DOCUMENT RESUME

ED 216 936 SE 038 140

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TITLE Hot Spots in the Earth's Crust. Crustal Evolution Education Project. Teacher's Guide [and] Student Investigation.
INSTITUTION National Association of Geology Teachers.
SPONS AGENCY National Science Foundation, Washington, D.C.
REPORT NO CEEP-MOD-MD5-1-6; ISBN-0-89873-016-3; ISBN-0-89873-017-1
PUB DATE 79
GRANT SED-75-20151; SED-77-08539; SED-78-25104
NOTE 21p.
AVAILABLE FROM Ward's Natural Science Establishment, Inc., P.O. Box 1712, Rochester, NY 14603 (or P.O. Box 1749, Monterey, CA 93940.)

EDRS PRICE MF01 Plus Postage. PC Not Available from EDRS.
DESCRIPTORS *Earth Science; *Geology; Heat; Instructional Materials; *Science Activities; *Science Course Improvement Projects; *Science Curriculum; Science Education; Science Instruction; Secondary Education; *Secondary School Science; Seismology; Teaching Guides; Teaching Methods
IDENTIFIERS *Crustal Evolution Education Project; National Science Foundation; *Plate Tectonics

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. Using volcanic areas ("hot spots") as the focal point, students record patterns existing in familiar earth materials, describe the force necessary to produce these patterns and force produced in areas located over hot spots, identify crustal plates moving rapidly and those moving relatively slowly, describe surface features in a hot spot area, and describe what changes take place as a hot spot continues to develop. (Author/JN)

ED216936

CEEP™

CRUSTAL EVOLUTION EDUCATION PROJECT

Hot Spots In The Earth's Crust

Hot Spots In The Earth's Crust

TEACHER'S GUIDE

Catalog No. 34W1009

For use with Student Investigation 34W1109
Class time: three 45-minute periods

Developed by
THE NATIONAL ASSOCIATION OF GEOLOGY TEACHERS

Produced and Distributed by
Ward's Natural Science Establishment, Inc. Rochester, NY • Monterey, CA

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Hot Spots In The Earth's Crust

INTRODUCTION

In the early 1960s J. Tuzo Wilson, a Canadian earth scientist, initiated a theory that there are hot spots in the mantle from which material rises to the surface of the earth. Wilson suggested that these hot spots could explain the formation of some surface features such as the Hawaiian Islands. He proposed that, as a crustal plate moves over a hot spot, rising molten material punches through the plate (like a cutting torch through a sheet of metal) producing an island.

Expanding upon this idea, some scientists suggested that when a hot spot begins to form it pushes up the earth's surface like an inflating balloon. If this bulging continues, the crust of the earth will split much like the crust of a baking pie, usually forming three cracks about 120° apart.

Recently J. Tuzo Wilson and Kevin Burke have found evidence for more than 100 of these hot spot crack patterns throughout the world. This is an activity in which students will have an opportunity to investigate aspects of the force and characteristic patterns of hot spots.

In previous activities you have examined some of the evidence for the idea that the earth's great crustal plates are moving. Such things as the shape of the coastlines, rock type and magnetic patterns of the ocean floor indicate, for example, that South America and Africa are moving outward from the Mid-Atlantic Ridge

That the plates are moving is generally accepted But it is not possible to determine if both continents are moving (in opposite directions) or if one is stationary and the other is moving away from it Are both Africa and South America moving or is only one moving while the other remains stationary?

Scattered around the earth are more than 100 volcanic areas known to earth scientists as "hot spots" Hot spots, anchored in deep layers of the earth, can be used to help determine which continents are moving and which ones are stationary Where are these hot spots, how do they form and how can they be recognized?

PREREQUISITE STUDENT BACKGROUND

Concepts developed in the module, *Movement Of The Pacific Ocean Floor*, are highly recommended for background understanding before beginning this activity. Basic graphing skills, as well as the ability to measure angles with a protractor, are necessary. (If students are weak in these skills, this activity provides excellent practice.)

OBJECTIVES

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

1. Recognize and record patterns that may exist in familiar earth materials
2. Describe the type of force necessary to produce these patterns
3. Describe the type of force that would be produced in an area located over a hot spot
4. Identify those crustal plates that are thought to be moving rapidly and those that are thought to be relatively stationary
5. Tell what surface features one would expect to find in a hot spot area
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That the plates are moving is generally accepted. But it is not possible to determine if both continents are moving (in opposite directions) or if one is stationary and the other is moving away from it. Are both Africa and South America moving or is only one moving while the other remains stationary?

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MATERIALS

For each group of 3:

- An "undisturbed," dried-up mud puddle
- Tracing paper or clear plastic
- Balloon, 7" or larger
- Can, 10 to 12 oz., one end open
- "Crust mixture"
- Rubber band
- Hot plate
- Map, *The Physical World*. National Geographic Society, Educational Services, Department 79, Washington. D.C. 20036.
- Protractor—one for each student

If the activity cannot be done outdoors, sections of mud cracks can be brought inside or a "pie pan puddle" can be made by pouring a mud slurry into a pie pan or pans, or a cafeteria tray, and allowed to dry overnight in a warm, dry area.

Advance preparation is required for the "balloon" model used in PART B. The balloon should be stretched over a 10 oz. (soup) can. A thin layer of "crust," about 1 mm thick, should be smoothed over the center portion of the balloon and allowed to dry overnight. (See Figure 4.) You should experiment with various types of mixes, such as clay-rich mud, gelatin, patching compounds, etc. A compound that has good adhesion to the balloon, with the right degree of flexibility and brittleness, is required. (Be sure to wash the balloon first to assure good adhesion.) Some materials are too brittle and upon expansion, disintegrate through numerous fractures. Others are so rigid that they do not yield to the tensional strain. One good crustal mixture is a 2:1 mixture of flour and salt with enough water to make a thick, pasty batter. A can should be prepared for each group and allowed to dry for a day. When the students are ready to begin PART B, the cans should be placed on a warm hot plate and removed after the center rises approximately 2 cm.

BACKGROUND INFORMATION

Most volcanic areas are located along mid-ocean ridges or active subduction zones. Some volcanic areas, however, are located in the centers of crustal plates. Wilson, Burke and others have referred to these areas as "hot spots" and have suggested that these volcanoes could be the result of relatively stable zones of hot rising material that originate in the mantle. Crustal plates that are moving relatively rapidly appear to have little or no hot spot development. More stable crustal plates have larger concentrations of visible surface features of hot spots. Radioactive decay has been hypothesized as a source of the heat. Convection of hot material in the mantle has been suggested as the force which moves the crustal plates.

There is evidence that if convection does occur, it takes place only in that part of the mantle comprising the comparatively plastic asthenosphere. Based upon small-scale experiments with clay and putty-like material, it has been shown that convection does not take place in long continuous lines such as mid-ocean ridges. What typically happens is that the rising, less dense material pokes its way up in bloblike columns.

Since the earth scientist is not able to duplicate in the laboratory the high pressures that exist in the mantle, it is impossible to conduct an accurate experiment to determine what form convection might take in the mantle. As naturalists, earth scientists have to turn to the earth itself to see if it offers any hints about hot spot characteristics.

In areas where continental crust is being domed upward, there is evidence for tensional forces acting primarily in the horizontal plane. These forces eventually rupture the crust, forming three vertical fractures that radiate out from a center or centers, ideally forming three 120° angles. As the dome continues to grow, two of the cracks will continue to develop while the third becomes less active; it is said to be the "failed arm" of the juncture. Over 100 of these hot spot areas have been identified. One of the best examples is in the Middle East. With the Arabian Peninsula to the north and east Africa to the south, the Red Sea and Gulf of Aden form two of the arms, with the African Rift Valley as the third or failed arm of the juncture. These three features lie approximately 120° apart from each other. In addition to providing a reference standard by which actual plate motion can be measured, the study of hot spots in recent years has provided valuable insight into the geological formation of many areas all over the world.

SUGGESTED APPROACH

Students should work in groups of two or three while they are accumulating data. However, graphing, data interpretation and answering questions should be done individually so that each student can discover the basic patterns and concepts.

Be careful not to tell the students what is happening in PART B, or how the balloon model relates to the interpreted "real world" situation. It is important that students be allowed to make their own inferences. Appropriateness and limitations of the model can be discussed at the end of PART B. The map, *The Physical World*, if not available for each group, can be posted in the classroom.

PROCEDURE

PART A What patterns can you see in cracked mud?

Students record and determine the pattern of mud cracks.

Key words: "best fit" line, mean, mud crack juncture, compression, tension

Time required: one 45-minute period

Materials an "undisturbed," dried-up mud puddle, protractor, tracing paper or sheet of clear plastic

1. Locate a dried-up mud puddle on the school grounds or, if this is not possible, use previously prepared "pie pan" mud puddles

2. Carefully sketch the mud crack pattern onto tracing paper or a sheet of clear plastic

3. Using your protractor, measure all the angles at the juncture of a mud crack (There should be three angles to measure for each juncture) See Figure 1a Since mud cracks do not make perfectly straight lines, a **best fit straight line** should be sketched before measuring the angles A best fit straight line is one that averages out the crooks in the actual crack See Figure 1b

Measure the angles surrounding 10 **mud crack junctures.** Record all angles on the Student Data Sheet (Worksheet 1) Try to be consistent in measuring For instance, first measure the angle on the left and then, going clockwise, measure the other two angles See Figure 1

4. Determine the mean (average) number of degrees for each mud crack juncture Record this data at the bottom of each column of Worksheet 1

5. Graph the data from columns 1, 2 and 3 of the Student Data Sheet (Worksheet 1) onto the Student Graph Sheet (Worksheet 2)

6. Using Worksheet 2, determine the most likely juncture angle made by mud cracks (Hint First determine the most common range and then the mean)

Using representative data from actual mud cracks, the most common angles range between 105° and 135°. The mid-point of this range is 120°. Students should obtain similar results.

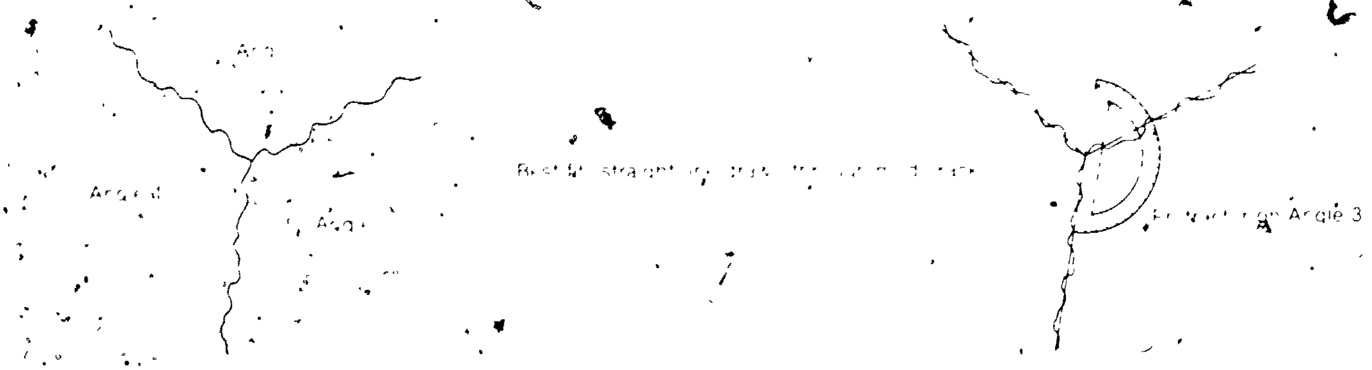


Figure 1 Mud crack pattern

a A mud crack juncture and the three surrounding angles.

b "Best fit" straight lines are drawn through the mud cracks A protractor is used to measure the angles

7. From Worksheet 1, what is the smallest juncture angle you recorded?

Although this will vary somewhat, 88° is the smallest juncture angle in the representative data.

What is the greatest juncture angle you recorded?

Although this will vary somewhat, 164° is the greatest juncture angle in the representative data.

What is the most commonly occurring juncture angle you recorded?

The range between 105°–135° is the most commonly occurring range. The mid-point of this range is 120°.

8. The branches of a tree are said to make a random pattern. Does the pattern made by the mud cracks appear to be random? Explain

Unlike the random pattern of a tree's branches, mud cracks intersect in a preferred manner. Typically, a mud crack juncture consists of the intersection of three cracks with a 120° angle of separation.

9. Why do you suppose mud cracks form?

As a mud crack dries, tensional stress builds up as a result of the change in volume that occurs in the mud. Tensional cracks develop in response to this stress.

Two main types of force are evident on the earth. One type of force occurs when things are squeezed. This type of force is called compression. The other type of force occurs when things are pulled. This type of force is called tension.

10. What type of force, compression or tension, do you think is at work during the forming of mud cracks? Why?

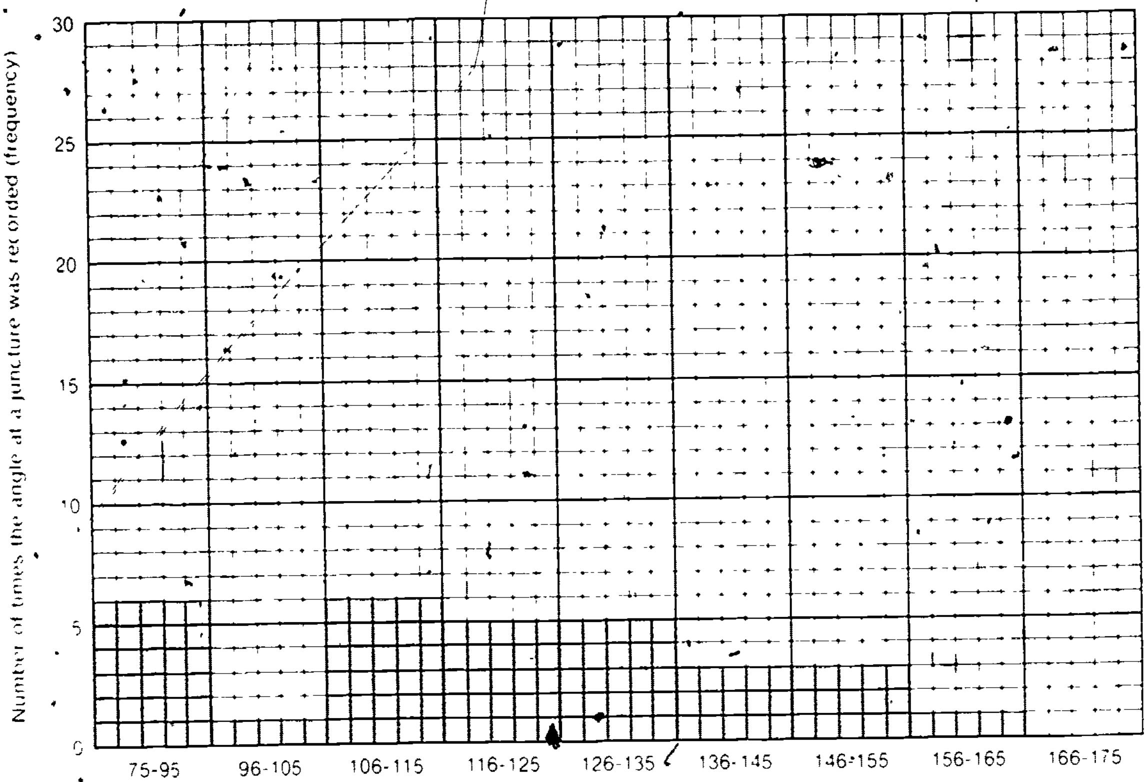
Tension. The preference for mud cracks to intersect at approximately 120° indicates a force that is pulling the sides of the mud cracks apart.

Student Data Sheet
(sample figures only)

Mud Crack Juncture Number	*Number of Degrees Between First Set of Cracks (Angle 1)*	*Number of Degrees Between Second Set of Cracks (Angle 2)*	*Number of Degrees Between Third Set of Cracks (Angle 3)*
1	128°	112°	120°
2	130°	90°	140°
3	126°	130°	104°
4	120°	146°	94°
5	90°	106°	164°
6	143°	122°	95°
7	92°	150°	118°
8	115°	132°	113°
9	147°	125°	88°
10	107°	108°	145°

$$\text{Mean} = \frac{\text{sum of 10 angles above}}{10} \qquad \text{Mean} = \frac{\text{sum of 10 angles above}}{10} \qquad \text{Mean} = \frac{\text{sum of 10 angles above}}{10}$$

$$\text{Mean} = \frac{1198}{10} = 119.8^\circ \qquad \text{Mean} = \frac{1221}{10} = 122.1^\circ \qquad \text{Mean} = \frac{1181}{10} = 118.1^\circ$$



Answer Sheet 2 (PART A)

PROCEDURE

PART B What kind of pattern in the earth's crust is formed over hot spots?

Students study the tensional force of hot spots and plate movement with a balloon model.

Key words: none

Time required: one 45-minute period

Materials balloon, can, "crust mixture," hot plate, rubber band

1. Stretch a portion of the balloon over the top of the can as shown in Figure 2

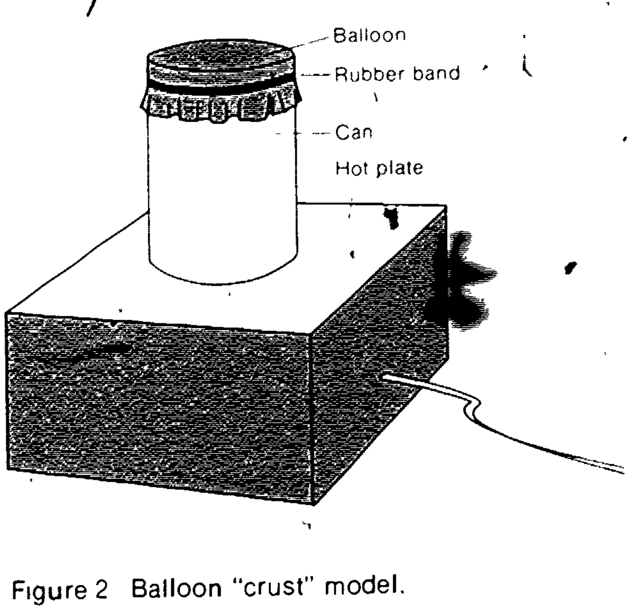
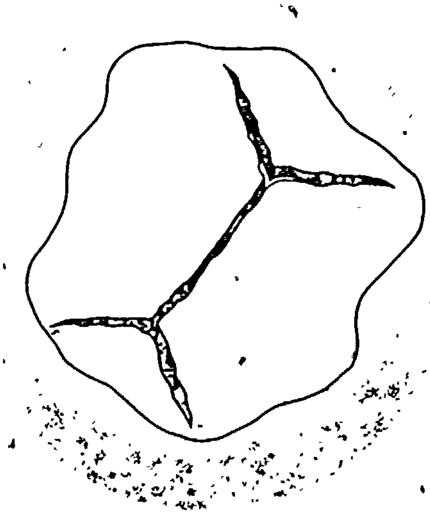


Figure 2 Balloon "crust" model.

2. Spread a light coat of the "crust mixture" over the surface of the balloon (mostly near the center, not clear out to the edge) and allow enough time for the mixture to set up (Your teacher may have prepared this for you in advance)

3. Place the can on a warm hot plate As the balloon expands, observe what changes take place in the crust mixture BE CAREFUL NOT TO GET THE HOT PLATE TOO HOT! JUST WARM. AS SOON AS THE BALLOON DOMES UP, THE CAN SHOULD BE REMOVED FROM THE HOT PLATE

4. Here make an accurate sketch of the cracks in the crust mixture after the balloon domed up.



(looking down on the top of the can after doming)

5. What type of force, compression or tension, was acting on the center of the balloon and crust mixture when the can was heated?

Tension

6. Measure the angles surrounding the major juncture(s) in the sketch above. (Be certain to use best fit straight lines.) Is there any similarity between these angles and the mud crack angles measured in PART A?

As with the mud cracks, these angles should be about 120°.

7. Does the pattern of cracks (on the can) suggest the presence of the force indicated in question 5 above? Explain.

The pattern of cracks with a near 120° preference suggests the presence of a tensional force acting along the surface of the balloon.

8. What pattern of cracks would you expect to find in the earth's crust over "hot spots"?

Because of the doming upward of the earth's crust over a hot spot area, a similar 120° preference crack (or fracture) pattern would be expected.

When a crustal plate comes to rest over a hot spot, the hot material coming up from deep layers forms a dome. Almost all hot spots are areas of broad crustal domes. Over 100 of these hot spots have been found. About 50 of these are in ocean basins, and 70 are on continents. It is believed that on moving continental plates, hot spot domes do not have a chance to become well developed. It is thought that the uplifting dome is smeared out, making it difficult to detect. On relatively stable continental plates, upwelling material has enough time to build a broad crustal dome.

9. Look at Figure 3. Which crustal plate has the greatest number of hot spots?

The African Plate

10. What does this indicate about the movement of this crustal plate?

The large number of hot spots indicates relatively little or no movement of the African Plate.

11. What does the number of hot spots on the South American Plate suggest about the movement of this plate?

The lack of hot spot areas in South America indicates that this crustal plate is moving relatively rapidly, having the effect of "smearing" out any hot spots that might be present under the continental crust.

If the above ideas are correct, the South Atlantic Ocean is widening largely from the movement of the **South American** crustal plate.

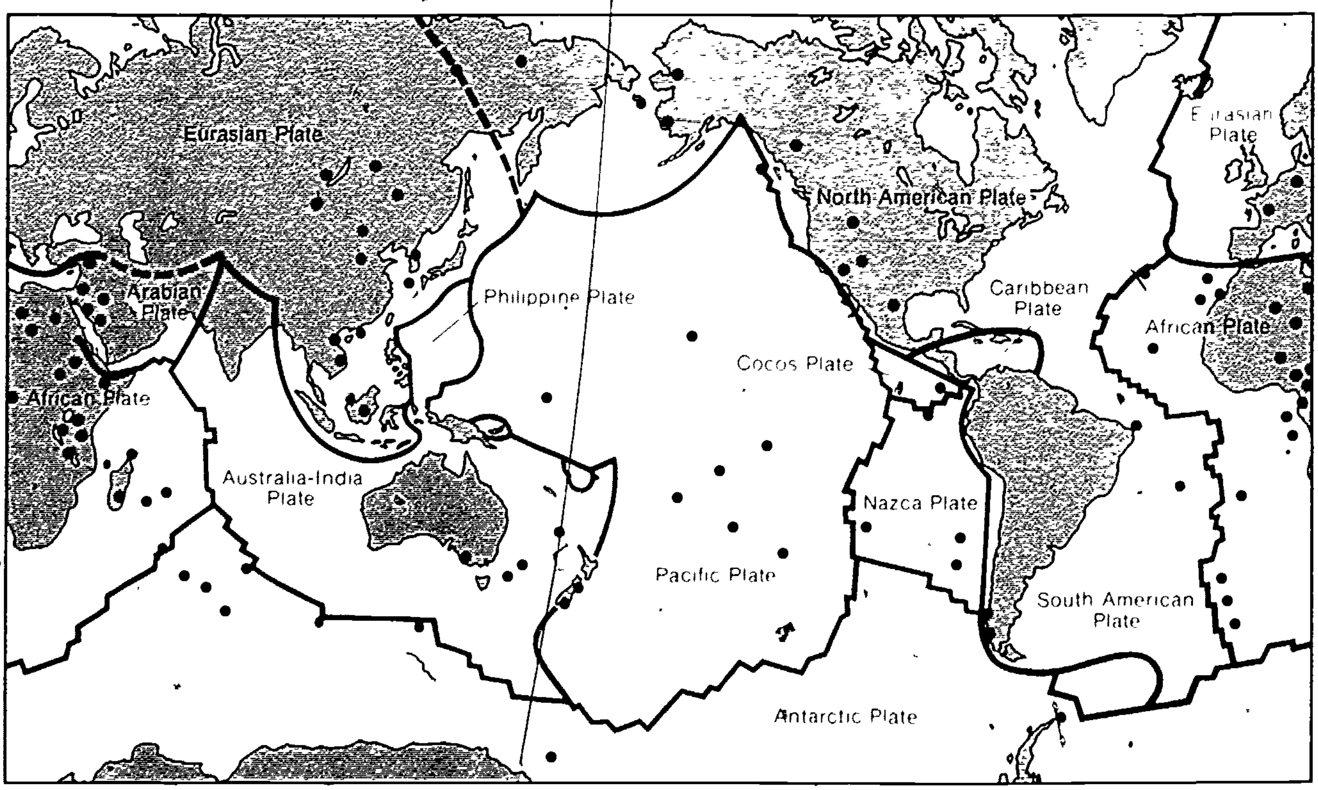


Figure 3. Distribution of Hot Spots. Over 100 hot spots and areas of crustal doming have developed during the past 10 million years (modified from Burke and Wilson, 1976).

PROCEDURE

PART C. Are the earth's crustal plates under tension?

Students relate the mud crack and the crustal mixture patterns to the characteristic triple-juncture pattern of hot spot domes.

Key word: failed arm

Time required: one 45-minute period

Materials: map, *The Physical World*, tracing paper, pencil, protractor

Some earth scientists have suggested that as the hot spot dome continues to develop, two of the cracks will continue to enlarge while one of the cracks becomes less active. The inactive crack is called the **failed arm** of the three-armed pattern See Figure 4

One such hot spot area that has been studied recently is in east Africa. This area lies between Ethiopia and the Arabian Peninsula. It is called the Afar Triangle If you find the lowest spot in Africa (512 feet below sea level, near Lake Assal) on *The Physical World* map, you will have found the center of what is believed to be a three-armed juncture

1. What evidence exists for a developing dome with a three-armed juncture pattern? To help collect the evidence, use tracing paper to make a tracing from *The Physical World* map of each of the following features the Red Sea, Gulf of Aden and the East African Rift Valley (between the Somali Peninsula and the Ethiopian Highlands) Draw a best fit straight line through each of these features. Using your protractor, measure the number of degrees between them

a) the Red Sea and the Gulf of Aden
approximately 112°

b) the Gulf of Aden and the African Rift Valley
approximately 145°

c) the African Rift Valley and the Red Sea
approximately 103°

There is some distortion in the projection of this map, but it can be discounted here and elsewhere in this activity.

2. Is there any similarity between these angles and the mud crack angles measured in PART A, and the crustal mixture crack angles measured in PART B?

Yes, a three-armed pattern with a 120° preference.

3. What type of force is likely to be present in the Afar Triangle area?

Tensional force.

4. What geographic feature is considered to be the failed arm of the juncture pattern?

The African Rift Valley that runs southwestward from Lake Assal and east of the Mitumba Mountain Range.

5. Look at the Earth's Crust Map on the bottom right of *The Physical World* map The yellow dots represent the location of earthquakes Is there any evidence that earthquakes are associated with developing hot spot domes? Explain

Yes. A large number of earthquakes appear to be concentrated in the three-armed pattern created by the Red Sea, Gulf of Aden and African Rift Valley zone.

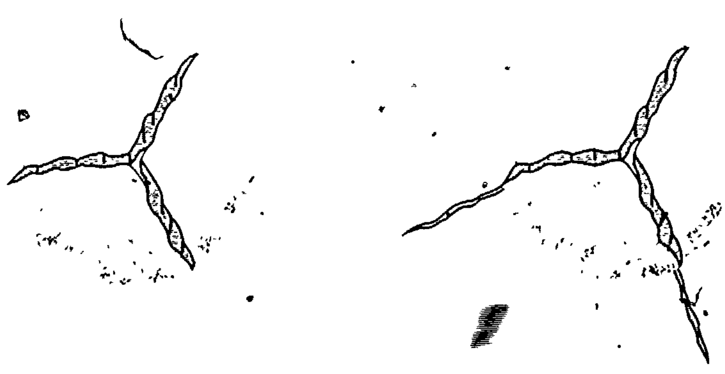


Figure 4 Development of a three-armed juncture pattern As the dome continues to bulge upward, two of the cracks continue to enlarge while the third arm, the failed arm, becomes inactive

6. Look again at the Distribution of Hot Spots, Figure 3. Is there any evidence that the junctures of some of the earth's crustal plates are under tension?

Yes. Many of the crustal plates form junctures that have this characteristic 120° pattern.

What would be the relative movement of the above plates?

The relative movement is away from the juncture.

7. What do you suppose would happen if a row of hot spots developed on a continent?

If a row of hot spots developed on a continent, the continent would develop a split or rift. If the split continued to enlarge, a new ocean could be created. The failed arms of the junctures could become rift zones or river valleys that would empty into the newly created ocean.

SUMMARY QUESTIONS

1. What type of force is present in the area of a crustal hot spot?

A tensional force.

2. What conditions are necessary to produce a three-armed juncture pattern in the earth's crust?

A relatively stable continent and tensional stress created by a hot spot.

3. How can hot spots be used to determine which continents are moving and which ones are stationary?

Continents that have relatively rapid movement are not stabilized in one location long enough for the deep-seated hot spots to develop surface domes and related three-armed fracture patterns. Consequently, those continents without hot spots are considered to have relatively rapid motion. Continents that do have extensive hot spot development can be interpreted to be relatively stable continents with little or no motion.

EXTENSION

Students should be encouraged to look for the surface expression of three-armed junctures in hot spot areas. Some of these are well defined by rift zones and/or river valleys, while others are at best tenuous from surface expressions portrayed on the map, *The Physical World*. Students should use the Distribution of Hot Spots (Figure 3) to locate the positions and *The Physical World* map to illustrate the surface features of these hot spots.

Using the Distribution of Hot Spots (Figure 3) to locate the position of hot spots and *The Physical World* map to illustrate the surface features present at these locations, determine what hot spot areas have well developed three-armed patterns.

REFERENCE

Burke, K.C. and Wilson, J. Tuzo, 1976, Hot spots on the earth's surface. *Scientific American*, v. 235, no. 2 (Feb.), p. 46-57.

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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CEEP MODULE NO. MD5 1-6
-89873-016-3

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CEEP

CRUSTAL EVOLUTION EDUCATION PROJECT

NAME DATE

Student Investigation

Catalog No 34W1109

Hot Spots In The Earth's Crust

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OBJECTIVES

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

1. Recognize and record patterns that may exist in familiar earth materials
2. Describe the type of force necessary to produce these patterns
3. Describe the type of force that would be produced in an area located over a hot spot.
4. Identify those crustal plates that are thought to be moving rapidly and those that are thought to be relatively stationary
5. Tell what surface features one would expect to find in a hot spot area.
6. Describe what changes take place as a hot spot continues to develop

PROCEDURE

PART A What patterns can you see in cracked mud?

Materials an "undisturbed," dried-up mud puddle, protractor, tracing paper or sheet of clear plastic

1. Locate a dried-up mud puddle on the school grounds or, if this is not possible, use previously prepared "pie pan" mud puddles

2. Carefully sketch the mud crack pattern onto tracing paper or a sheet of clear plastic

3. Using your protractor, measure all the angles at the juncture of a mud crack (There should be three angles to measure for each juncture) See Figure 1a Since mud cracks do not make perfectly straight lines, a **best fit straight line** should be sketched before measuring the angles A best fit straight line is one that averages out the crooks in the actual crack See Figure 1b

Measure the angles surrounding 10 **mud crack junctures.** Record all angles on the Student Data Sheet (Worksheet 1) Try to be consistent in measuring For instance, first measure the angle on the left and then, going clockwise, measure the other two angles See Figure 1

4. Determine the **mean** (average) number of degrees for each mud crack juncture Record this data at the bottom of each column of Worksheet 1

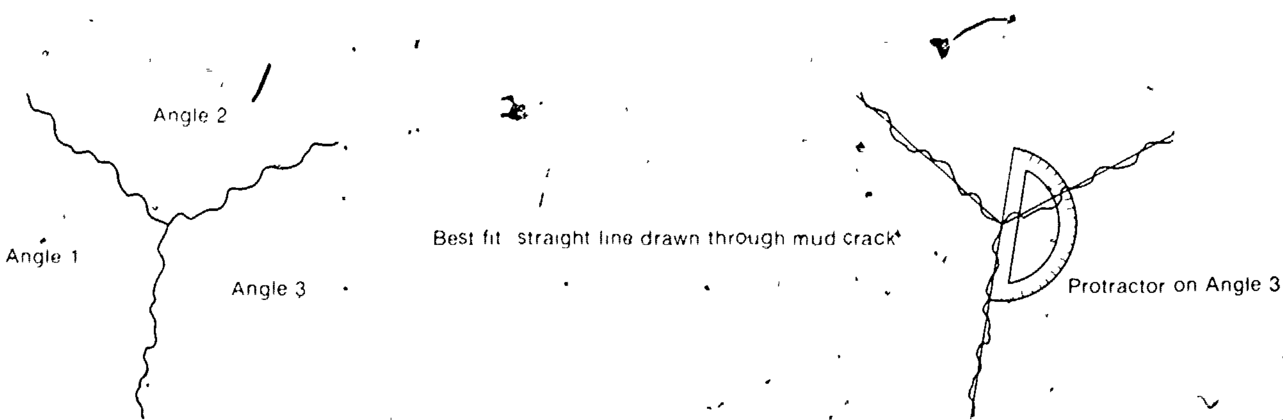
5. Graph the data from columns 1, 2 and 3 of the Student Data Sheet (Worksheet 1) onto the Student Graph Sheet (Worksheet 2)

6. Using Worksheet 2, determine the most likely juncture angle made by mud cracks (Hint. First determine the most common range and then the mean)

7. From Worksheet 1, what is the smallest juncture angle you recorded?

What is the greatest juncture angle you recorded?

What is the most commonly occurring juncture angle you recorded?



a A mud crack juncture and the three surrounding angles

b "Best fit" straight lines are drawn through the mud cracks A protractor is used to measure the angles.

Figure 1 Mud crack pattern.

Student Data Sheet

Mud Crack Juncture Number	Number of Degrees Between First Set of Cracks (Angle 1)	Number of Degrees Between Second Set of Cracks (Angle 2)	Number of Degrees Between Third Set of Cracks (Angle 3)
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			

$$\text{Mean} = \frac{\text{sum of 10 angles above}}{10} \qquad \text{Mean} = \frac{\text{sum of 10 angles above}}{10} \qquad \text{Mean} = \frac{\text{sum of 10 angles above}}{10}$$

This space for calculations

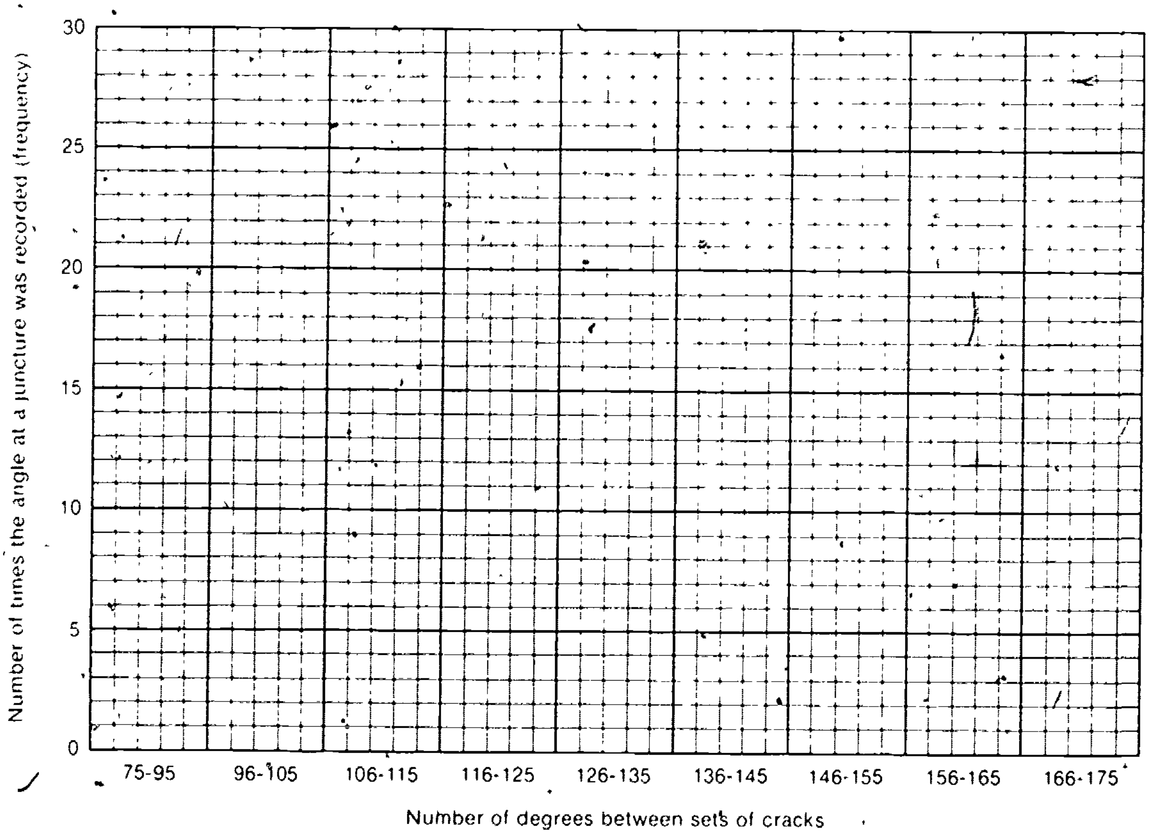
Worksheet 1 (PART A)

8. The branches of a tree are said to make a random pattern. Does the pattern made by the mud cracks appear to be random? Explain.

9. Why do you suppose mud cracks form?

Two main types of force are evident on the earth. One type of force occurs when things are squeezed. This type of force is called **compression.** The other type of force occurs when things are pulled. This type of force is called **tension.**

10. What type of force, compression or tension, do you think is at work during the forming of mud cracks? Why?



PROCEDURE

PART B What kind of pattern in the earth's crust is formed over hot spots?

Materials balloon, can, "crust mixture," hot plate, rubber band

1. Stretch a portion of the balloon over the top of the can as shown in Figure 2

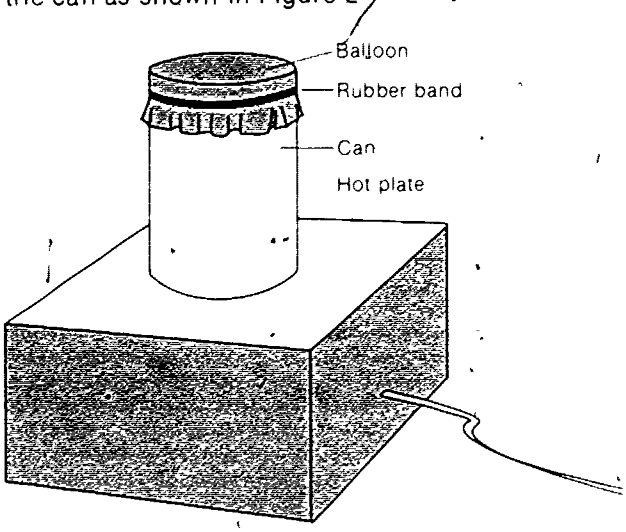
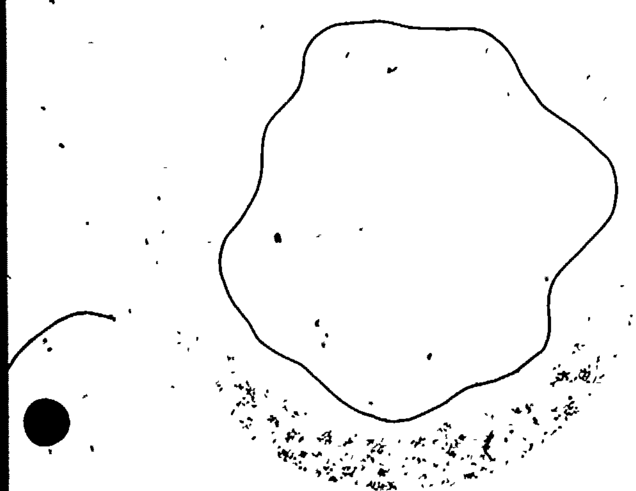


Figure 2 Balloon "crust" model

2. Spread a light coat of the "crust mixture" over the surface of the balloon (mostly near the center; not clear out to the edge) and allow enough time for the mixture to set up (Your teacher may have prepared this for you in advance.)

3. Place the can on a warm hot plate. As the balloon expands, observe what changes take place in the crust mixture BE CAREFUL NOT TO GET THE HOT PLATE TOO HOT! JUST WARM. AS SOON AS THE BALLOON DOMES UP, THE CAN SHOULD BE REMOVED FROM THE HOT PLATE

4. Here make an accurate sketch of the cracks in the crust mixture after the balloon domed up



(Looking down on the top of the can after doming)

5. What type of force, compression or tension, was acting on the center of the balloon and crust mixture when the can was heated?

6. Measure the angles surrounding the major juncture(s) in the sketch above (Be certain to use best fit straight lines) Is there any similarity between these angles and the mud crack angles measured in PART A?

7. Does the pattern of cracks (on the can) suggest the presence of the force indicated in question 5 above? Explain

8. What pattern of cracks would you expect to find in the earth's crust over "hot spots"?

When a crustal plate comes to rest over a hot spot, the hot material coming up from deep layers forms a dome Almost all hot spots are areas of broad crustal domes. Over 100 of these hot spots have been found. About 50 of these are in ocean basins, and 70 are on continents. It is believed that on moving continental plates, hot spot domes do not have a chance to become well developed. It is thought that the uplifting dome is smeared out, making it difficult to detect On relatively stable continental plates, upwelling material has enough time to build a broad crustal dome

9. Look at Figure 3 Which crustal plate has the greatest number of hot spots?

10. What does this indicate about the movement of this crustal plate?

11. What does the number of hot spots on the South American Plate suggest about the movement of this plate?

If the above ideas are correct, the South Atlantic Ocean is widening largely from the movement of the _____________ crustal plate

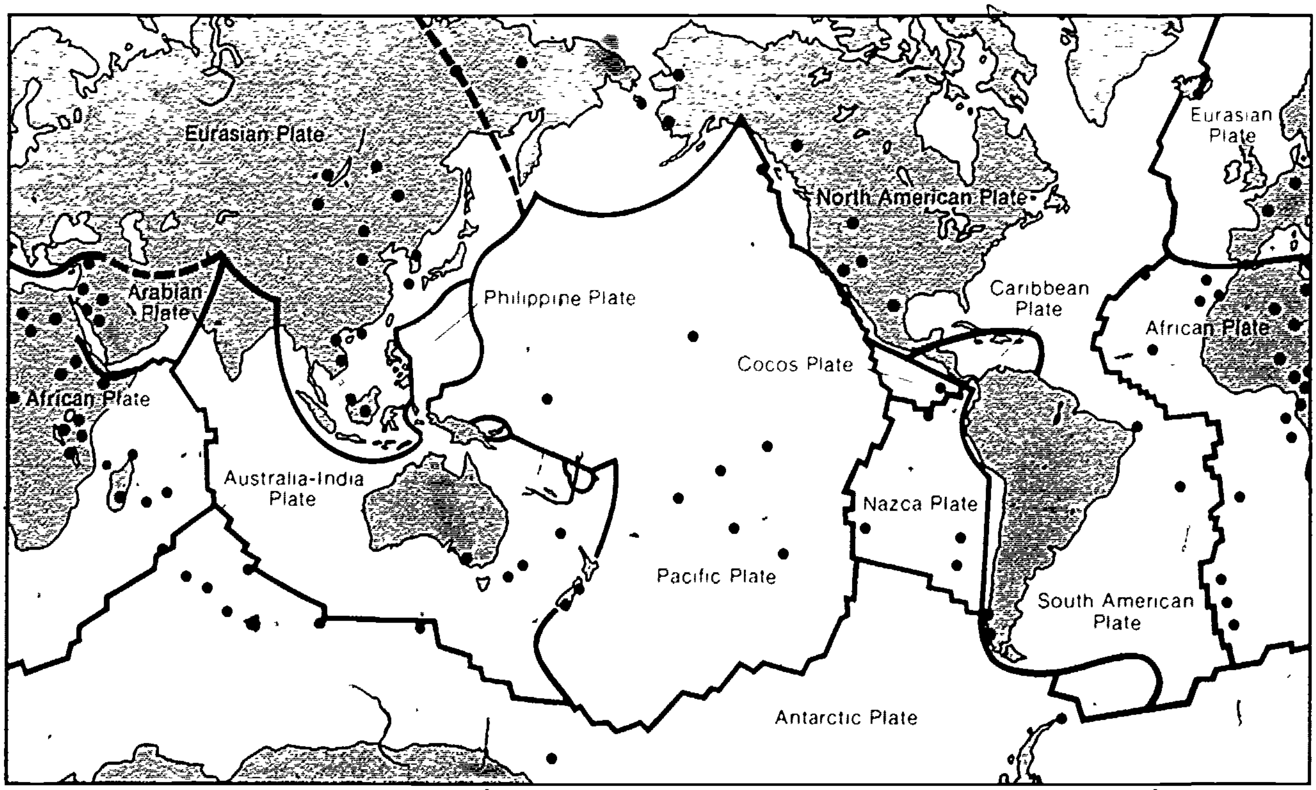


Figure 3 Distribution of Hot Spots. Over 100 hot spots and areas of crustal doming have developed during the past 10 million years (modified from Burke and Wilson, 1976).

PROCEDURE

PART C Are the earth's crustal plates under tension?

Materials map, *The Physical World*, tracing paper, pencil, protractor

Some earth scientists have suggested that as the hot spot dome continues to develop, two of the cracks will continue to enlarge while one of the cracks becomes less active The inactive crack is called the **failed arm** of the three-armed pattern See Figure 4

One such hot spot area that has been studied recently is in east Africa This area lies between Ethiopia and the Arabian Peninsula It is called the Afar Triangle If you find the lowest spot in Africa (512 feet below sea level, near Lake Assal) on *The Physical World* map, you will have found the center of what is believed to be a three-armed juncture

1. What evidence exists for a developing dome with a three-armed juncture pattern? To help collect the evidence use tracing paper to make a tracing from *The Physical World* map of each of the following features the Red Sea, Gulf of Aden and the East African Rift Valley (between the Somali Peninsula and the Ethiopian Highlands)

Draw a best fit straight line through each of these features Using your protractor, measure the number of degrees between them

a) the Red Sea and the Gulf of Aden

____

b) the Gulf of Aden and the African Rift Valley

____

c) the African Rift Valley and the Red Sea

____

2. Is there any similarity between these angles and the mud crack angles measured in PART A, and the crustal mixture crack angles measured in PART B?

3. What type of force is likely to be present in the Afar Triangle area?

4. What geographic feature is considered to be the failed arm of the juncture pattern?

5. Look at the Earth's Crust Map on the bottom right of *The Physical World* map The yellow dots represent the location of earthquakes Is there any evidence that earthquakes are associated with developing hot spot domes? Explain

Figure 4 Development of a three-armed juncture pattern As the dome continues to bulge upward, two of the cracks continue to enlarge while the third arm, the failed arm, becomes inactive

6. Look again at the Distribution of Hot Spots, Figure 3 Is there any evidence that the junctures of some of the earth's crustal plates are under tension?

What would be the relative movement of the above plates?

7. What do you suppose would happen if a row of hot spots developed on a continent?

SUMMARY QUESTIONS

1. What type of force is present in the area of a crustal hot spot?

2. What conditions are necessary to produce a three-armed juncture pattern in the earth's crust?

3. How can hot spots be used to determine which continents are moving and which ones are stationary?

EXTENSION

Using the Distribution of Hot Spots (Figure 3) to locate the position of hot spots and *The Physical World* map to illustrate the surface features present at these locations, determine what hot spot areas have well developed three-armed patterns

REFERENCE

Burke, K C and Wilson, J Tuzo, 1976, Hot spots on the earth's surface *Scientific American*, v 235, no 2 (Feb), p 46-57

Developed by
THE NATIONAL ASSOCIATION OF GEOLOGY TEACHERS

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

WARD'S

Ward's Natural Science Establishment, Inc. Rochester, NY • Monterey, CA

ISBN 0-89873-017-1
Printed in U.S.A.