CRUSTAL EVOLUTION EDUCATION PROJECT
Student Investigation
Catalog No. 34W1129

Volcanoes: Where And Why?

TEACHER'S GUIDE

NOTE: Text in italics found only in the Teacher's Guide

Volcanoes: Where and Why?

INTRODUCTION

In these activities, the students find the differences in the chemical compounds that make up various rocks, plot a number of volcano sites in and around the Pacific and relate their observations to plate boundaries and motions.

Geologists group volcanoes by the different kinds of rocks they produce. Some ways in which volcanic rocks differ are in color, texture (size of crystals), mineral composition and chemical composition. Let's look at volcanoes and their rocks in one of these ways.

PREREQUISITE STUDENT BACKGROUND

In order to do these activities the students should have a basic knowledge of chemical compounds, igneous rocks, plate motions (including subduction zones) and use of latitude and longitude to plot locations.

OBJECTIVES

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

1. Tell one way in which volcanoes differ, and use this difference to classify them into certain groups.

2. Explain why groups of volcanoes are different.

3. Show on a map where groups of volcanoes of different kinds are located.

MATERIALS

Black, red and blue pencils for each student

BACKGROUND INFORMATION

Volcanic rocks are formed by molten rock that originates within the earth's crust and solidifies by cooling on the earth's surface, either on land or underwater. Most volcanic rocks are erupted through volcanoes, but some may come up through fissures and other types of vents.

There are many different kinds of volcanic rocks, and almost as many ways of classifying them. Some of the properties that have been found useful for classification are color, texture (e.g., size of crystals), mineral composition and chemical composition. Chemical composition is probably the most reliable property, but it is also the most difficult and expensive to determine.

Basalt, andesite and rhyolite are names given to three of the most common types of volcanic rocks in practically all classifications. These rocks differ significantly in their mineral and chemical compositions. Basalt is dark-colored because it contains dark-colored minerals in abundance. Rhyolites are lighter in color because they contain light-colored minerals. The color of andesite is usually in between basalt and rhyolite.

Differences in color and in mineral composition reflect differences in chemical composition. Basalts contain the greater amounts of iron, calcium and magnesium and the least amount of silica. Rhyolite contains lots of silica—enough, in fact, that quartz (5102) crystals can form. The amount of silica in volcanic rocks is used in this activity to classify them as basalt, andeslte or rhyolite.

The students can learn some important characteristics about the earth's crust by determining the chemical composition of volcanic rocks and then classifying them. Representative chemical analyses, for example, indicate that basalt Is the only type of volcanic rock to occur in the deep ocean; rhyolite occurs only on continental areas and andesite is typically found along the margins of continents. There are exceptions to this simple scheme (basalt, for example, is not restricted to the ocean), but it is generally true.

Generally, then, the earth's crust beneath the ocean is of basaltic composition, whereas the crust beneath the continents tends to be rhyolitic. Andesite, which is part way between basalt and rhyolite in its silica content, characterizes theareas where oceanic and continental crustal material tends to overlap.

This can best be explained by plate tectonics. Molten rock that comes to the surface in the Pacific and other ocean areas, flows out as basaltic lava. This will be low in silica. The same basalt, coming from the subduction zone up through the edge of the continent, is mixed with continental rock material, so the silica content of the andesitic lava will be somewhat higher. The highest silica content is found farther into the continent where the rhyolite lava is continental rock rather than ocean-bottom rock.

SUGGESTED APPROACH

Basically, these activities should be carried out by the students as independent inquiry. The students can work through the various steps at their own pace. At the end of the activities encourage the students to discuss their conclusions. You may wish to contribute some additional information on the subject.

PROCEDURE

PART A: Where are most volcanoes located?

In this activity the students plot the location of volcanoes and relate them to plate boundaries.

Key words: none

Time required: one 45-minute period

Materials: black pencil

1. Write down the names of all the volcanoes you can think of that are in or around the Pacific Ocean.

Give students some time to do this.

2. Compare your list with the rest of the class.

Let them expand their lists by comparing with others in the class.

3. Table 1 lists the locations of 30 volcanoes. You or others in your class may have named some of these. Plot the location of all the volcanoes in Table 1 on the map on the Worksheet. (Use latitude and longitude to find the places.) Write the name of the volcano next to each location.

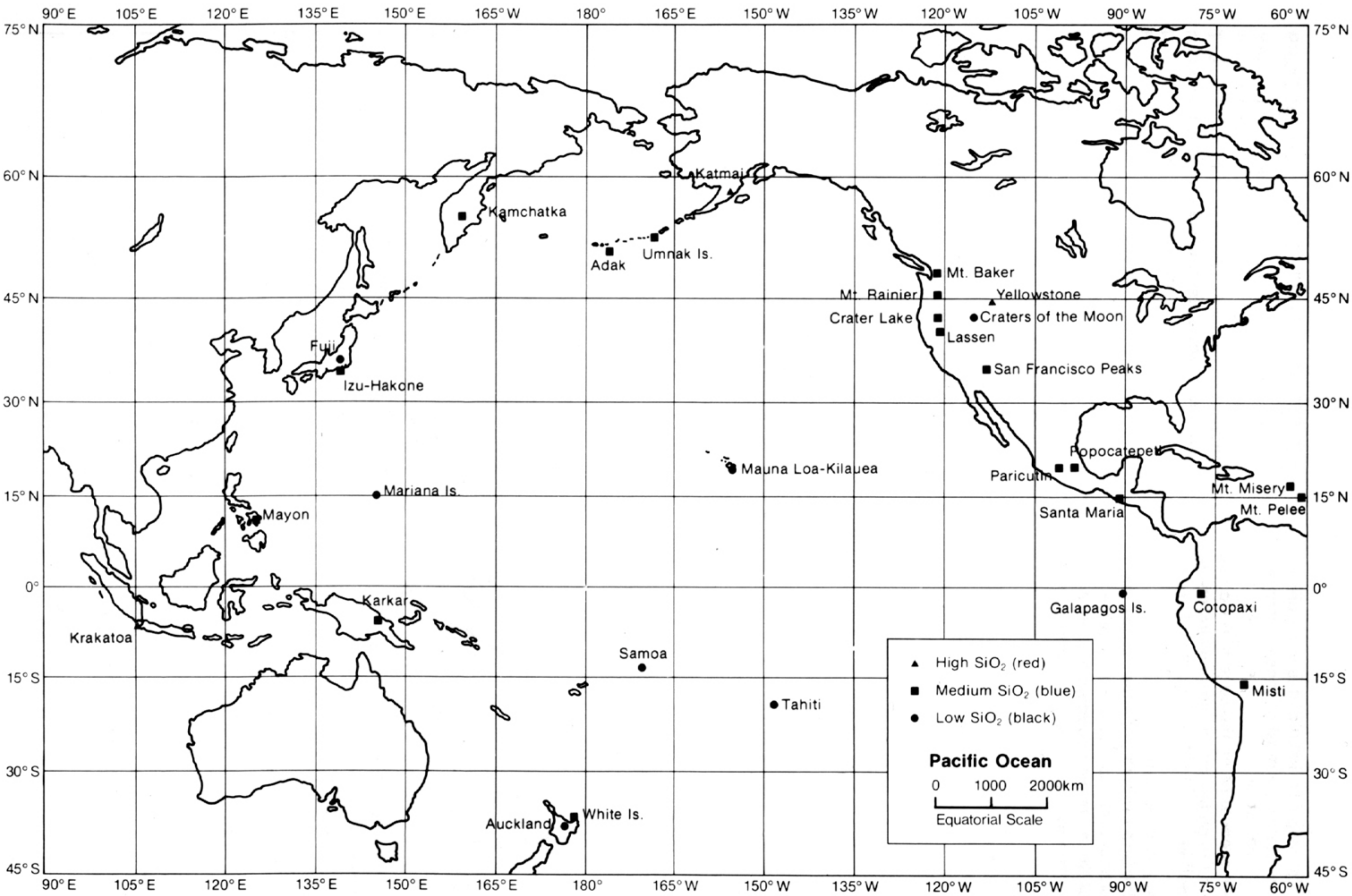
See Answer Sheet.

4. Where are most of these volcanoes located?

Most are around the edge of the Pacific Ocean. Some are farther inland, and some are In the ocean far from continents.

Table 1.
Locations of volcanoes

	Latitude (approximate)	Longitude (approximate)
Western United States, Pacific Border		
Lassen, California	40°N	121°W
Crater Lake, Oregon	43°N	122°W
Mt. Rainier, Washington	47°N	122°W
Mt. Baker, Washington	49°N	122°W
Western United States, Western Interior		
Yellowstone Park, Wyoming	45°N	111°W
Craters of the Moon, Idaho	43°N	114°W
San Francisco Peaks, Arizona	35°N	112°W
Central America and West Indies		
Paricutin, Mexico	19°N	102°W
Popocatepetl, Mexico	19°N	98°W
Mt. Pelee, Martinique	15°N	61°W
Santa Maria, Guatemala	15°N	92°W
Mt. Misery, St. Kitts	17°N	63°W
South America		
Cotopaxi, Ecuador	1°S	78°W
Misti, Peru	16°S	71°W
Alaska and Aleutian Islands Area		
Katmai, Alaska	58°N	155°W
Adak, Aleutians	52°N	177°W
Umnak Island, Aleutians	53°N	169°W
Kamchatka, USSR	57°N	160°E
Japan		
Fuji, Honshu	35°N	139°E
Izu-Hakone, Honshu	35°N	139°E
East Indies		
Mayon, Philippines	13°N	124°E
Krakatoa (between Java & Sumatra)	6°S	105°E
Karkar, New Guinea	5°S	146°E
Central Pacific		
Mauna Loa or Kilauea, Hawaii	19°N	156°W
Galapagos Islands	1°S	91°W
Mariana Islands	16°N	145°E
South Pacific		
White Island, New Zealand	37°S	177°E
Auckland, New Zealand	38°S	176°E
Tahiti	18°S	149°W
Samoa	13°S	172°W



Answer Sheet (PARTS A and B)

5. Look at the map of crustal plates in Figure 1. Where on the plates are most of these volcanoes located?

Most of them seem to be on the edge of the crustal plates where the plates are moving toward or past one another.

6. How can you explain this?

The bumping and rubbing of plates causes the friction and heat that make volcanoes. (Note that most of them are over subduction zones. Some students may make this observation.)

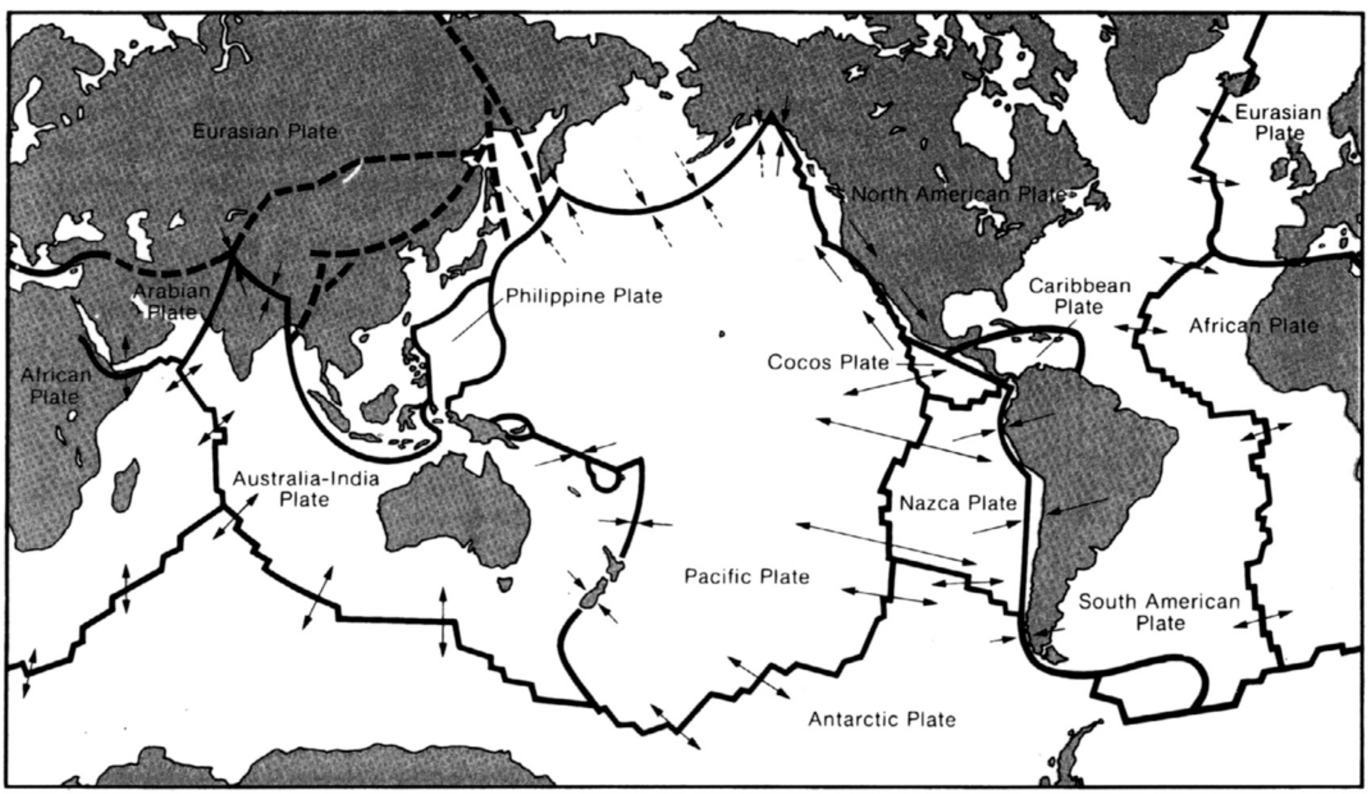


Figure 1. Map of crustal plates. Arrows indicate direction of plate movement.

PROCEDURE

PART B: What makes volcanic rocks different from each other?

The students identify the SiO_2 *differences among rocks, plot* SiO_2 *groups and relate these to plate boundaries and motions.*

Key words: none

Time required: one 45-minute period Materials: Three pencils (red, black, and blue).

1. List all the ways in which you think volcanic rocks can be different from each other.

Color, texture (crystal size), mineral content and chemical composition.

2. From your list and the lists of other students, which characteristics of a volcano depend on where the rocks come from more than how the rock material was erupted? When a volcano erupts, rock material may either be exploded out or poured out.

Composition and mineral content depend on where the rocks came from, i.e., geography. Texture relates to the way they were erupted, which to some extent depends on composition. Color depends on composition and other factors like weathering.

3. Listed below are the complete chemical analyses (by percent) of two volcanic rocks that came from different volcanoes. Look at the information and tell which of the chemical compounds differs by the largest amount.

	Obsidian Cliff, Yellowstone National Park	Basalt, Hawaiian Islands (average)
Si O_2	75.50	49.58
$A1_2O_3$	13.25	13.19
Fe_2O_3	1.02	2.40
FeO	0.91	9.49
MgO	0.07	8.30
CaO	0.90	10.69
Na_2O	4.76	2.25
K_2O	2.85	0.55
H_2O+	0.41	—
TiO_2	—	3.17
P_2O_5	—	.26
	100.05	100.00

The SiO_2 *differs between these two rocks by about 26 percent.*

When the chemical composition of many volcanic rocks is studied, it is found that silicon dioxide (SiO_2) varies the most. The minerals in the rock, and many of the other things about volcanic rocks, can be related to the SiO_2 content.

For these reasons, one simple classification system for volcanic rocks is based on whether the rock has a high, medium or low amount of SiO_2. This classification system is given below. Examples are listed in parentheses.

High SiO_2 — more than 66 percent SiO_2 (rhyolite, obsidian, pumice)

Medium SiO_2 — between 66 percent and 52 percent SiO_2 (andesite)

Low SiO_2 — less than 52 percent SiO_2 (basalt)

4. Table 2 gives the chemical compositions for the volcanoes listed in Table 1. On the Worksheet enlarge each volcano spot you plotted, with color, to show if it has a high, medium or low amount of SiO_2. So that everyone in the class can compare their maps, use these colors:

RED for high SiO_2 (more than 66 percent)

BLUE for medium SiO_2 (between 66 percent and 52 percent)

BLACK for low SiO_2 (less than 52 percent)

Table 2.
Chemical compositions

	SiO_2	Al_2O_3	FeO+ Fe_2O_3	MgO+ CaO	Na_20+ K_2O
Western United States, Pacific Border					
Lassen, California	57.3	18.3	6.2	12.7	11.0
Crater Lake, Oregon	55.1	18.0	7.1	13.2	4.5
Mt. Rainier, Washington	62.2	17.1	5.1	8.1	5.8
Mt. Baker, Washington					
Western United States, Western Interior					
Yellowstone Park, Wyoming	75.5	13.3	1.9	1.0	7.6
Craters of the Moon, Idaho	51.5	14.0	5.2	8.8	5.9
San Francisco Peaks, Arizona	61.2	17.0	5.7	6.9	7.0
Central America and West Indies					
Paricutin, Mexico	55.1	19.0	7.3	11.9	4.9
Popocatepetl, Mexico	62.5	16.6	4.9	8.4	6.1
Mt. Pelee, Martinique	65.0	17.8	4.5	7.5	4.7
Santa Maria, Guatemala	59.4	19.9	5.9	7.0	5.1
Mt. Misery, St. Kitts	59.8	18.3	7.3	9.2	4.5
South America					
Cotopaxi, Ecuador	56.2	15.3	9.7	12.7	6.7
Misti, Peru	60.1	19.0	5.0	7.1	7.2
Alaska and Aleutian Islands Area					
Katmai, Alaska	76.9	12.2	1.4	0.9	7.3
Adak, Aleutians	60.0	17.0	6.9	10.4	4.8
Umnak Island, Aleutians	52.5	15.1	12.8	12.7	4.7
Kamchatka, USSR	60.6	16.4	7.9	8.9	5.0
Japan					
Fuji, Honshu	49.8	20.6	11.2	15.4	1.9
Izu-Hakone, Honshu	53.8	14.8	13.0	13.5	2.7
East Indies					
Mayon, Philippines	53.1	20.0	8.2	13.1	4.2
Krakatoa	67.3	15.6	4.3	4.0	7.0
Karkar, New Guinea	60.1	16.4	9.6	10.4	2.6
Central Pacific					
Mauna Loa or Kilauea (average), Hawaii	49.6	13.2	11.9	19.0	2.8
Galapagos Islands	48.4	15.4	11.8	18.1	3.2
Mariana Islands	51.2	17.3	10.9	15.9	3.3
South Pacific					
White Island, New Zealand	62.2	14.3	6.0	9.8	4.9
Auckland, New Zealand	49.3	15.6	11.9	18.0	4.1
Tahiti (average)44.3	14.3	12.4	19.6	5.1	
Samoa (average of 5 flows)	48.4	13.3	12.3	15.9	5.0

5. After coloring all of your locations, answer these questions:

See Answer Sheet.

a. Where are most of the red dots (high SiO_2) located?

Near the edge of the continent or inland.

b. Where are most of the blue dots (medium SiO_2) located?

Near the edge of the continent.

c. Where are most of the black dots (low SiO_2) located?

Most are in the Pacific Ocean, but some are on the continents.

6. Geologists have found that "low SiO_2" rocks underlie most of the oceans, and that most of the continents are made up of "high SiO_2." Why do you think the different kinds of volcanoes are located where they are? List the reasons. (Here is a hint: think about what happens at subduction zones.)

Ocean volcanoes are more uniform in composition because they can only originate by the melting of low SiO_2 rock of the ocean basins or the low SiO_2 rock from greater depths.

Volcanoes associated with subduction zones are varied for several reasons:

a. A greater variety of materials may be melted, such as ocean rock or sediments being carried down the subduction zone. High SiO_2 rocks related to the substructure of the continents may also be melted.

b. After rock has melted, it may be mixed with other materials as it moves upward. A low SiO_2 melt may reach the surface as low SiO_2 lava or it may be mixed with other material so that it is a medium SiO_2 or even a high SiO_2 lava by the time it reaches the surface.

All reasonable ideas by the students should be accepted and encouraged. Through a class discussion perhaps the whole concept can be fairly well developed by the students.

SUMMARY QUESTIONS

1. How do volcanic rocks differ in composition?

Mainly in the amount of SiO_2 that they contain.

2. How is the composition of volcanic rocks related to their location on crustal plates?

Low silica volcanic rocks are found mostly well in the interior of ocean basin plates, medium silica rocks are at the edge of plates above subduction zones, and high silica rocks are located mostly in the continental parts of plates.

EXTENSION

Find the location of volcanoes in other parts of the world. Using the plate boundary map in Figure 1, tell whether each of those volcanoes should be high, medium or low in SiO_2.

Without chemical analysis reports you cannot be sure how the students are doing on this EXTENSION, but you can judge their methods, logic and probability of being correct for the places they choose.

HELPFUL BACKGROUND MATERIAL FOR CLASSROOM PRESENTATION

Films:
Heartbeat of a volcano *(20 min.), AGI-EBE, 425 N. Michigan Ave., Chicago, IL 60611*

Volcano: the birth of a mountain *(24 min.), AGI-EBE, 425 N. Michigan Ave., Chicago, IL 60611*

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Hamilton, W., 1976, Plate tectonics and man, in *GeologicalSurvey AnnualReport, Fiscal Year 1976*. Washington, U.S. Government Printing Office, p. 39-57.

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