- 11 finishing nails or paper clips
- Electric coil or strong bar magnet

BACKGROUND INFORMATION

When molten volcanic material cools and solidifies, usually around 500° C (called the Curie point), magnetic minerals in it are magnetized in the direction of the earth's magnetic field. As long as the rocks remain below this temperature, they retain the magnetism, thus providing magnetic "memories" (much like the magnetic memory elements of a computer) of the direction of the earth's field in the place, and at the time, they cooled and solidified. See Figures A1 and A2.

In 1906, the French physicist Bernard Brunhes found volcanic rocks in France that were magnetized, not in the direction of the earth's present field, but in the exact opposite. This gave rise to the possibility that the earth's magnetic field had been reversed in the past. This concept attracted little attention until some years later, when it was interpreted that igneous rocks can become magnetized and then not lose or reorient their magnetism when the magnetic field of the earth reverses.

Scientists have studied magnetized volcanic rocks from land areas throughout the world, as well as sediments of the sea floor. These studies have established that the earth's magnetic field has two stable states: as it exists today, with the north magnetic pole near the north geographic pole, and in a reversed position, with the north magnetic pole near the south geographic pole. Further, the magnetic poles of the earth appear to have repeatedly alternated between these two orientations. It has been calculated that in the past 70 million years the earth's poles "flip-flopped" more than 170 times. See Figure 1.

Surveys of the northeast Pacific floor in 1958 revealed a series of anomalies (irregularities) in the intensity of the magnetic field. These intensity differences were interpreted as reversals in the magnetic field of the earth. They appear as a series of stripes when graphically portrayed on an ocean map. In 1963 it was suggested by two young British investigators, F.J. Vine and D.H. Matthews of Cambridge University, that these anomalies not only are the result of magnetic reversals but that they also represent "stripes" of ocean floor created during sea-floor spreading. See Figure 4.

Although models help us understand difficult concepts, their accuracy is usually limited. In the sea-floor model the student's compass will actually flip-flop. In reality, a change of intensity in the earth's magnetic field was recorded by a magnetometer. This change was interpreted to be part of the ocean floor that was formed at the mid-ocean ridge at a time of reverse polarity.

At its strongest point near the poles, the earth's magnetic field is several hundred times weaker than the field of a toy horseshoe magnet. Although it is a weak field, it occupies a very large volume and involves a large amount of energy, since the energy of a magnetic field is proportional to its volume.

The magnetic field in the wires of the model is hundreds of times stronger than the magnetism in the rocks of the sea floor. Another limitation of the model is that it illustrates only magnetic declination.

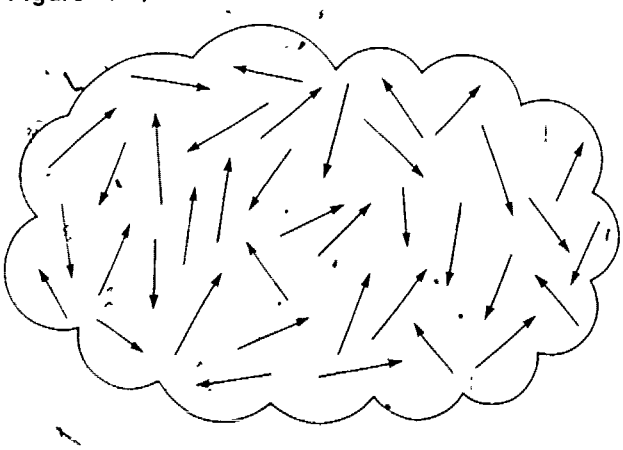

Figure A1. Above the Curie point, atoms take random directions.

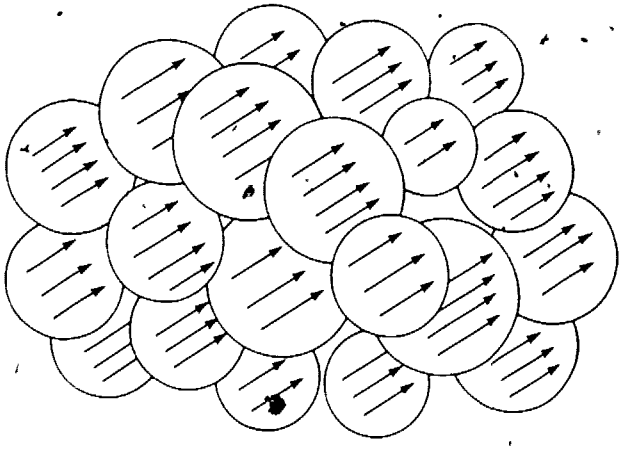

Figure A2. Below the Curie point, and in the presence of an external magnetic field, domains line up.

Over most of the Northern Hemisphere the north-seeking end of a compass needle will not only swing in a horizontal plane but it will also dip downwards. The angle the needle makes with the horizontal is called the magnetic dip. (In the Southern Hemisphere it points up.)

Although in this activity only the horizontal magnetic component is utilized, the earth's magnetic field is best represented as a vector defined by two angles, the angle of declination and the angle of dip.

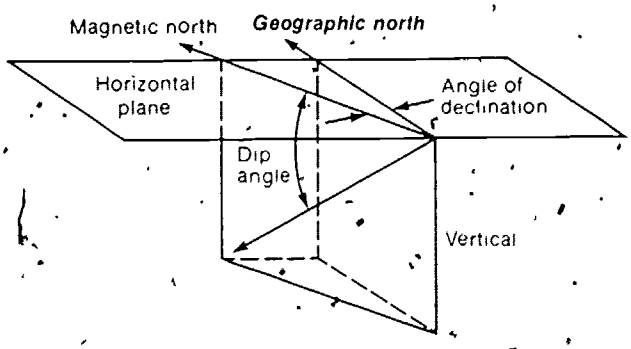

Figure B. The angle of declination and the angle of dip for the earth's magnetic field.

SUGGESTED APPROACH

This module provides an opportunity for students to operate a physical model to better understand the striped magnetic pattern which develops across many mid-ocean ridges. Students should be familiar with sea-floor spreading, magnetic field, magnetic field reversal and mid-ocean ridges.

Most teachers will want to review these concepts with students before they work the magnetic model. A teacher skilled in inquiry techniques may want to present the students with the model before discussing these concepts.

Ideally, students should work with this activity in groups of two or three. The data-gathering can take place during a period of about 30 minutes, but each part of the module, PART A and PART B, will take one class period. An additional class period is suggested for a worthwhile follow-up discussion. Some students will need help with some of the calculations involving time and distance. You should also aid the students in applying the various concepts developed by the model to sea-floor spreading.

A sea-floor model should be pre-assembled for each group. Construct the model as follows:

1. Cut out a piece of corrugated cardboard, 18 cm x 34 cm, and label it as shown in Figure C.
2. Magnetize 11 finishing nails or straightened paper clips (about 6 cm long) by putting them in an electric coil and magnetizing, or stroking them with one end of a strong bar magnet.
3. Wedge the wires or nails into the holes along the edge of the corrugated cardboard. (See directions for spacing in Figure D.)

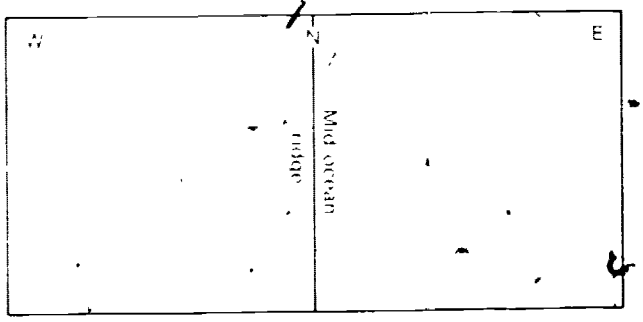

Figure C. Labeling instructions for the corrugated cardboard.

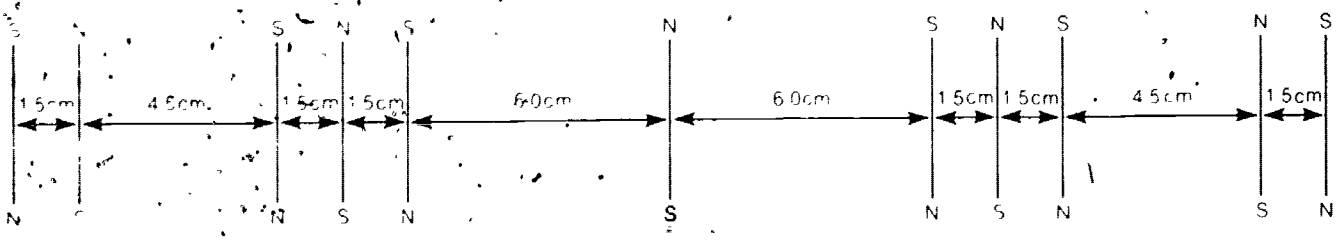

Figure D. Suggested spacing for magnetized nails or wires in the sea-floor model.

4. Draw a vertical line on the paper strip through every arrow that is parallel to the edge of the paper strip

5. Color in red each section in which the compass needle pointed south

6. Color in blue each section in which the compass needle pointed north

Then answer the following questions:

7. How many time intervals of north-seeking (normal) magnetic polarity were found on the model?

If the model is constructed according to the representative diagram, 5 time intervals of north-seeking (normal) magnetism will be recorded. Different model constructions may vary this number.

8. How many time intervals of south-seeking (reverse) magnetic polarity were found on the model?

If the model is constructed according to the representative diagram, 6 time intervals of south-seeking (reverse) magnetism will be recorded. Again, different constructions may vary this number.

9. How does the pattern of magnetism on the right side of the mid-ocean ridge (right side of model) compare with the magnetic pattern on the left side of the mid-ocean ridge?

The pattern of magnetism on the right side of the model should be exactly the reverse of the pattern on the left. This is referred to as a "mirror image."

10. How does the amount of area where there is no normal or reverse polarity (called **transition periods**) compare with the amount of area where there is normal or reverse polarity?

If the model is constructed as shown in Figure D, then it will have 6 transition periods, all of which occupy a relatively small area compared with the areas occupied by the normal and reverse magnetic fields.

REFERENCES

Cox, Allan, Dalrymple, G B and Doell, R R , 1967, Reversals of the earth's magnetic field *Scientific American*, v 217, no 2 (Feb), pp 44-54

Matthews, S W , 1973, This changing earth *National Geographic*, v 143, no 1 (Jan), pp 1-37

Orowan, Egon, 1969, The origin of the oceanic ridges *Scientific American*, v. 221, no 5 (Nov), pp 102-119

Vine, F J , 1966, Spreading of the ocean floor. new evidence *Science*, v 154, no 3755 (Dec 16), pp 1405-1415.

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Wilson, J. Tuzo, 1969, Some aspects of the current revolution in the earth sciences. *Journal of Geological Education*, v 17, no. 4 (Oct.), pp. 145-150

See Step 5 PART B about location of this line

Figure 3 Diagram showing the magnetic polarity west of British Columbia Areas believed to be of normal magnetic polarity are shown in black Areas believed to be of reverse magnetic polarity are shown in white. Black lines that cut across the pattern are faults (Permission granted from Raff and Mason, Bulletin of the Geological Society of America.)

PROCEDURE

PART B: What causes the sea floor to spread apart?

In this activity students work with a copy of the original magnetic field diagram west of British Columbia. The Juan de Fuca Ridge area shown in Figure 3 (arrows) is an area with which Matthews and Vine worked in developing the sea-floor spreading hypothesis. The student's magnetic stripe map, made in PART A, and an actual magnetic field change map will be compared for similarities and differences. Using a paleomagnetic time scale, students calculate an average rate of spread, away from the Juan de Fuca Ridge.

Key word: paleomagnetism

Time required: one 45-minute period

Materials. sea-floor model

Figure 3 is a map of the sea floor west of British Columbia. It shows the pattern of magnetic polarity in the area of an ocean ridge. This ocean ridge is called the Juan de Fuca Ridge. Its location is shown by the two arrows on the map.

Compare the map in Figure 3 with the striped map you made of the sea-floor model. Answer the following questions.

1. In what ways is your striped map similar to the map in Figure 3?

Both maps show parallel stripes of normal and reverse magnetic fields.

2. In what ways is the map in Figure 3 different from yours?

The magnetic field map of the area west of British Columbia is far more complex and detailed than the student map. Faults which have offset the magnetic field pattern and changes in the spreading rate are two of the factors which complicate the magnetic pattern shown in Figure 3.

Some years ago, a few earth scientists came up with the idea that ocean ridges were places where the sea floor was spreading apart. Figure 4 shows a way in which this spreading could happen.

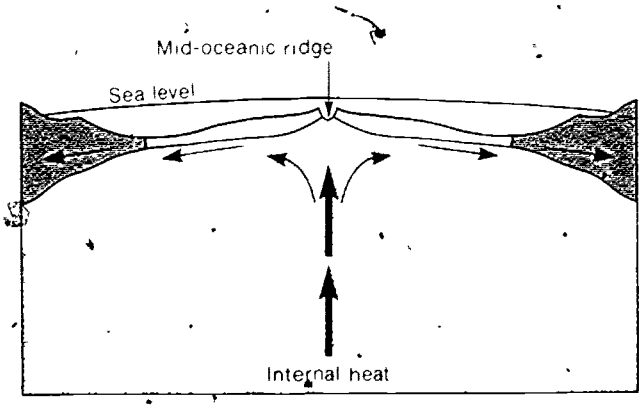

Figure 4. Convection currents are spreading the sea floor away from the ocean ridges

Just having an idea in science is not enough. Ideas can often come easy. Getting some proof is often more difficult. How could one get some kind of proof for the idea that crustal plates are moving away from ocean ridges?

Interestingly enough, the first real break-through came about because of the reasoning of a 24-year-old graduate student, Frederick Vine. Vine could see that the pattern of magnetic stripes is similar on both sides of mid-ocean ridges (a long submarine ridge found in all major ocean basins of the world, commonly centrally located in the basin and having a prominent valley down the middle). He reasoned that the magnetic pattern reflected the magnetic field recorded in the ocean floor rocks when they were formed. The "duplicate" striped pattern sequence on either side of the ocean ridges was a major finding. It provided evidence for the idea that new material (lava) rises to the surface, cools, becomes magnetized and gets carried outward away from both sides of the ridge as the sea floor spreads apart.

Figure 5 shows how this process is believed to occur.

3. Why do you think the magnetic stripes are of different width?

The difference in the widths of the magnetic stripes could be explained by: 1) varying rates of sea-floor spreading in the geologic past, and 2) the length of time that the earth's magnetic field stayed in a particular magnetic position.

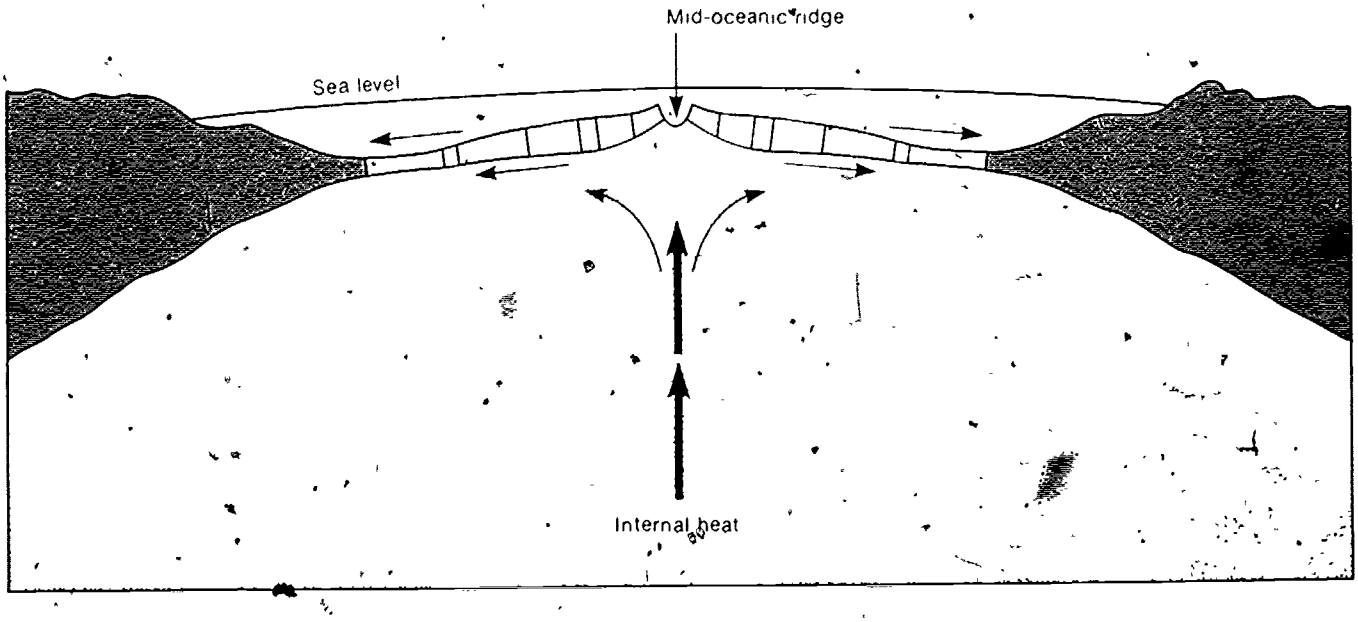

Figure 5. As the lava is brought up at the mid-ocean ridge, the sea floor spreads and it "records" the earth's magnetic field.

Scientists who study paleomagnetism (the history of the earth's magnetic field as recorded in the rocks) have been able to work out a paleomagnetic time scale. This time scale shows the intervals of different magnetic polarity. Part of this scale is shown as Figure 6.

4. Using the time scale in Figure 6, determine how many magnetic reversals have taken place in the past 3 million years.

Using the time scale in Figure 6, students should be able to determine 7 time intervals of magnetic reversals have occurred in the past 3 million years.

5. Look at Figure 3. Start at the ridge marked by the arrows. Going east, count the same number of reversals that you determined (in question 4) have taken place in the past 3 million years. Measure this distance in kilometers, using the scale at the bottom of Figure 3.

Using Figure 3, the students can count 7 stripes outward from the ridge indicated by the arrows in the figure. Because of the fault patterns in the area, counting eastward should be easier than counting westward. Using the scale provided to measure from the ridge to the seventh stripe, the students should find a distance of approximately 90 km.

6. What is the average rate of spreading during this time? *Hint:* Divide the distance by the time. You will have to convert km into cm. Remember, 1 km = 100,000 cm

$$\text{Rate} = \frac{\text{Distance in cm}}{\text{Time in years}}$$

The average rate of spreading can be determined by dividing the distance the plates are interpreted to have spread (approximately 90 km) by the time involved (3 million years). Since the students should express the final answer in cm/year, be certain that the appropriate conversions are made.

$$R = \frac{D}{T} \qquad R = \frac{90\ \text{km}}{3\ \text{m.y.}}$$

$$R = \frac{9{,}000{,}000\ \text{cm}}{3{,}000{,}000\ \text{years}} = 3.0\ \text{cm/year}$$

SUMMARY QUESTIONS

1. Explain the appearance and nature of the magnetic pattern of the sea floor.

The recorded magnetic pattern of the sea floor is striped, and there are alternate and duplicate (mirror image) bands of inferred normal and reverse magnetism on the sea floor.

2. Explain how the alternating magnetic stripes of the ocean floor might be formed.

Students should be encouraged to write their own ideas in their own way when answering this question. One explanation is: The magnetic particles in the rocks of the ocean floor are magnetized in the direction of the earth's magnetic field at the time they are forming along the mid-ocean ridge. As sea-floor spreading moves the ocean floor, reversals in the earth's magnetic field are recorded by the magnetic particles in new sea-floor rock. This process creates a series of bands, or magnetic striped pattern.

3. Explain why you think that the striping of sea-floor magnetism is either for or against the idea of sea-floor spreading.

Although you should encourage students to write various responses to this question, you can expect many to express ideas similar to the following:

I think the striping of the sea-floor magnetism supports the idea of sea-floor spreading. When the alternating magnetic pattern and the similarity of the pattern on either side of the ridge are considered, it is difficult to think of any other way in which the striping pattern could have formed. Assuming that the reversals in the earth's magnetic field have taken place, then sea-floor spreading is a way in which this pattern could have been produced.

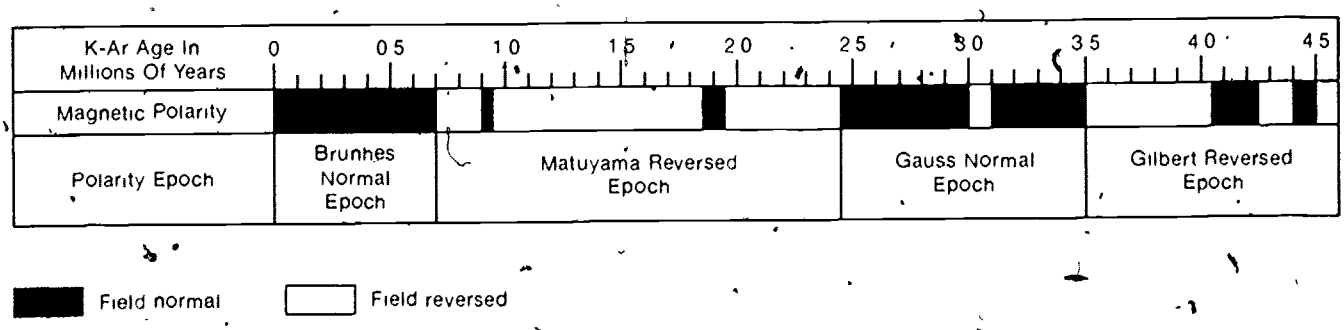

Figure 6. This diagram shows the time intervals of different magnetic polarity during the past 4.5 million years.

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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Student Investigation

Catalog No 34W1101

A Sea-floor Mystery: Mapping Polarity Reversals

INTRODUCTION

One interesting find that scientists have made in recent years is that the earth's magnetic field has two favored positions. One position is as it exists today, with the **north** magnetic pole near the **north** geographic pole. (See Figure 1a) The other is exactly the reverse, with the **north** magnetic pole near the **south** geographic pole (See Figure 1b) The **magnetic polarity** (the geographic directions of the north and south magnetic poles) appears to have reversed positions many times in the past

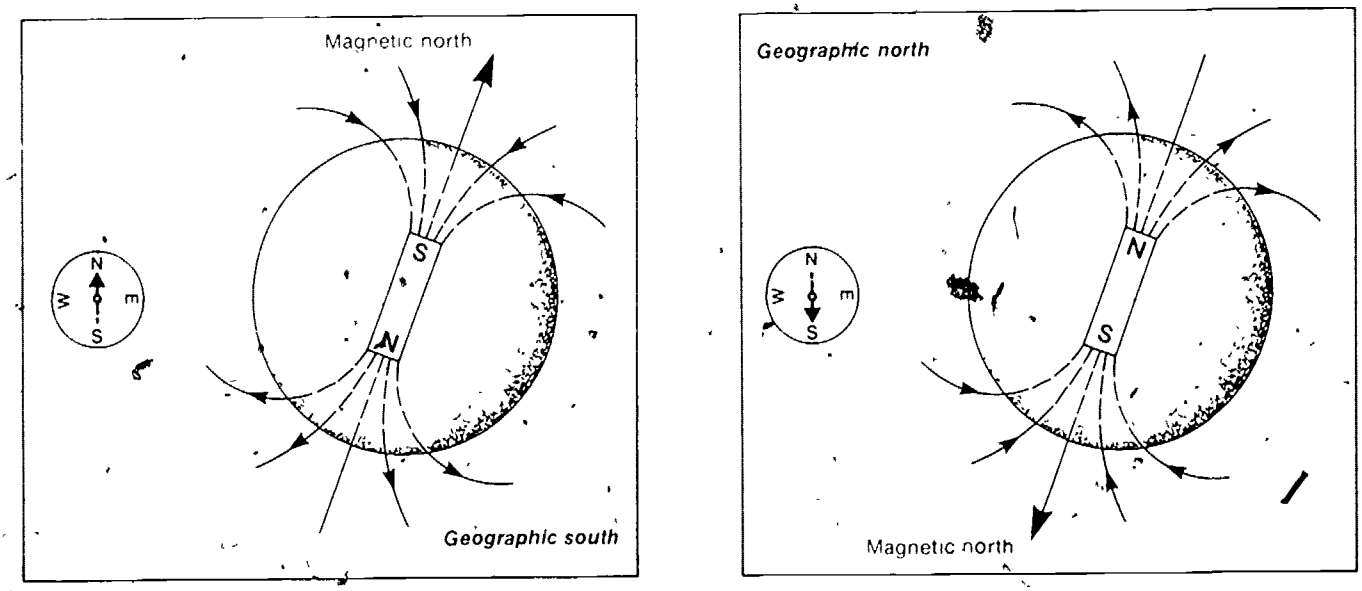

Figure 1. Magnetic polarity of the earth

a. Normal magnetic polarity—earth's magnetic field as it occurs today.

b. Reverse magnetic polarity—earth's magnetic field as it has occurred at a number of times in the past.

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OBJECTIVES

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

1. Describe the magnetic pattern that was found on the sea-floor model
2. Identify the areas on the model that have normal magnetism and the areas that have reverse magnetism
3. Compare the magnetic pattern on one side of the model mid-ocean ridge with that on the opposite side of the ridge
4. Suggest some possible ways in which the striped magnetic pattern could have been formed
5. Calculate the amount of sea-floor spreading that has occurred in the past 3 million years
6. Calculate the rate of sea-floor spreading that has occurred in the past 3 million years.

PROCEDURE

PART A What is the magnetic pattern of a mid-ocean ridge area?

Materials sea-floor model, compass, strip of adding machine tape, masking tape and red and blue pencils for each group

This model has been made to show some features of the magnetic field that are recorded in the rocks of the sea floor

1. Place the cardboard model in front of you Lay the strip of adding machine tape along the length of the cardboard model as close to the center as possible Attach it at both ends with tape
2. Place the compass at the very center of the strip of adding machine tape. This point represents the center of a mid-ocean ridge You will very *slowly* slide the compass to the *right* along the paper strip. Wherever the compass needle is parallel ⟶ or perpendicular ↑ to the edge of the paper strip, carefully lift the compass and draw a small arrow to show the direction of the north-seeking end of the compass. Keep plotting all the way to the right end of the tape.
3. Again, place the compass at the center of the strip of adding machine tape This time slide the compass *slowly* to the *left* along the paper strip As before, whenever the compass needle is parallel ⟶ or perpendicular ↑ to the edge of the paper strip, carefully lift the compass and draw a small arrow to show the direction of the north-seeking end of the compass. Keep plotting all the way to the left end of the tape.
4. Draw a vertical line on the paper strip through every arrow that is parallel to the edge of the paper strip
5. Color in red each section in which the compass needle pointed south
6. Color in blue each section in which the compass needle pointed north

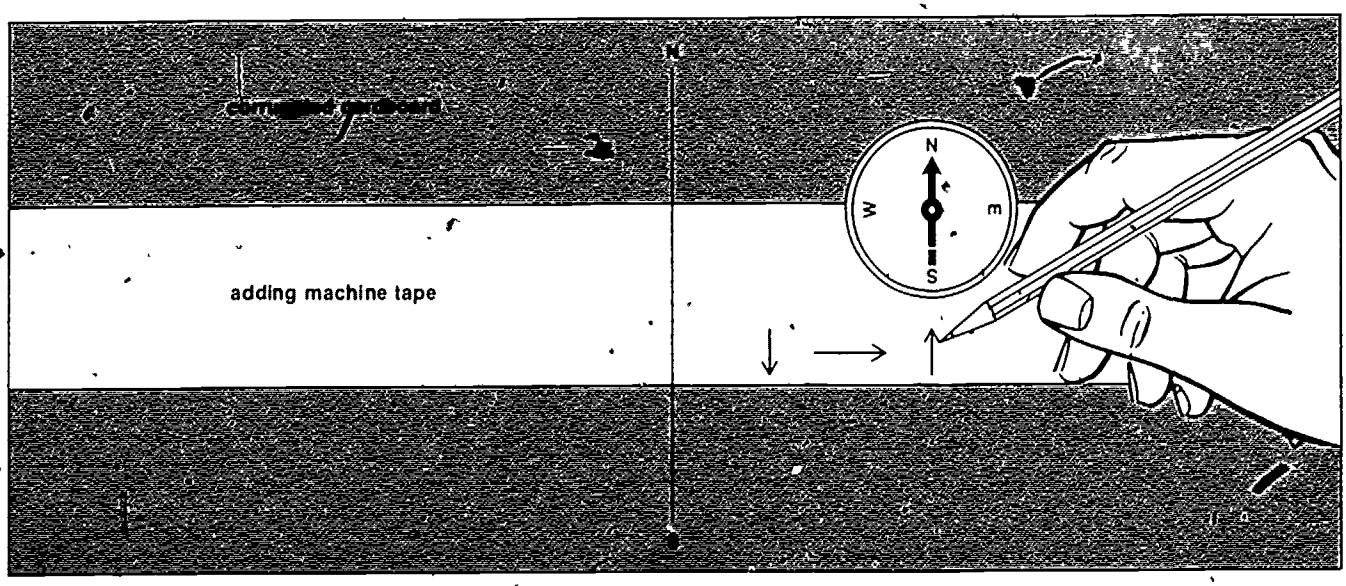

Figure 2. Sea-floor model. Diagram showing how to indicate with a small arrow when the compass needle is parallel or perpendicular to the edge of the paper strip.

Then answer the following questions:

7. How many time intervals of north-seeking (normal) magnetic polarity were found on the model?

8. How many time intervals of south-seeking (reverse) magnetic polarity were found on the model?

9. How does the pattern of magnetism on the right side of the mid-ocean ridge (right side of model) compare with the magnetic pattern on the left side of the mid-ocean ridge?

10 How does the amount of area where there is no normal or reverse polarity (called **transition periods**) compare with the amount of area where there is normal or reverse polarity?

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Figure 3 Diagram showing the magnetic polarity west of British Columbia Areas believed to be of normal magnetic polarity are shown in black Areas believed to be of reverse magnetic polarity are shown in white Black lines that cut across the pattern are faults (Permission granted from Raff and Mason, Bulletin of the Geological Society of America)

PROCEDURE

PART B What causes the sea floor to spread apart?

Materials sea-floor model

Figure 3 is a map of the sea floor west of British Columbia It shows the pattern of magnetic polarity in the area of an ocean ridge. This ocean ridge is called the Juan de Fuca Ridge. Its location is shown by the two arrows on the map.

Compare the map in Figure 3 with the striped map you made of the sea-floor model. Answer the following questions:

1. In what ways is your striped map similar to the map in Figure 3?

2. In what ways is the map in Figure 3 different from yours?

Some years ago, a few earth scientists came up with the idea that ocean ridges were places where the sea floor was spreading apart. Figure 4 shows a way in which this spreading could happen.

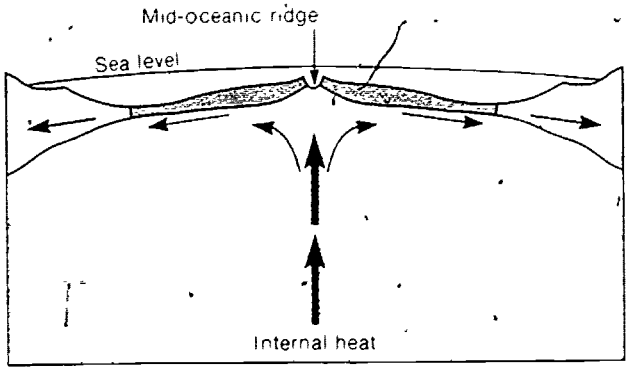

Figure 4 Convection currents are spreading the sea floor away from the ocean ridges

Just having an idea in science is not enough Ideas can often come easy. Getting some proof is often more difficult How could one get some kind of proof for the idea that crustal plates are moving away from ocean ridges?

Interestingly enough, the first real break-through came about because of the reasoning of a 24-year-old graduate student, Frederick Vine. Vine could see that the pattern of magnetic stripes is similar on both sides of mid-ocean ridges (a long submarine ridge found in all major ocean basins of the world, commonly centrally located in the basin and having a prominent valley down the middle) He reasoned that the magnetic pattern reflected the magnetic field recorded in the ocean floor rocks when they were formed. The "duplicate" striped pattern sequence on either side of the ocean ridges was a major finding It provided evidence for the idea that new material (lava) rises to the surface, cools, becomes magnetized and gets carried outward away from both sides of the ridge as the sea floor spreads apart

Figure 5 shows how this process is believed to occur

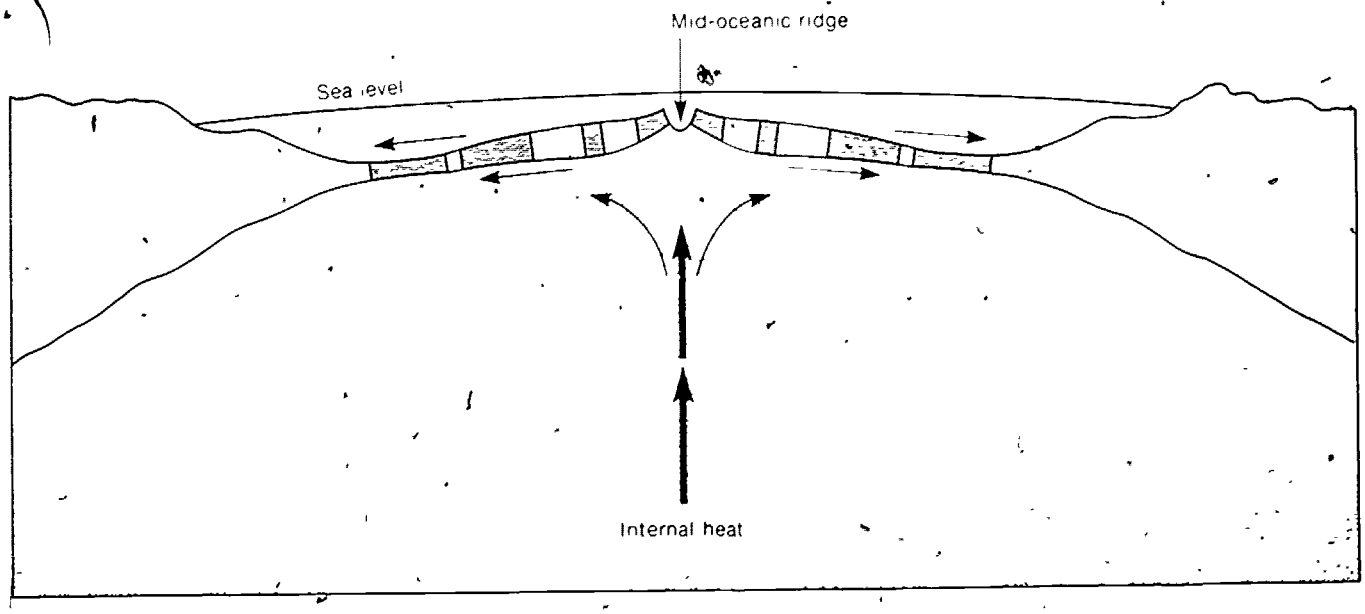

Figure 5 As the lava is brought up at the mid-ocean ridge, the sea floor spreads and it "records" the earth's magnetic field.

3. Why do you think the magnetic stripes are of different width?

Scientists who study **paleomagnetism** (the history of the earth's magnetic field as recorded in the rocks) have been able to work out a paleomagnetic time scale. This time scale shows the intervals of different magnetic polarity. Part of this scale is shown as Figure 6.

4. Using the time scale in Figure 6, determine how many magnetic reversals have taken place in the past 3 million years

5. Look at Figure 3 Start at the ridge marked by the arrows Going east, count the same number of reversals that you determined (in question 4) have taken place in the past 3 million years Measure this distance in kilometers, using the scale at the bottom of Figure 3

6. What is the average rate of spreading during this time? *Hint.* Divide the distance by the time. You will have to convert km into cm. Remember, 1 km = 100,000 cm.

$$\text{Rate} = \frac{\text{Distance in cm}}{\text{Time in years}}$$

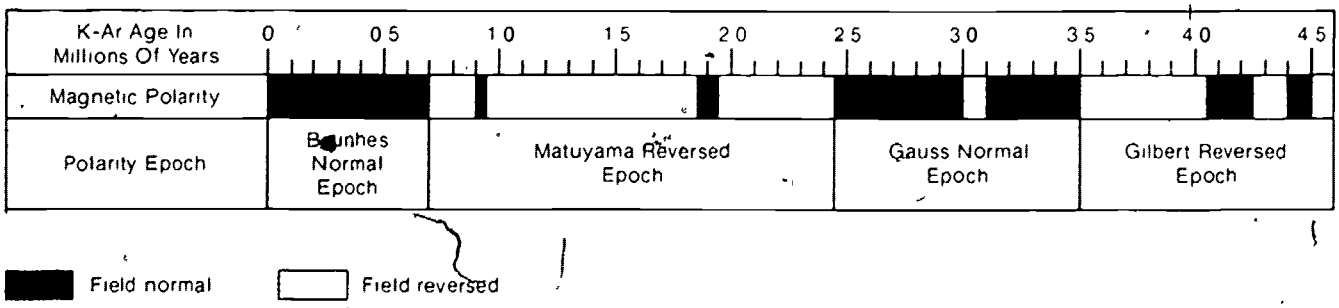

Figure 6. This diagram shows the time intervals of different magnetic polarity during the past 4.5 million years.

SUMMARY QUESTIONS

1. Explain the appearance and nature of the magnetic pattern of the sea floor.

2. Explain how the alternating magnetic stripes of the ocean floor might be formed.

3. Explain why you think that the striping of sea-floor magnetism is either for or against the idea of sea-floor spreading.

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