Using Google Earth to Study the Basic Characteristics of Volcanoes

by Stacia Schipper and Stephen Mattox

Landforms, natural hazards, and the change in the Earth over time are common material in state and national standards. Volcanoes exemplify these standards and readily capture the interest and imagination of students. With a minimum of training, students can recognize erupted materials and types of volcanoes; in turn, students can relate these characteristics to eruption violence and potential risk to both nearby and distant populations. With the advent of Google Earth and the database of volcanoes supplied by the Smithsonian Institutions' Global Volcanism

Program (*www.volcano.si.edu*), students can describe almost any volcano on Earth. Although about 60 volcanoes erupt in an average year, there are 15 to 20 that have been continuously active for many years, and will probably continue to erupt for decades. In this article, we will guide students to use tools in Google Earth to quantify the characteristics of continuously active volcanoes and synthesize the information to recognize shield volcanoes, stratovolcanoes, cinder cones, and lava domes.

The lesson does not require any prior knowledge about volcano types or morphology, but it does assume that students are aware of volcanic materials, especially lava and ash. We often start our volcano unit by asking students to draw a volcano (see Mattox 2000 for detailed procedures). Although exploding stratovolcanoes are most common, students tap their prior knowledge and produce an array of volcano shapes and eruption styles. These drawings serve as a reference as we move forward and add new knowledge. Alternatively, a simple web search for videos using "volcano eruption" yields numerous clips that show volcano shapes and commonly erupted materials. The website Volcano Live (*www.volcanolive.com/volcanocams.html*) provides links to numerous live webcams.

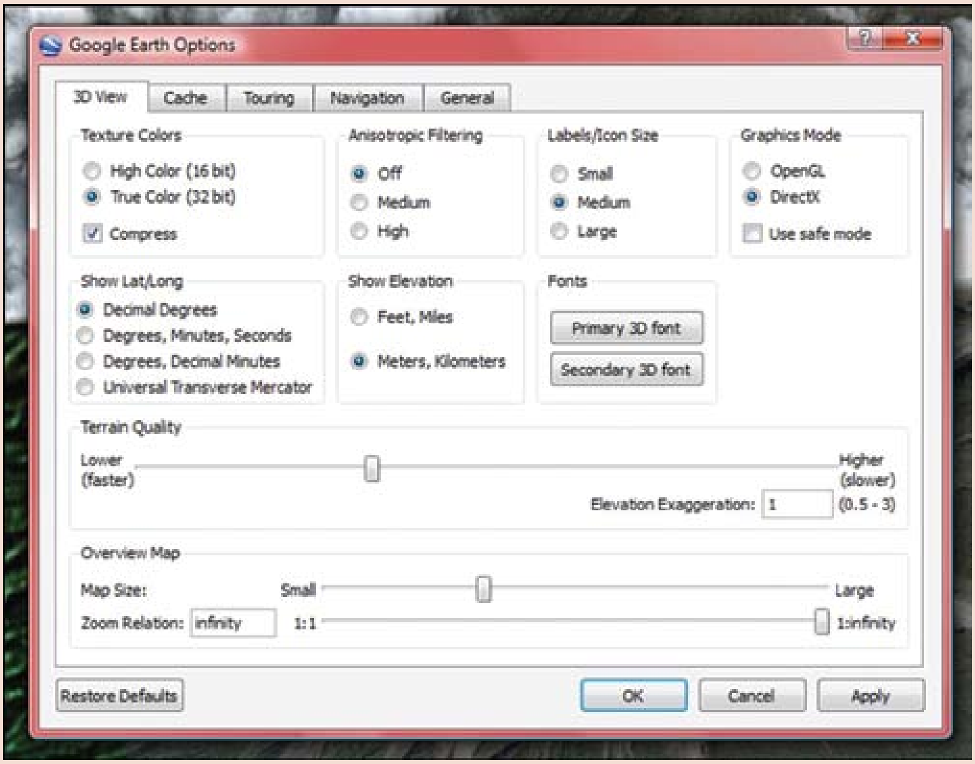
Getting started with Google Earth

Google Earth is a program that allows you to explore the Earth in great detail. This virtual globe allows you to visit any location on Earth and observe a 3-D view of Earth's surface and gather other data. Google Earth can be downloaded for free from *http://earth.google.com* .

To allow students to be able to view the 3-D relief of volcanoes, the "terrain" feature should be selected. This can be achieved by going to the "Layers" pull-down menu and checking the box labeled "terrain." To ensure that metric units of measurement are being used, go to the "Tools" tab and select "Options." Click the "3D View" category, and choose "Meters, Kilometers" in the "Show Elevation" box (Figure 1).

Tutorials on how to use Google Earth can be found by going to *http://earth.google.com* and clicking on the "Help" tab and then on the "User Guide" tab. We commonly start this part of the les-

FIGURE 1 In Google Earth Options, set the elevation measurements to metric meters and kilometers



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Activity worksheet: Exploring Volcanoes Using Google Earth

Directions for students

For your volcanoes, please measure the following and record data in the data table.

Elevation: The surface elevation at the location of the cursor is provided at the bottom of the screen in Google Earth (Figure 7). Use this reading to measure the height of your volcano in meters at the summit and the lower flanks of your volcano. The summit is the highest point on your volcano. The lower flank of the volcano is where the slope flattens out into level ground. Record the elevations in the data table.

Relief: A volcano's relief is the difference between the summit elevation and the elevation of the lower flanks. Calculate your volcano's relief and copy its value into the data table.
Relief = Summit elevation – lower flanks elevation.
Note: You can estimate the elevation at several locations, both at the summit and on the flank, before deciding which measurements are most accurate.

Radius: The radius of the volcano is a measure of how wide a volcano is. It is the distance from the middle of the volcano, marked by the summit, to the lower flanks of the volcano, or where the volcano's slope flattens out. To measure the radius of your volcano, click on the ruler tool located at the top of the Google Earth page. Change the measuring unit to meters, and click to draw a line reaching from the summit to the lower flanks. Record your data in the data table.

Slope: Based on your math ability, slope can be calculated in two different ways:

1. Trigonometry

One way to calculate the slope of the volcano is to use your data and a calculator or an online tool to calculate the slope with trigonometry.

Use the relief (A) and radius (B) from the data table to calculate the slope of the volcano's flank (Figure 8). To do this, calculate the value of A/B and find the slope by calculating:

$$\text{slope} = \tan^{-1}(A/B).$$

This can be calculated using a calculator or the following website: *www.ajdesigner.com/phptrigonometry/trigonometry_inverse_tangent_arctan_equation.php*. Input the value of A/B for "y" and click "calculate." The slope is the solution given in degrees.

Record the value of the slope in the data table below:

Volcano	Elevation summit (m)	Elevation lower flanks (m)	Relief (A) (m) (summit –lower flanks)	Radius (B) (m)	Slope (degrees) Tan = A/B	Color index	Other observations

2. Protractor

A simpler way to calculate slope is to view the Google Earth image of the volcano from a side view and physically measure the slope with a protractor.

In order to tilt the image of the volcano from a top-down view in Google Earth to an image of the volcano's profile from a side view showing the slope of the volcano, use the Look Joystick in the top right-hand corner of the screen. Pressing the "up" arrow in the Look Joystick tilts the view from a top-down view to one that is parallel with the surface of the Earth, allowing you to see the side view of the volcano.

The slope of the volcano can be viewed as the angle made by the lower flank of the volcano and the peak of the volcano (Figure 8). To measure the volcano's slope using a protractor, hold the protractor against the computer screen. Then, place the vertex of the protractor on the edge of the lower flanks, and keep the bottom edge of the protractor horizontal with the base of the volcano. The slope of the volcano defines a ray that intersects the scale on the protractor. Record your measurement in degrees in the data table. See the teacher if you need help measuring the volcano slope.

Color index: A color index is a measure of the dark minerals/material in a rock. Dark minerals/materials are called *mafic* by geologists. Mafic magma tends to erupt nonviolently to make pyroclastic cones or lava flows. Geologists call light minerals/materials *felsic*. Felsic magma tends to erupt violently to make a *caldera*, a volcanic depression, or an ash deposit. Intermediate magmas behave both ways.

Use the color index chart provided in Figure 9 to estimate if your rocks are light, intermediate, or dark in color. Hold the chart against the appropriate part of the computer screen. Record the percentage for the color index in the data table.

Other observations: Study the appearance of your volcano using Google Earth. Details that can be observed from the surface of the volcano and surrounding area can provide hints about the nature of the volcano. The activity of the volcano and its possible effects on the surrounding populations can be observed by looking at its image in Google Earth.

Based on your personal knowledge built from seeing images, news stories, and even Hollywood movies, make the following interpretations. Record your observations in the data table.

- Do you observe glowing lava or an ash plume?
- Are the upper slopes showing barren rock or vegetation? What is the significance of this?
- Are there any nearby towns or cities?
- Are there any man-made structures to lessen damage?

son by demonstrating the use of Google Earth using one volcano and projecting the image for all to see. Ideally, students work on the activity at individual computers while the teacher facilitates. If only a small number of computers are available, students can work individually or in pairs as the remaining students work on other aspects of the volcano unit.

Background information for teachers

This lesson will best fit near the beginning of a unit on volcanoes, after students have learned the volcanic materials that can be erupted (e.g., lava and ash). This lesson introduces different volcano types and their characteristics. To begin their investigation of volcanoes, students will first locate a volcano in Google Earth. Twenty suggested volcanoes are shown in Figure 2. Students will use the "Exploring Volcanoes Using Google Earth" activity worksheet to guide them through the exercise and record their observations. With the exception of the cinder cones and lava dome, these volcanoes have been continuously active for many years. Using such active volcanoes for this lesson increases the likelihood that images of the volcanoes in Google Earth will show them during an eruption. Although the cinder cones and lava dome are not continuously erupting, they have been included here to allow students to see and compare four types of volcanoes, and these examples are of volcanoes likely to erupt again. Once students locate a volcano with Google Earth, they will begin measuring features of the volcano and making observations. After recording the data they collect, the class will share and synthesize their findings to make determinations about the characteristics of the different types of volcanoes.

To locate a volcano, students will investigate using Google Earth. Students type the volcano's latitude and longitude into the "Fly To" search section on the left side of the screen. A list of the coordinates of 20 volcanoes is found in Figure 2. Projecting this list to the entire class before students log onto Google Earth will allow students to record the coordinates of the volcanoes they will investigate before getting started.

Once students locate a volcano, labeling its position on the map with a "placemark" in Google Earth will allow students to easily locate it again. Once a location is labeled with a placemark, an icon will appear at the location. Clicking the icon brings the viewer directly to the placemarked location. To label the position with a placemark, click on the placemark button and name the location.

For students familiar with Google Earth, assigning two or three different volcanoes to be studied is

FIGURE 2 A summarization of volcanic data collected using Google Earth

Volcanoes	Latitude, Longitude	Volcano type
Kilauea	19.419391°, -155.288567°	Shield
Etna	37.752018°, 14.996273°	Shield
Stromboli	38.787763°, 15.209230°	Stratovolcano
Merapi	-7.539363°, 110.446336°	Stratovolcano
Erta Ale	13.606314°, 40.665857°	Shield
Ol Doinyo Lengai	-2.763028°, 35.915886°	Stratovolcano
Unzen	32.761182°, 130.298506°	Stratovolcano
Yasur	-19.530652°, 169.449397°	Stratovolcano
Arenal	10.462551°, -84.703479°	Stratovolcano
Erebus	-77.529340°, 167.152955°	Stratovolcano
White Island	-37.520597°, 177.178902°	Stratovolcano
Ambrym	-16.258500°, 168.117524°	Stratovolcano
Pacaya	14.382390°, -90.601501°	Stratovolcano
Reunion	-20.949203°, 55.332670°	Shield
Fuego	14.474443°, -90.880397°	Stratovolcano
Rabaul	-4.239074°, 152.209033°	Pyroclastic shield
Sakurajima	31.583460°, 130.657599°	Stratovolcano
Paricutin	19.493453°, -102.250890°	Cinder cone
Anak Krakatau	-6.101915°, 105.422905°	Cinder cone
Mount St. Helens	46.199942°, -122.188606°	Lava dome

FIGURE 3 Students will plot the data from the volcanoes they researched on this graph in order to see size relationships among volcano types

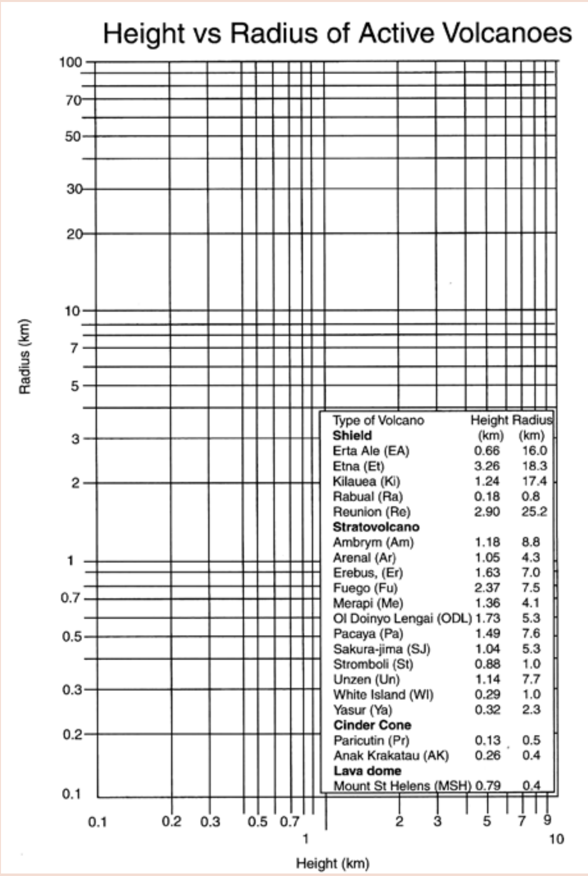
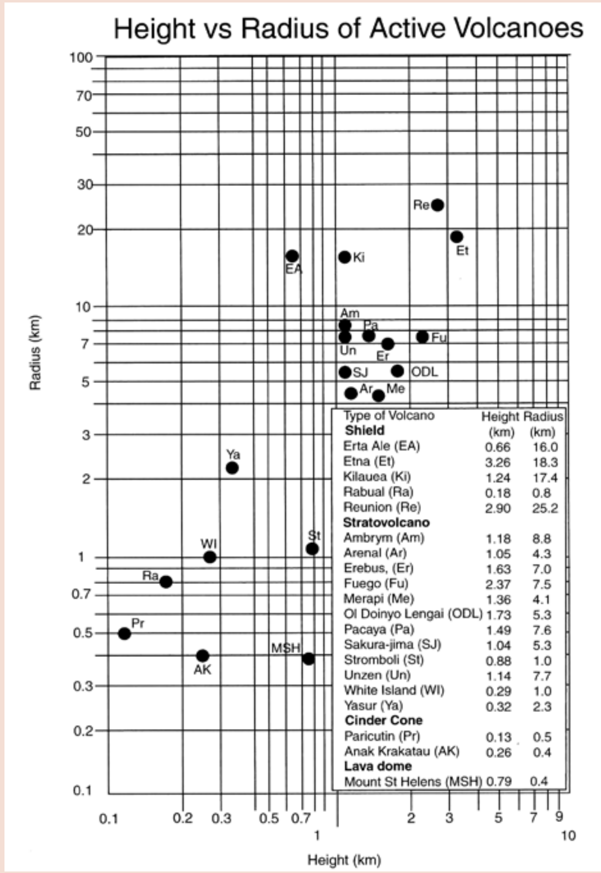


FIGURE 4 Shield volcanoes are shown to be the largest volcanoes, and all except for the pyroclastic shield are graphed at a radius above 10 km. The stratovolcanoes are grouped near one another, and most are graphed at a height between 1 and 3 km. The cinder cone and lava dome are smaller than most of the other volcanoes



sufficient enough for a 50-minute investigation. In order for students to experience different volcano types using Google Earth, at least two of their volcanoes should be a different type. Volcano types are listed in Figure 2, but do not need to be shared with students until later in the lesson. To ensure that students are investigating volcanoes of various types and that the collective group is studying a variety of volcanoes, it works well for the teacher to assign two or three volcanoes to students.

A list of documented volcanoes, including the ones used here, can be found in the Smithsonian's Global Volcanism Program website at *www.volcano.si.edu*. From the tab "Volcanoes of the World" click on "Global Volcano Lists" and choose which list to use.

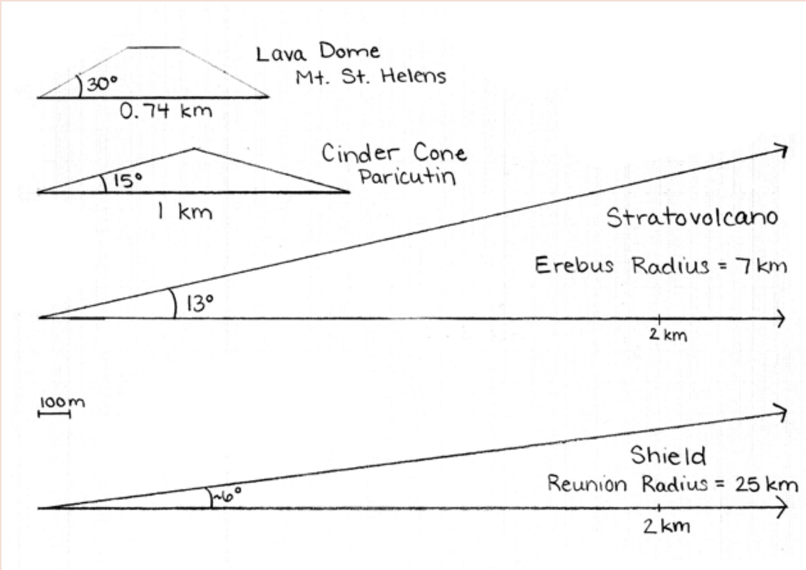
Synthesizing student observations

After students have individually gathered data about their volcanoes, the collected data can be shared with the entire class. One way to facilitate the group sharing of data is to go through each volcano, displaying its Google Earth image to the entire class, and asking students who researched the volcano to share their findings. Once students have shared the data for all of the volcanoes, the data can be synthesized, allowing students to recognize characteristics of the different types of volcanoes. By sharing data with their peers, students are mimicking a basic tenant of science and are afforded the opportunity to check their work, repeating and confirming measurements.

Volcano height and width: Most volcanoes can be classified by size. Invite students to the board to plot their data on a projection of Figure 3; alternatively, each student could plot data on Figure 3 as a handout. Students should initial each point with the abbreviation for the volcano. Figure 4 shows these data already plotted. Have students use their data to answer the following questions:

1. Can volcano type be distinguished based on size alone? Explain your answer.
2. How much wider are shield volcanoes compared to stratovolcanoes? (circle one)
   same size, 10x, 100x, 1000x
3. How much higher are stratovolcanoes compared to cinder cones? (circle one)
   same size, 10x, 100x, 1000x
4. How much larger are lava domes compared to cinder cones? (circle one)
   same size, 10x, 100x, 1000x
5. What would be the best way to tell a lava dome from a cinder cone?
6. How much wider is a shield volcano compared to a cinder cone (circle one)
   same size, 10x, 100x, 1000x, 10,000x, 100,000x

FIGURE 5 When graphed to scale, shield volcanoes are shown as the largest, followed by stratovolcanoes. Lava domes and cinder cones are similar in size and are much smaller than the other volcano types



Answers

1. Volcano type cannot be distinguished based on size alone. Cinder cones and lava domes are similar in size and must be compared in a different way to accurately tell them apart. Some volcanoes are smaller or larger than other volcanoes of their type, and trying to classify these by their size only could be misleading.
2. 10x
3. 10x
4. Same size
5. Looking at the volcanic materials would be the best way to tell a lava dome from a cinder cone. Lava domes erupt felsic material, while cinder cones erupt mafic material.
6. 100x

Volcano size and slope: After obtaining data tables from all students, the relative sizes of the four main types of volcanoes examined here (shield, stratovolcano, cinder cone, and lava dome) can be analyzed. One of each type of volcano can be graphed to scale on a piece of graph paper to compare their relative sizes (Figure 5). To print free metric graph paper, visit *www.printfreegraphpaper.com/gp/e-m-1-a4.pdf.*

The following directions can be used by the teacher to guide students as they graph volcanoes to scale:

1. Select an appropriate scale factor. (Students can determine their own scale, or alternatively, suggest a scale of 1 cm = 200 m.)
2. Graph a point to represent the outer flanks of the volcano on your graph paper. Using your scale, move horizontally, and graph another point at the distance representing the radius of the volcano, which was recorded in the activity worksheet data table.

FIGURE 6 Data collected using Google Earth for the 20 volcanoes explored

	Latitude/longitude	Relief	Elevation base	Elevation summit	Radius	Diameter	Slope
Kilauea	19.419391°, -155.288567°	1,242 m	0 m	1,242 m	17.4 km, 50.3 km		4.083, 1.414
Etna	37.752018°, 14.996273°	3,260 m	0 m	3,260 m	18.25 km	36.5 km	10.128
Stromboli	38.787763°, 15.209230°	878 m	0 m	878 m	1 km, 3.3 km		41.283, 14,899
Merapi	-7.539363°, 110.446336°	1,358 m, 2,161 m	1,548 m, 745 m	2,906 m	4.1 km		18.326, 27.793
Erta Ale	13.606314°, 40.665857°	660 m	-80 m	580 m	16 km, 40 km		2.362, 0.945
Ol Doinyo Lengai	-2.763028°, 35.915886°	1,727 m	1,153 m	2,880 m	5.3 km, 6.7 km		18.048, 14.453
Unzen	32.761182°, 130.298506°	1,143 m	0 m	1,443 m	7.7 km	35.4 km	8.443
Yasur	-19.530652°, 169.449397°	320 m	0 m	320 m	2.3 km	4.8 km	7.921
Arenal	10.462551°, -84.703479°	1,053 m	554 m	1,607 m	4.3 km		13.76.
Erebus	-77.529340°, 167.152955°	1,633 m	2,052 m	3,685 m	7 km	14 km	13.131
White Island	-37.520597°, 177.178902°	291 m	0 m	291 m	1.0 km		16.225
Ambrym	-16.258500°, 168.117524°	1,175 m	0 m	1,175 m	8.8 km		7.605
Pacaya	14.382390°, -90.601501°	1,494 m	1,070 m	2,564 m	7.6 km		11.121
Reunion	-20.949203°, 55.332670°	2,901 m	0 m	2,901 m	25.2 km		6.567
Fuego	14.474443°, -90.880397°	2,367 m	1,385 m	3,752 m	7.5 km		17.516.
Rabaul	-4.239074°, 152.209033°	178 m	0 m	178 m	0.8 km		12.544
Sakurajima	31.583460°, 130.657599°	1,040 m	0 m	1,040 m	5.3 km		11.102
Paricutin	19.493453°, -102.250890°	134 m	2,640 m	2,774 m	0.5 km		15.003
Anak Krakatau	-6.101915°, 105.422905°	260 m	0 m	260 m	0.4 km		33.024
Mount St. Helens	46.199942°, -122.188606°	172 m	2,000 m	2,172 m	0.37 km		12.052

FIGURE 6 Data collected using Google Earth for the 20 volcanoes explored

	Type of volcano	Materials	Explosivity	Notes
Kilauea	shield	basalt lava	0,1	radius is summit to ocean entry or to east end of island; black lava is basalt; Puu Oo is active vent; degassing at summit and Puu Oo
Etna	shield	basalt lava	1,2,3	basalt lava and gas visible; degassing at summit craters
Stromboli	stratovolcano	tephra layers	2,3	possible degassing
Merapi	stratovolcano	light material	1,2	rhyolite or dacite lava domes. Radius taken to nearby city or edge of drainage field; degassing
Erta Ale	shield	basalt lava	0,2	collapsed summit caldera; pit craters; gas?
Ol Doinyo Lengai	stratovolcano	not discernable	2,3	poor resolution; no gas visible
Unzen	complex	light material	1,2	lahar dams visible; similar to Merapi
Yasur	stratovolcano	gray ash	3	cloud cover in photo, crater visible, villages nearby
Arenal	stratovolcano		3,4	visible lava flows and visible glow at summit
Erebus	stratovolcano		1,2	poor resolution
White Island	stratovolcano	light-colored ash	2,3	no habitation, clear picture, no eruption visible
Ambrym	stratovolcano	pyroclastic, mafic	2,3	glowing vents, plume visible, crater, lava lake, vegetation, and high drainage density
Pacaya	complex	mafic lavas, aa wall	2,3	gas plume visible, different ages of aa flows visible
Reunion	shield	mafic lava flows	0,1,2	clearly black, nice shield shape
Fuego	stratovolcano	light colored ash	1,2,3,4	clear picture, only forested on lower slopes, degassing at summit
Rabaul	pyroclastic shield	gray ash	explosive-gray ash 1,2	large plume visible from vent
Sakurajima	stratovolcano	gray	1,2	populated to the north, diversion structures
Paricutin	cinder cone	black pyroclast, black lava	4	
Anak Krakatau	cinder cone		1,2	
Mount St. Helens	lava dome		2,3	

FIGURE 7 The surface elevation at the location of the mouse on the computer screen is displayed at the bottom of the screen in Google Earth.

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3. Connect these two points with a line.
4. Use a protractor to draw an angle equal to the slope of the volcano. Extend the line from this angle to the point where it lies directly above the radius of the volcano (at the summit).
5. If the volcano being drawn is small enough (cinder cone or lava dome), a complete volcano can be drawn on the paper. If it is larger (stratovolcano or shield), the volcano from the flanks to the summit or less may fit on the page.
6. Repeat steps 2–5 for the next three volcano types. The resulting images will show the relative size differences of the four types of volcanoes examined here.

Color and eruption behavior: Students can discover the general relationship between the composition of the material and the type that the volcano erupts. A closer look at a complete data set compiled by students (Figure 6) shows that all of the shields are made of black or mafic lava. The volcanoes are made by the gentle, nonexplosive eruption of lava that pours across the landscape. Stratovolcanoes display a more complex relationship where other factors, such as gas content, also influence eruption style. For example, Arenal is clearly a stratovolcano based on slope and size, yet erupts mafic lava flows (frequently accompanied by moderate explosive activity). In contrast, stratovolcanoes such as Merapi and Unzen are clearly made of light-colored, felsic material (lava and ash). The cinder cones at Anak Krakatau and Paricutin are the result of weak explosions of gassy mafic material. At the opposite end of the volcanic spectrum, the lava dome at Mount St. Helens is made of viscous felsic lava.

Further exploration

With the skills your students have developed, they can now explore the Earth as a volcanologist. Students can study other volcanoes that are historically important, such as Vesuvius or Fuji, or currently receiving

FIGURE 8 The slope of the volcano is the angle (α) made from the lower flanks of the volcano and the summit of the volcano. The Look Joystick arrows are in the top circle in the upper-right corner.

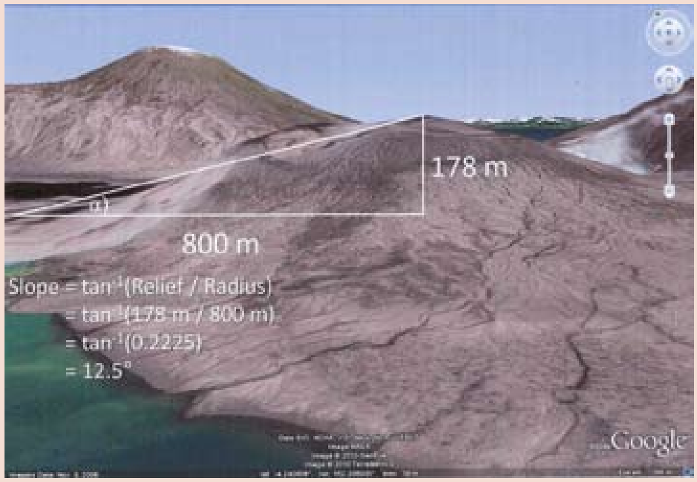

FIGURE 9 The color index of a rock estimates the percentage of dark minerals and materials in a rock and can be estimated using the chart.

media (and scientific attention), such as Iceland's Eyjafjallajokull volcano, and make their own assessment of volcano type and eruption style. ■

Reference

Mattox, S.R. 2000. Teaching the basics about volcanoes to K–16 students. *Journal of Geoscience Education* 48 (5): 576–77.

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