Chapter 7
Volcano Monitoring, Research, and Careers

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Activities
These activities focus on career opportunities in the Earth sciences and include an overall assessment of the student's knowledge of the field of volcanology in Alaska. Through literature review students will learn about career opportunities in volcanology in Alaska, Hawaii, the lower-48 states, and abroad. Students also will be given an opportunity to discuss the reality of docudrama and Hollywood's portrayals of volcanologists and volcanic eruptions. By conducting a culminating role playing activity and possible eruption scenario students will also understand what observatory staff do and be able to exhibit their knowledge of the study of Alaskan volcanism. This chapter ends with a series of pointers and suggestions on specific guidebook activities and resources available during heightened volcanic activity and eruptions in Alaska.

Activity I. So, you say you are a volcanologist…
Activity II. Hooray for Hollywood*: Dante's Peak* and *Supervolcano*
Activity III. A Day in the Life of a Volcano Observatory
Activity IV. Consider before, during, or after a volcanic eruption

Activity I. So, You Say You Are a Volcanologist…

Grade Level 7−11

Setting Classroom

Time 50 minutes

Correlations to Alaska State Department of Education (2006) Science Performance Standards (Grade Level Expectations)

A1—Science as Inquiry and Process

SA2[6-11] Students develop an understanding that the processes of science require integrity, logical reasoning, skepticism, openness, communication, and peer review.

SA3[6-11] Students develop an understanding that culture, local knowledge, history, and interaction with the environment contribute to the development of scientific knowledge, and local applications provide opportunity for understanding scientific concepts and global issues.

E1—Science and Technology

SE[6-11] Students develop an understanding of the relationships among science, technology, and society.

SE2[6-11] Students develop an understanding that solving problems involves different ways of thinking, perspectives, and curiosity that lead to the exploration of multiple paths that are analyzed using scientific, technological, and social merits.

SE3[6-11] Students develop an understanding of how scientific discoveries and technological innovations affect and are affected by our lives and cultures**.**

F1—Cultural, Social, Personal Perspectives, and Science

SF[6-11] Students develop an understanding of the dynamic relationships among scientific, cultural, social, and personal perspectives.

SF1[6-11] Students develop an understanding of the interrelationships among individuals, cultures, societies, science, and technology.

SF2[6-11] Students develop an understanding that some individuals, cultures, and societies use other beliefs and methods in addition to scientific methods to describe and understand the world.

SF3 [6-11] Students develop an understanding of the importance of recording and validating cultural knowledge.

Overview

Through literature research and review students will learn about career opportunities in volcanology in Alaska, Hawaii, the lower-48 states, and abroad.

Background

Volcanology is an uncommon profession, but it is a very important, exciting, and interesting career. Volcanology, the study of volcanoes, is accomplished by a wide subset of Earth scientists, few of whom hold the actual title "Volcanologist." More commonly, the people who study volcanoes in an observatory are geologists and geophysicists and they rely heavily on technology experts (satellites, mapping, field instrumentation, radio telemetry, data storage and transfer, software developers, etc.). Professionals in Alaska face many challenges not faced by those who study volcanoes elsewhere within the United States, or even worldwide. Working in Alaska means dealing with poor weather, cloud cover, challenging access to remote locations, low sun angle, and high snow levels in winter, and working on Federal, state and private land with varying degrees of restriction.

Professional volcanologists, geophysicists and geologists are prolific throughout the sciences, and may be found hard at work at academic and government entities including colleges and universities, research laboratories, in the classroom, and among Federal state and local land management and educational organizations. There are volcanologists who study volcanism on other planets and who study the volcanism on the Earth's sea floor. A thorough discussion of career opportunities available to students interested in pursuing degrees and experiences in the geosciences and volcanology in particular is incomplete as only an observatory setting is discussed.

Objective

By learning about volcanologists, including those in Alaska, students will gain a perspective on the wide variety of careers and job duties preformed by this select and dedicated group of individuals.

Materials

- access to volcanologist narratives, media, texts, articles, podcasts, and radio programs through library, on-line, and classroom resources

Procedure

A. Literature research and review: Volcanologists

1. Assign students to complete a paper, poster, podcast, or digital presentation about the jobs of volcanologists. Make sure students do not focus solely on scientists at volcano observatories.

Extension

1. Encourage students to write fictional stories about volcanic research they would conduct if they were a volcanologist.

2. Give students time to work in groups to illustrate, present, or write about how they would work as a team to solve a specific mystery at an Alaskan volcano.

Reference Cited

Alaska State Department of Education and Early Development, 2006, Standards and grade level expectations, March 2006: State of Alaska website, accessed October 2009 at http://www.eed.state.ak.us/tls/assessment/GLEHome.html.

Activity II. Hooray for Hollywood*: Dante's Peak* and *Supervolcano*

Grade Level PG-13+

Setting Classroom, auditorium

Time 4–5 hours

Vocabulary (see Glossary)
andesite, basalt, basaltic andesite, block and ash flow, caldera, dacite, Electronic Distance Meters (EDM), frequency content, fumarole, leachate, leveling survey, long-period or volcanic earthquake, phreatomagmatic, pyroclastic flow, rhyolite, strainmeter, tiltmeter, volcano-tectonic-type earthquake, waveform

Correlations to Alaska State Department of Education (2006) Science Performance Standards (Grade Level Expectations)
A1—Science as Inquiry and Process

SA[6-11] Students develop an understanding of the processes and applications of scientific inquiry.

SA1[6-11] Students develop an understanding of the processes of science used to investigate problems, design, and conduct repeatable scientific investigations, and defend scientific arguments.

SA2[6-11] Students develop an understanding that the processes of science require integrity, logical reasoning, skepticism, openness, communication, and peer review.

SA3[6-11] Students develop an understanding that culture, local knowledge, history, and interaction with the environment contribute to the development of scientific knowledge, and local applications provide opportunity for understanding scientific concepts and global issues.

E1—Science and Technology

SE[6-11] Students develop an understanding of the relationships among science, technology, and society.

SE1[6-11] Students develop an understanding of how scientific knowledge and technology are used in making decisions about issues, innovations, and responses to problems and everyday events.

SE2[6-11] Students develop an understanding that solving problems involves different ways of thinking, perspectives, and curiosity that lead to the exploration of multiple paths that are analyzed using scientific, technological, and social merits.

SE3[6-11] Students develop an understanding of how scientific discoveries and technological innovations affect and are affected by our lives and cultures**.**

F1—Cultural, Social, Personal Perspectives, and Science

SF[6-11] Students develop an understanding of the dynamic relationships among scientific, cultural, social, and personal perspectives.

SF1[6-11] Students develop an understanding of the interrelationships among individuals, cultures, societies, science, and technology.

SF2[6-11] Students develop an understanding that some individuals, cultures, and societies use other beliefs and methods in addition to scientific methods to describe and understand the world.

SF3[6-11] Students develop an understanding of the importance of recording and validating cultural knowledge.

Overview

Nothing beats watching someone carry out dramatic job responsibilities quite like in a movie! Through dramatizations, special effects, and actual eruption footage, a well-prepared movie script can demystify the roles of volcanologists and provide insights about common responses of communities in peril.

Background

The BBC and Discovery docudrama *Supervolcano* explores the effect of a large caldera-forming eruption at Yellowstone volcano in Wyoming. The movie realistically depicts what could happen if an eruption of this magnitude were to occur again. Although the drama is set in the future, it does an acceptable job of addressing some of the issues that scientists grapple with today.

Dante's Peak is a volcano-disaster thriller from Universal Studios. This movie dramatizes some real-world concerns faced by communities located near active volcanoes in the United States. Set in the northern Cascade Range of Washington State, the movie portrays the roles of USGS scientists and public officials during the re-awakening and eruption of a fictional volcano—one that resembles dozens of real volcanoes in Alaska, British Columbia, Washington, Oregon, and northern California. Keep in mind that both the volcano and the town portrayed in this movie are named Dante's Peak.

Objective

Students should recognize that the "science" in these two movies has roots in reality, but not everything portrayed is thoroughly explained or realistic**.** Students should learn to appreciate that volcanologists, no matter what their specialty, have an exciting, sometimes stressful, and crucial job to do. Students will be able to assess fact and fiction using the included question (and answer) worksheets to help separate fact from fiction in these two popular, mainstream movies.

Materials

— BBC and Discovery Docudrama *Supervolcano*, 120 minutes (in two parts)
— Universal Studios *Dante's Peak*, PG-13, 109 minutes
— *Dante's Peak FAQ's* and *Supervolcano* worksheets

Procedure
A.
1. You may choose to use one or both of the movies and associated worksheets.
- *Dante's Peak*
  - Watch movie as a class
  - You may hand out the *Dante's Peak FAQ's* worksheet and have the students fill them out or at least take notes during the movie.
  - Students will likely need to research many of the questions using additional resources and you may consider completion of the worksheet as a homework assignment.
  - Review the questions and answers with the students when they are completed.
- *Supervolcano*
  - Watch movie as a class
  - You may hand out the *Supervolcano* worksheet and have the students fill them out or at least take notes during the movie.
  - Students will likely need to review additional materials from the Yellowstone Volcano Observatory (YVO) website and other resources. You may consider completion of the worksheet as a homework assignment.
  - Review the questions and answers with the students when they are completed.

Extensions
1. Have students develop their own questions and use the included answer sheets to assist in answering them.

2. Have the students generate their own questions associated with additional volcano movies and research the answers. Review those questions and answers as class discussion.

3. Watch additional volcano movies and use available teaching materials associated with them. Movies with teaching materials include:
   - *Mystery of the Megavolcano*
     http://www.pbs.org/wgbh/nova/teachers/programs/3312_megavolc.html
   - *Volcano Above the Clouds*
     http://www.pbs.org/wgbh/nova/teachers/programs/3017_kilimanj.html
   - *Volcano Under the City*
     http://www.pbs.org/wgbh/nova/teachers/programs/3215_volcanoc.html
   - *Volcano's Deadly Warning*
     http://www.pbs.org/wgbh/nova/teachers/programs/2913_volcano.html
   - *Volcanoes of the Deep*
     http://www.pbs.org/wgbh/nova/teachers/programs/2609_abyss.html
   - *Buried in Ash*
     http://www.pbs.org/wgbh/nova/teachers/programs/2117_ash.html
   - *Deadly Shadow of Vesuvius*
     http://www.pbs.org/wgbh/nova/teachers/programs/2515_vesuvius.html
   - *Hawaii Born of Fire*
     http://www.pbs.org/wgbh/nova/teachers/programs/2211_hawaii.html
   - *In the Path of a Killer Volcano*
     http://shop.wgbh.org/product/show/7832

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Glossary

Andesite – A gray to black volcanic rock with between about 52 and 63 weight percent silica (SiO_2). The low-end silica value rock is also known as **basaltic andesite**.

Basalt – Basalt is a hard, black volcanic rock with less than about 52 weight percent silica (SiO_2).

Block and ash flow – A flow consisting of blocks from the collapse of an active volcanic dome, volcanic gases, and volcanic ash.

Caldera – A caldera is a large, usually circular depression at the summit of a volcano formed when magma is withdrawn or erupted from a shallow underground magma reservoir. The removal of large volumes of magma may result in loss of structural support for the overlying rock, thereby leading to collapse of the ground and formation of a large depression. Calderas are different from craters, which are smaller, circular depressions created primarily by explosive excavation of rock during eruptions.

Dacite – A rock that is often light gray to dark gray or black that consists of about 63 to 68 percent silica dioxide (SiO_2).

Electronic Distance Meters (EDM) – The EDM is an ultra-precise distance-measuring instrument used to measure crustal deformation along faults and near volcanoes.

Frequency content – A concept similar to the musical pitch of sound. Just as vocal range is classified in terms of bass, baritone, and tenor, the frequency content of a seismic signal can be classified as very long period (VLP), long period (LP), and high frequency.

Fumarole - Vents from which volcanic gas escapes into the atmosphere. Fumaroles may occur along tiny cracks or long fissures, in chaotic clusters or fields, and on the surfaces of lava flows and thick deposits of pyroclastic flows. They may persist for decades or centuries if they are above a persistent heat source or disappear within weeks to months if they occur atop a fresh volcanic deposit that quickly cools.

Leachate – Potentially harmful water-soluble substances (mainly acids and salts), which cling to glass and crystals particles

Leveling survey – A type of surveying used to establish a baseline and re-survey a leveling line typically for benchmarks that were.

Long-period or volcanic earthquake – A type of earthquake occurring in a volcanic system resulting from fluid motion in a confined cavity, conduit, or crack. Long-period earthquakes and volcanic tremor are often grouped together in the general category of "long-period seismicity."

Phreatomagmatic – A volcanic explosion that extrudes steam and magmatic gases; it is caused by the contact of magma with shallow or surface water.

Pyroclastic flow –A ground-hugging avalanche of hot ash, pumice, rock fragments, and volcanic gas that rushes down the side of a volcano as fast as 100 km/h (~60 mi./h) or more. The temperature within a pyroclastic flow may be greater than 500°C (900°F), sufficient to burn and carbonize wood. Once deposited, the ash, pumice, and rock fragments may deform (flatten) and weld together because of the intense heat and the weight of the overlying material. The emplaced flow is called a deposit.

Rhyolite – A light-colored rock with silica (SiO_2) content greater than about 68 weight percent. Sodium and potassium oxides can reach about 5 weight percent.

Strainmeter – An instrument placed in the ground that detects small changes in length and volume associated with deformation of the earth by tectonic stresses or by the passage of seismic waves.

Tiltmeter – An instrument placed in the ground designed to measure very small changes from the horizontal level, either on the ground or in structures.

Volcano-tectonic-type earthquake – This type of earthquake occurs in a volcanic system that is smaller in magnitude, but otherwise indistinguishable from common tectonic earthquakes. These earthquakes are associated with shear slip along a pre-existing or newly formed fault plane.

Waveform – The different types of patterns appearing on a time series of recorded ground motion, or seismogram. A waveform is usually a small part or subset of a seismogram linked to a particular phenomenon (for example, an earthquake). For instance, if two earthquakes occur close to each other at almost the same time, their waveforms, as recorded on a seismogram, are said to overlap.

Source of Glossary Definitions

Bates, R.K., and Jackson, J.A., eds., 1987, Glossary of Geology, third edition: Falls Church, Va., American Geological Institute.

Volcano Hazards Program–USGS Photo Glossary of volcanic terms website http://volcanoes.usgs.gov/images/pglossary/index.php

USGS Earthquake Program Two-color EDM http://quake.usgs.gov/research/deformation/twocolor/twocolor.html

Dr. Matthew Haney, U.S. Geological Survey, Research Geophysicist, oral commun., 2009

USGS Hawaiian Volcano Observatory—State-of-the-Art Volcano-Monitoring Instruments Installed on Mauna Loa and Kilauea volcanoes http://hvo.wr.usgs.gov/howwork/strain/

USGS Cascades Volcano Observatory: Description: Tiltmeters and Tilt Measurements http://vulcan.wr.usgs.gov/Monitoring/Descriptions/description_tilt.html

Name ___________________________________ Date ______________ Period _____

Dante's Peak FAQ's

Dante's Peak (1997) is a volcano-disaster thriller from Universal Studios. It dramatizes some real-world concerns faced by communities located near active volcanoes in the United States. Set in the northern Cascade Range of Washington State, the movie portrays the roles of U.S. Geological Survey (USGS) scientists and local officials during the re-awakening and eruption of a fictional volcano—one that resembles dozens of real volcanoes in Alaska, British Columbia, Washington, Oregon, and northern California.

I. General Questions

1. Can scientists really forecast volcanic eruptions? If so, how?

2. Are specific predictions of an eruption's time, place, and character possible?

3. Is there really a U.S. Geological Survey (USGS) and does it provide eruption warnings?

4. If so, how do the USGS and its partners provide eruption warnings?

5. How many active volcanoes are there in the United States and its territories? In Alaska?

6. How many active volcanoes are there on Earth?

7. What are the names of historically active volcanoes in the Alaska?

8. Which Alaskan volcano will erupt next and why do you think so?

II. Volcanic Eruptions

1. Is the eruption depicted in *Dante's Peak* realistic? Why or why not?

2. Can eruptions really threaten helicopters, as in the movie, and other aircraft? If so, how?

3. Can the temperature of hot springs near a restless volcano change quickly enough to injure bathers? Why or why not?

4. Do earthquakes large enough to collapse buildings and roads accompany most volcanic eruptions? Why or why not?

5. Can a town's water supply become contaminated when a volcano is restless? If so, how?

6. Do scientists drive across moving lava flows? If so, where and when?

7. Can carbon dioxide (CO_2) gas from volcanoes kill trees and wildlife? If so, how?

8. Can volcanoes suddenly become restless and erupt within 1 day of the first signs of activity? Why or why not?

9. Are robots used to monitor volcanoes? If so, how?

10. Can volcanoes produce large explosive eruptions and rivers of fluid lava at the same time? If so, how?

11. Can lakes near volcanoes become acidic enough to be dangerous to people? If so, how?

III. Eruption precursors

1. What kinds of unusual activity might be noticed before an eruption?

2. What is volcanic tremor, and how does it differ from earthquakes?

3. Do volcanoes produce different kinds of earthquakes, and if so, what are they and how do they differ?

4. What kind of gases escape from volcanoes?

5. Are there any volcanoes exhibiting heightened volcanic activity in the U.S. and its territories today?

IV. Volcano Monitoring

1. Does the USGS have a team of volcanologists that can respond to volcanic unrest on short notice? If so, can you describe the team?

2. Does the USGS have a team for rapid response to volcano emergencies in other countries? If so, can you describe the team?

3. How does the USGS monitor volcanoes in the United States and its territories?

4. How are earthquakes monitored?

5. How are ground movements measured?

6. How are volcanic gases measured?

7. Can mudflows be monitored? If so, how?

8. What else do scientists measure at volcanoes?

V. Volcanic Hazards

1. What kinds of hazards were depicted in the movie, and what part have they played in real volcanic eruptions? Are they realistic?

2. Can volcanoes be dangerous even when they do not erupt? If so, how?

3. How can residents who live near volcanoes prepare for future eruptions?

Dante's Peak FAQ's Key

(based on http://vulcan.wr.usgs.gov/LivingWith/PopCulture/DantesPeak/dantes_peak.html)

Dante's Peak (1997), a volcano-disaster thriller from Universal Studios, dramatizes some real-world concerns faced by communities located near active volcanoes in the United States. Set in the northern Cascade Range of Washington State, the movie portrays the roles of U.S. Geological Survey (USGS) scientists and local officials during the re-awakening and eruption of a fictional volcano—one that resembles dozens of real volcanoes in Alaska, British Columbia, Washington, Oregon, and northern California.

I. General Questions

1. Can scientists really forecast volcanic eruptions? If so, how?

   Yes, in many cases, but most reliably only for volcanoes that have been studied geologically. By studying and determining the age of deposits of rock and ash formed by past events, volcanologists can re-construct the history of a volcano in considerable detail. This allows them to make general forecasts about future activity, because the past often is, although not always, a good guide to the future. For example, Alaska Volcano Observatory (AVO) scientists who studied Augustine volcano during its eruptions throughout the 1900s recognized that, for thousands of years, it had been the most frequently active volcano in the Cook Inlet region of Alaska. When seismic and other data began to indicate a renewal in activity in the summer and autumn 2005, AVO scientists forecasted that Augustine volcano might be the next Cook Inlet volcano to erupt. The eruption began on January 11, 2006. This eruption lasted several months.

2. Are specific predictions of an eruption's time, place, and character possible?

   Yes, in some cases, but specific predictions require more and different kinds of information. Using seismometers and other sensitive monitoring instruments on-site a local volcanoes, AVO scientists are keeping an eye on more than 30 volcanoes in Alaska. Additional monitoring by satellite allows AVO scientists to view activity at all Alaska's potentially active volcanoes as weather and data acquisition allows. At the first sign of trouble, they will intensify their monitoring efforts, as depicted in the movie. Taking the pulse of a restless volcano in this way allows scientists to refine their assessment of hazards and make increasingly specific statements about future activity, including the time, location, and type of activity expected.

   For example, in 1991, an accurate prediction of the largest eruption on Earth in almost 80 years saved thousands of lives and millions of dollars worth of property near Mount Pinatubo in the Philippines.

3. Is there really a U.S. Geological Survey (USGS) and does it provide eruption warnings?

   Yes, the USGS was established by Congress in 1879. The USGS provides biologic, geologic, hydrologic, and topographic information to the Nation. The USGS is mandated by Congress to provide timely warnings about geologic hazards, including volcano hazards, to U.S. citizens and public officials. This mission is accomplished mainly through the USGS Volcano Hazards Program, which operates volcano observatories in Washington, Alaska, Hawaii, Yellowstone, and California, and supports research on volcanoes and volcanic processes at other locations in the U.S such as the Northern Marianas Islands.

   The Alaska Volcano Observatory (AVO) is a joint program of the United States Geological Survey (USGS), the Geophysical Institute of the University of Alaska Fairbanks (UAFGI), and the State of Alaska Division of Geological and Geophysical Surveys (ADGGS). The Alaskan-USGS based operations are at the USGS Alaska Science Center in Anchorage.

   - Alaska Volcano Observatory website
     http://www.avo.alaska.edu/
   - USGS Alaska Science Center website
     http://alaska.usgs.gov/
     - USGS Alaska Science Center, 2007, Alaska Science Center—Providing timely, relevant, and impartial study of the landscape, natural resources, and natural hazards for Alaska an our Nation: U.S. Geological Survey Fact Sheet 2007-3019, 4 p.
       Website http://pubs.usgs.gov/fs/2007/3019/
       PDF http://pubs.usgs.gov/fs/2007/3019/pdf/fs20073019.pdf

4. If so, how do the USGS and its partners provide eruption warnings?

   The USGS warning system varies depending on the nature and proximity of volcanic hazards to surrounding communities or aircraft. Before a crisis starts, the USGS prepares volcano hazard-zonation maps, preliminary hazard assessments and other information about the frequency of eruptions and extent of specific hazards for use by the public, public officials, land-use planners, and emergency-management agencies. When a volcano becomes restless, USGS volcano observatories and their partners use various instrumental data and direct observations by people, cameras, and satellites to track activity and issue frequent statements about the volcano's activity and hazards. For the aviation sector, the USGS works with the Federal Aviation Administration and National Weather Service (and other state and local officials) to provide airline pilots with timely information about hazardous volcanic ash clouds.

   When communities are at risk, scientists give hazards information directly to public officials to help them make decisions about land-use or evacuations. Unlike the movie, warnings are delivered only after a thorough analysis of all existing information and careful consultation among members of the USGS response team and other experts that may be needed. The goal is always to keep natural processes from becoming natural disasters.

5. How many active volcanoes are there in the United States and its territories? In Alaska?

   According to the USGS Cascades Volcano Observatory FAQ’s on-line, about 170 volcanoes in the U.S. have been active in the past 10,000 years. Scientists consider these the most likely to erupt again in the future. Most of these are located in Alaska, where eruptions occur virtually every year. Many others are located in the Cascade Range (Washington, Oregon, northern California), or in Hawaii on the islands of Hawaii and Maui.

   Alaska contains more than 140 volcanoes and volcanic fields, which have been active within the last 2 million years. Of these volcanoes, about 90 have been active within the last 10,000 years, and more than 50 have been active within historical time (since about 1760, for Alaska).
   - AVO webpage concerning historically active volcanoes in Alaska. http://www.avo.alaska.edu/volcanoes/about.php

6. How many active volcanoes are there on Earth?

   According to the Smithsonian Institute Global Volcanism Program, there are about 1,500 potentially active volcanoes worldwide. About 87 percent of these erupted in the Holocene (past 10,000 years) and about 550 of these have had documented eruptions. Many of these volcanoes are located along the Pacific Rim in what is known as the "Ring of Fire." In the U.S., volcanoes in the Cascade Range and Alaska (including Cook Inlet and the Aleutian volcanic chain) are part of the Ring; however, Hawaiian volcanoes form over a "hot spot" near the center of the Ring. These values do not include the more or less continuous belt of volcanoes atop oceanic spreading centers deep below the surfaces of the Atlantic and Pacific oceans.
   - Smithsonian Institution Global Volcanism Program webpage http://www.volcano.si.edu/faq/index.cfm?faq=03

7. What are the names of historically active volcanoes in the Alaska?
   - AVO website (**Bold, black** font on this webpage indicates a volcano is historically active). http://www.avo.alaska.edu/volcanoes/index.php
   - Wallace, K.L., McGimsey, R.G., and Miller, T.P., 2000, Historically active volcanoes in Alaska—A quick reference: U.S. Geological Survey Fact Sheet 118-00, 2 p.
     Website http://pubs.usgs.gov/fs/2000/fs118-00/
     PDF http://www.avo.alaska.edu/pdfs/usgsfs118-00.pdf
   - Schaefer, J. and Nye, C.J., 2002, Historically active volcanoes of the Aleutian Arc: Alaska Division of Geological & Geophysical Surveys Miscellaneous Publication MP 0123.
     Page Size http://www.avo.alaska.edu/pdfs/mp123_pagesize.pdf
     Poster Size http://www.avo.alaska.edu/pdfs/mp123.pdf

- Nye, C.J., and others, 1998, Volcanoes of Alaska: Alaska Division of Geological & Geophysical Surveys Information Circular 38.
  - PDF Front http://www.dggs.dnr.state.ak.us/webpubs/dggs/ic/oversized/ic038ed1998_sh001.PDF and
  - PDF Back http://www.dggs.dnr.state.ak.us/webpubs/dggs/ic/oversized/ic038ed1998_sh002.PDF

8. Which Alaskan volcano will erupt next and why do you think so?

   No one knows for sure, but the volcanoes that have been most active since 1700 could be the next to erupt.
   - AVO About Alaska's Volcanoes webpage http://www2.avo.alaska.edu/volcanoes/about.php

II. Volcanic Eruptions

1. Is the eruption depicted in *Dante's Peak* realistic? Why or why not?

   In many, but not all respects, the movie's depiction of eruptive hazards hits close to the mark. The move accurately conveys the enormous power unleashed during an explosive eruption. Stratovolcanoes in the Cascade Range and Alaska—like the one in the movie—often erupt explosively and produce pyroclastic flows, clouds of volcanic ash, and debris flows (also known as mud flows and lahars) that behave much as shown in the movie. Lava flows at these volcanoes, though, are usually thick and slow moving, unlike the fluid, rapidly flowing lava flows in the movie. Fast-moving flows of basalt lava are common in Hawaii, though. Real eruptions may be considerably larger or smaller, and affect larger or smaller areas, than those shown in the film.

2. Can eruptions really threaten helicopters, as in the movie, and other aircraft? If so, how?

   Yes. Encounters between aircraft and clouds of volcanic ash are a serious concern. Jet engines and other aircraft components are vulnerable to damage by fine, abrasive volcanic ash, which can drift in dangerous concentrations hundreds of miles downwind from an erupting volcano.

   From 1973 to 2008 (inclusive) 121 jet aircraft encountered volcanic ash plumes and in 10 of those cases, 1 or more engines temporarily lost power. In the past 20 years (1989-2008, inclusive), 78 aircraft have accidently encountered volcanic ash clouds and in 6 of those cases the aircraft experienced temporary engine power loss (M. Guffanti, oral commun., 2009). An international consortium of government agencies, including the USGS, Federal Aviation Administration, and National Weather Service, is working cooperatively with the International Civil Aviation Organization (ICAO), the Air Line Pilots Association (ALPA), and other aviation government and industry organizations to make sure that aircraft receive ample warning of potentially dangerous ash clouds and other eruptive phenomena.

3. Can the temperature of hot springs near a restless volcano change quickly enough to injure bathers? Why or why not?

   Temperature changes can and do occur, but usually more slowly than shown in the movie. In fact, the temperature of hot springs may increase, decrease, or stay the same during volcanic unrest. Increases in water temperature, when they do occur, usually take days or weeks to develop, rather than a few seconds as shown in the movie. That being said, earthquakes can suddenly disrupt a volcano's hot groundwater system, changing its temperature and flow characteristics. In rare cases, changes in the flow of water from hot springs has caused the onset of geyser-like activity that could threaten bathers and such changes may occur without felt earthquakes (B. Evans, written commun., 2009).

   - Farrar, C.D., Evans, W.C., Venezky, D.Y, Hurwitz, Shaul, and Oliver, L.K., 2007, Boiling water at Hot Creek—The dangerous and dynamic thermal springs in California's Long Valley Caldera: U.S. Geological Survey Fact Sheet 2007-3045, 4 p.
     PDF http://pubs.usgs.gov/fs/2007/3045/fs2007-3045.pdf

4. Do earthquakes large enough to collapse buildings and roads accompany most volcanic eruptions? Why or why not?

   Not usually. Earthquakes associated with most eruptions rarely exceed magnitude 5 and these moderate earthquakes are probably not big enough to destroy the kinds of buildings, houses, and roads that were demolished in the movie. The largest earthquakes at Mount St. Helens in 1980 were magnitude 5, large enough to sway trees and damage buildings, but not destroy them. During the huge eruption of Mount Pinatubo in the Philippines in 1991, several hundred thousand people felt dozens of light to moderate earthquakes (magnitude 3 to 5). Many houses collapsed, but not primarily because of the shaking. Heavy, wet ash from the eruption and a hurricane accumulated on roofs and crushed them.

   Stronger earthquakes sometimes occur near volcanoes as a result of tectonic faulting. For example, four magnitude 6 earthquakes struck Long Valley caldera, California, in 1980, and a magnitude 7.2 earthquake struck Kilauea Volcano, Hawaii, in 1975. Both volcanoes were quiet at the time. The Hawaii earthquake triggered a small eruption at the summit of Kilauea. No eruption has yet occurred at Long Valley, but the area has been restless since the 1980 earthquakes.

   Earthquakes associated with caldera forming eruptions, however, may reach higher magnitudes. The 1912 eruption of Novarupta volcano on the Alaska Peninsula and the associated collapse of Mt. Katmai (creating the Katmai caldera) generated 14 earthquakes of magnitude 6–7 during the 60-hour-long eruption (see link below). This eruption is also the largest volcanic eruption in the world in the Twentieth century. The eruption of the remote volcano and associated earthquakes, hundreds of miles from the nearest significant buildings, houses, and roads, did not destroy any infrastructure. Nearby villages with semi-subterranean housing constructed by nomadic populations, however, were buried in volcanic ash fall deposits.

- Fierstein, Judy, Hildreth, Wes, Hendley, J.W., II, and Stauffer, P.H., 1998, Can another great volcanic eruption happen in Alaska?: U.S. Geological Survey Fact Sheet 0075-98, 2 p.
  Website http://pubs.usgs.gov/fs/fs075-98/
  PDF http://pubs.usgs.gov/fs/fs075-98/fs075-98.pdf

5. Can a town's water supply become contaminated when a volcano is restless? If so, how?

   Yes, but probably not as quickly as shown in the movie. If a town's water supply originates directly from a volcano's groundwater system or from a stream that has been covered with volcanic ash, the water could become contaminated with foul-smelling gases or fine ash and other sediment. Some volcanic gases such as sulfur dioxide dissolve in groundwater, making the water acidic. The most common sulfurous odors, however, are caused by hydrogen sulfide gas, which smells like rotten eggs.

   Potentially harmful substances in some volcanic ash are the water-soluble materials called leachates, mostly acids and salts, which cling to the particles of glass and crystals. Rarely, volcanic eruptions produce ash that is high in Flourine. Excess fluorine is recognized as the most hazardous leachate in water supplies. The main concern of fluorine poisoning is for livestock, which graze on ash-contaminated grass and feed (see link below).
   - Volcanic Ash—Effects and mitigation strategies—What it can do and how to prevent damage: U.S. Geological Survey Water Supply website http://volcanoes.usgs.gov/ash/water/index.html

6. Do scientists drive across moving lava flows? If so, where and when?

   No. Any attempt to drive across an active lava flow, even one that has partly solidified to form a thin crust, is likely to lead to disaster. With a temperature of 2,000°F (1,100°C) or higher, fresh lava will quickly melt rubber tires and ignite gas tanks. If a vehicle is stuck in moving lava, well, you know the rest of the story. Furthermore, road access to Alaska’s volcanoes is scarce and AVO does not have an off road vehicle like that portrayed in the movie. Volcanoes in Alaska are on Federal, state, and private land with varying degrees of restriction as well.

7. Can carbon dioxide (CO_2) gas from volcanoes kill trees and wildlife? If so, how?

   Yes. At several volcanoes around the world, carbon dioxide gas released from magma has accumulated in the soil in sufficient concentrations to kill vegetation or has collected in low areas and suffocated animals. This colorless, odorless gas usually does not pose a direct hazard to life because it typically becomes diluted to low concentrations quickly whether it is released continuously from the ground or during episodic eruptions. In certain circumstances, however, CO_2 may become concentrated at levels lethal to people and animals. At Mammoth Mountain in California, carbon dioxide has killed about 100 acres of trees since 1989, and visitors to this area occasionally have suffered symptoms of asphyxiation when entering cabins or below-ground excavations. In 2003, three members of the Mammoth Ski Patrol were killed when they fell through an unstable snow roof over a well-known geologic feature called the Mammoth Mountain fumarole, a vent that releases water vapor and carbon dioxide. The snow roof had acted as a cap over the fumarole and a high level of CO_2 collected within the capped vent. USGS scientists have concluded that the gas is escaping from a magma body beneath Mammoth Mountain. The magma itself is not currently moving toward the surface, but the USGS is monitoring the situation carefully.

- Sorey, M.L., and others, 1996, Invisible CO_2 gas killing trees at Mammoth Mountain, California: U.S. Geological Survey Fact Sheet 172-96, 2 p.
  Website http://pubs.usgs.gov/fs/fs172-96/
  PDF http://pubs.usgs.gov/fs/fs172-96/fs172-96.pdf

8. Can volcanoes suddenly become restless and erupt within 1 day of the first signs of activity? Why or why not?

   Yes. The initial major phreatomagmatic, vent-clearing explosion of Redoubt volcano in Cook Inlet, Alaska occurred at 9:47 AM on December 14, 1989, and was preceded by only 1 day of intense earthquake activity. Three more ash-rich explosions occurred the following day, December 15, 1989. Okmok Volcano erupted explosively, with virtually no warning, starting July 12, 2008, sending ash to 50,000 feet. Other volcanoes, and even other eruptions at Okmok and Redoubt volcanoes in Alaska, have been restless for months or years before an eruption occurred, and sometimes a period of unrest does not produce an eruption at all.

   - AVO website
     - Redoubt reported activity—1989
       http://www.avo.alaska.edu/volcanoes/volcact.php?volcname=Redoubt&eruptionid=442&page=basics
     - Okmok reported activity—2008
       http://www.avo.alaska.edu/volcanoes/volcact.php?volcname=Okmok&eruptionid=604&page=basics

9. Are robots used to monitor volcanoes? If so, how?

   Presently the USGS relies on observations and measurements made by experienced scientists and on critical data sent by radio or satellite relay from monitoring instruments installed around a volcano. These instruments include seismometers, tiltmeters, Global Positioning System (GPS) receivers, gas sensors, mudflow (lahar or debris flow) sensors, temperature probes, active satellite radar, thermal imaging, ground-based ash radar, and additional satellite techniques.

   Robotic vehicles have been used to explore undersea volcanoes and the volcanic landscapes on the surface of Mars. A group of European scientists also investigated the use of robots in studying active volcanoes through a project called Robovolc.

   In the U.S., NASA has tested a robot named Dante at Mount Erebus volcano in Antarctica and Mount Spurr volcano in Alaska following the 1992 eruption of Crater Peak. More information on the NASA robot Dante II at Alaska’s Mt. Spurr in 1994 is available from various media sources on-line, such as the New York Times website.

10. Can volcanoes produce large explosive eruptions and rivers of fluid lava at the same time? If so, how?

    Not usually. During a single eruption, a volcano can produce lava flows and ash, sometimes simultaneously. The red, glowing lava fountains and lava flows in *Dante's Peak* (including the active flow across which Harry Dalton drives) are characteristic of a fluid magma, called basalt. In contrast, explosive gray ash columns and pyroclastic flows shown in other scenes are characteristic of viscous magmas, called andesite, dacite, or rhyolite. It is uncommon for a volcano to erupt magmas of widely different composition at the same time, but over the course of a lengthy eruption the eruptive products of an intermediate magma composition (like basaltic andesite) can transition from explosive (ash plume generation) to effusive (lava flow generation).

    Following precursory heightened volcanic activity that began in November 2005, Augustine Volcano in Alaska's Cook Inlet erupted in January 2006. The eruption lasted several months and consisted of multiple phases of eruption activity. The eruption began with an explosive phase, which lasted from January 11 to January 28, 2006. These explosions produced ash plumes, reported by the U.S. National Weather Service to have reached heights greater than 9 km (5.6 mi.) above sea level.

    The volcano then entered a period of more continuous eruptive activity that began on January 28 and lasted until February 2. The phase began with four explosive eruptions that generated ash plumes to heights of 9 km (5.6 mi) above sea level. These explosions generated substantial pyroclastic, block, and ash flows that destroyed scientific monitoring equipment on the west and north flanks of the volcano.

    Augustine then entered an effusive phase, which lasted from February 2 through March 6. During this period, the eruption lava was extruded at the summit and two blocky lava flows moved down the north and northeastern flanks. The effusion of lava stopped in late March 2006.

    - AVO website - Augustine reported activity - 2005 http://www.avo.alaska.edu/volcanoes/volcact.php?volcname=Augustine&eruptionid=547&page=basics

11. Can lakes near volcanoes become acidic enough to be dangerous to people? If so, how?

    Yes. Crater lakes atop volcanoes typically are the most acidic, with pH values as low as 0.1 (very strong acid). Normal lake waters, in contrast, have relatively neutral pH values near 7.0. The crater lake at El Chichon volcano in Mexico had a pH of 0.5 in 1983 and Mount Pinatubo's crater lake had a pH of 1.9 in 1992. The acid waters of these lakes are capable of burning skin, but are unlikely to dissolve metal quickly. Gases from magma that dissolve in lake water to form such acidic brews include carbon dioxide, sulfur dioxide, hydrogen sulfide, hydrogen chloride, and hydrogen fluoride. However, the movie's rapidly formed acidic lake capable of dissolving an aluminum boat in a matter of minutes is unrealistic.

In 2005, AVO received news of activity of Chiginigak volcano on the Alaska Peninsula from the owner of a nearby fishing lodge. It was later determined that between November 2004 and early May 2005, a flux of heat to the summit area caused melting of ice and snow filling the summit crater of Chiginagak, resulting in a cauldron containing an acidified lake. In early May 2005, a catastrophic release of sulfurous, clay-rich debris and acidic water from the lake, with an accompanying acidic aerosol component, traveled 27 km (~17 mi) downstream and flowed into the Mother Goose Lake, headwaters of the King Salmon River. Extensive vegetation damage occurred along the flood route and Mother Goose Lake was acidified (pH of 2.9–3.1), killing all aquatic life and preventing the annual salmon run. For more information on this acidic lake drainage in Alaska, see:

- AVO website Chiginigak reported activity – 2005 http://www.avo.alaska.edu/volcanoes/volcact.php?volcname=Chiginagak&eruptionid=535&page=basic

III. Eruption Precursors

Before a volcano erupts, magma must force its way upward through solid rock beneath a restless volcano. This process causes the ground above to heave and shake as rock is shoved aside or broken. At the same time, gases are released from the magma as it rises to shallower levels where the pressure is lower. These phenomena—ground movements, earthquakes, and changes in volcanic gases—provide the clues that scientists use to recognize a restless volcano and anticipate what might happen next.

1. What kinds of unusual activity might be noticed before an eruption?

   Common symptoms of volcanic unrest include an increase in the frequency or intensity of earthquakes beneath a volcano; the occurrence of volcanic tremor; swelling, subsiding, or cracking of the ground; increased steam emission or small steam explosions; melting snow or ice; changes in existing fumaroles or hot springs, or the appearance of new ones; and increased discharge of magmatic gases. Volcanologists assess the significance of volcanic unrest partly by monitoring the pace and intensity of such activity.

2. What is volcanic tremor, and how does it differ from earthquakes?

   Tremor is a seismic vibration, similar to a volcanic earthquake, but of longer duration and more continuous than earthquakes of the same amplitude. Volcanic tremor can last from minutes to days. It may be caused by magma moving through narrow cracks, boiling and pulsation of pressurized fluids within the volcano, or escape of pressurized steam and gases from fumaroles.

3. Do volcanoes produce different kinds of earthquakes, and if so, what are they and how do they differ?

   Yes. A variety of earthquake types can occur at a volcano that is getting ready to erupt. These include earthquakes caused by rocks breaking along faults or fractures (volcano-tectonic-type earthquakes). Another common type is called a long-period or volcanic earthquake. These can occur when bubble-filled magma is on the move beneath a volcano. In *Dante's Peak*, Harry Dalton states in one scene that he has felt some volcanic earthquakes. In fact, the differences between tectonic-type and long-period earthquakes are so subtle that they can be distinguished only by using seismometers and looking carefully at the waveforms and frequency content.

4. What kind of gases escape from volcanoes?

   The fumes escaping from a volcano consist mostly of water vapor (steam). Steam may be emitted from the hot interiors of volcanoes even when they are dormant. Steaming usually increases dramatically as magma intrudes and heats groundwater beneath a volcano. Magma gives off carbon dioxide (CO_2) and hydrogen sulfide (H_2S, rotten egg gas) that do not totally dissolve in groundwater and can therefore show up at the surface. As water inside the volcano boils away, other more water-soluble volcanic gases can reach the surface, signaling an increasing likelihood of eruption. These gases include sulfur dioxide (SO_2) and common halogen gases such as hydrogen chloride (HCl), and hydrogen fluoride (HF).

5. Are there any volcanoes exhibiting heightened volcanic activity in the U.S. and its territories today? In Alaska?
   - Latest U.S. Volcano Alerts and Updates webpage
     http://volcanoes.usgs.gov/

IV. Volcano Monitoring

To anticipate the awakening or reawakening of a volcano, volcanologists watch for changes caused by moving or pressurizing of magma and any associated changes in the hydrothermal system surrounding the magma. Much as depicted in Dante's Peak, magma moving toward the surface can cause swarms of earthquakes; swelling of the volcano, subsidence, or cracking of the volcano's flanks; and changes in the amount or types of gases emitted. The USGS continuously monitors many volcanoes in the states of Washington, Oregon, California, Hawaii, Alaska, Wyoming (Yellowstone) and the Northern Marianas Islands to detect unusual activity.

1. Does the USGS have a team of volcanologists that can respond to volcanic unrest on short notice? If so, can you describe the team?

   Yes. The USGS Volcano Hazards Team includes experts in all aspects of volcano hazard assessment, monitoring, information dissemination, and volcano- emergency response. As depicted in the movie, a group of USGS scientists will respond to any potentially hazardous volcanic activity in the United States.

2. Does the USGS have a team for rapid response to volcano emergencies in other countries? If so, can you describe the team?

   Yes. Such a team is operated by the USGS as part of the Volcano Disaster Assistance Program (VDAP). The team was formed in cooperation with the U.S. Office of Foreign Disaster Assistance (OFDA) of the U.S. Agency for International Development following the 1985 eruption of Nevado del Ruiz Volcano, Colombia, in which more than 23,000 people lost their lives. At the request of host countries and working through OFDA, VDAP scientists work with local scientists to quickly determine the nature of volcanic unrest and assess its possible consequences. VDAP has responded to volcano emergencies in more than a dozen countries during the past decade.

   In addition to helping people in other countries to get out of harm's way, VDAP's international work directly benefits volcano-hazard mitigation in the United States. Through VDAP, the USGS gains experience at active volcanoes that will help during future crises in the western United States, and collects important scientific data on eruption precursors that are used to understand better, how volcanoes work.

3. How does the USGS monitor volcanoes in the United States and its territories?

   One of the earliest signs of an impending eruption is often a subtle change in seismic or earthquake activity beneath a volcano. In cooperation with universities and state agencies, the USGS monitors seismic activity near volcanoes using networks of seismometers. When unusual activity is detected, a response team may install more seismometers and other instruments to track the location and depth of the earthquakes and determine if an eruption is likely. Scientists also monitor the amount and types of gases released at volcanoes, shrinking and swelling of volcanic edifices, changes in ground and hydrothermal temperatures at volcanoes, and several other monitoring streams to watch for changes indicative of magma movement.
   - About AVO webpage
     http://www.avo.alaska.edu/about/index.php

4. How are earthquakes monitored?

   By installing seismometers, which send information continuously by radio to a central recording site (observatory), scientists can determine the sizes and locations of earthquakes near a volcano. Scientists look for specific types of earthquakes that are often associated with volcanic activity. An increase in the number or size or shallow earthquakes below a volcano usually means that an eruption is likely. Anyone with internet access can view incoming real-time seismic data from dozens of seismometers placed at Alaskan volcanoes.
   - AVOs webicorders webpage
     http://www.avo.alaska.edu/webicorders/

5. How are ground movements measured? (number dropped off?)

   Ground deformation (swelling, subsidence, or cracking) is measured *in situ* using various techniques, including Electronic Distance Meters (EDM), the Global Positioning System (GPS), precise leveling surveys, strainmeters, and tiltmeters. EDMs use lasers to accurately measure changes in distance between reflectors installed at benchmarks (fixed points) with repeated measurements. GPS makes use of satellites orbiting the Earth to determine and track the locations of points. Strainmeters and tiltmeters are used to monitor subtle changes in shape of the ground surface.

   Scientists also rely on satellite-based images that illustrate ground movement over time. These images are generated by using active radar satellite data of the same area at two different points in time and subtracting one data set from the other. Changes in elevation will become apparent through this process, including whether an area has inflated or subsided. This technique is call Interferometric Synthetic Aperture Radar (InSAR) and the images produced using this technique of data subtraction are called interferograms. One suggested paper illustrating the use of InSAR in Alaska is:

   - Lu, Zhong, and others, 2003, Interferometric synthetic aperture radar studies of Alaska volcanoes: Earth Observation Magazine, v. 12, no. 3, p. 8-10.
     PDF
     http://quake.usgs.gov/research/deformation/modeling/papers/2003/lu_et_all_2003.pdf

6. How are volcanic gases measured?

   Instruments to measure volcanic gases can be mounted in aircraft or used on the ground on a tripod. Typically, scientists measure a concentration of a particular gas in a plume and then use the wind speed and width of the plume to determine the quantity of gas being emitted on a daily basis. In *Dante's Peak*, a correlation spectrometer (COSPEC) was mounted in a helicopter to monitor sulfur dioxide emissions from the volcano. The instrument that detects carbon dioxide can be used from an aircraft and also installed on a volcano and configured to send data continuously by radio to an observatory. Sulfur dioxide in volcanic clouds also can be measured from space with instruments aboard satellites.

   Volcanic gases also may be dissolved within the regional hydrothermal waters. Direct and repeat sampling of local waterways can be used to detect possible trends in the amount and types of dissolved gases with a volcanoes watershed. Scientists can be observed collecting water samples from glacial drainages of the Drift Glacier on redoubt volcano during heightened volcanic activity in 2009.

   - AVO movie: Measuring water temperature at the outflow of Drift Glacier, Redoubt Volcano webpage
     http://www.avo.alaska.edu/image.php?id=16552

Scientists are continuously improvising the ability of using satellite imagery to monitor volcanic gas plumes erupted from volcanoes. On August 7, 2008, Kasatochi volcano in the central Aleutian Islands erupted explosively. The cumulative volcanic cloud from the eruption of Kasatochi contained a large amount of sulfur dioxide gas that was detected by the Ozone Monitoring Instrument on NASA's EOS-Aura satellite for more than a week after the eruption as the cloud circled the globe.

- AVO News - Small Volcano, Big Eruption, Scientists Rescued Just in Time http://www.avo.alaska.edu/activity/Kasatochi08/Kasatochi2008PLW.php

7. Can mudflows be monitored? If so, how?

   The torrents of mud, rocks, logs, and other debris depicted in Dante's Peak are collectively called mudflows, debris flows, or lahars, an Indonesian term for volcanic mudflows. An instrument called an acoustic flow monitor can be installed near river valleys leading away from a volcano to help provide warnings of approaching flows. The system senses vibrations caused by the mudflows and sends alerts by radio to the volcano observatory or another official emergency office.

   - USGS Volcano Hazards Program, 1989–90 Eruption of Redoubt Volcano, Alaska, and the First Test Case of a USGS Lahar-Detection System, webpage http://volcanoes.usgs.gov/activity/methods/hydrologic/afm_redoubt.php

8. What else do scientists measure at volcanoes?

   Field observations by experienced volcanologists go hand in hand with more sophisticated equipment and techniques to form a complete system for monitoring volcanoes. Field observations may include water temperature and pH (acidity) measurements, as shown in *Dante's Peak*, or observations of ground cracking, new areas of avalanching rocks, and so on. An experienced observer can integrate many types of data on the spot and design simple measurements to assess further the significance of volcanic unrest. There is no substitute for well-trained, experienced observers when trying to determine how a volcano will behave. Additionally, understanding past eruption history serves as the key framework for evaluating current and future unrest and the most likely eruption scenarios.

V. Volcanic Hazards

In Dante's Peak, a restless volcano endangers nearby residents with clouds of ash, falling blocks of rock, pyroclastic flows or ash hurricanes, lava flows, and floods of debris or lahars. These hazards are typical of snow- and ice-covered stratovolcanoes like those in the Cascade Range and Alaska. Since 1980, volcanic activity has killed more than 29,000 people worldwide, mainly due to roof collapses under the weight of ash fall deposits and widespread disease from unsanitary conditions following a volcanic eruption. Most of the deaths were caused by lahars and pyroclastic flows; a few hundred people were killed by ash falls, which collapsed the roofs of buildings. Lists are available that rank the world’s deadliest volcanic eruptions.

- Pacific Disaster Center—Deadliest Eruptions webpage
  http://www.pdc.org/iweb/volcano_deadliest.jsp

1. What kinds of hazards were depicted in the movie, and what part have they played in real volcanic eruptions? Are they realistic?

   Debris flows, or lahars, are slurries of muddy debris and water like the one that carried away Paul Dreyfuss in *Dante's Peak.* They are caused by mixing of volcanic debris and local soil and rocks with water, melted snow, or ice. Lahars destroyed houses, bridges, and logging trucks during the May 1980 eruption of Mount St. Helens, and have inundated other valleys around Cascade volcanoes during prehistoric eruptions. Lahars at Nevado del Ruiz volcano, Colombia, in 1985, killed more than 23,000 people. At Mount Rainier, major landslides that apparently were neither triggered nor accompanied by eruptive activity have produced lahars. Lahars can travel many tens of miles in a period of hours, destroying everything in their paths. Mudflows have occurred during eruptions at Alaska's volcanoes—most notably those of Redoubt volcano in the Cook Inlet.

   Tephra (ash and coarser debris), like that which buried the town of *Dante's Peak*, is composed of fragments of magma or rock blown apart by gas expansion during an explosive eruption. Tephra accumulation is heavy, especially when wet, and can cause roofs to collapse, respiratory problems, and damage to machinery and infrastructure. Tephra can also severely damage aircraft in flight and short out power lines hundreds of miles downwind of eruptions. Explosions may also throw large rocks a few miles. As depicted in *Dante's Peak*, falling blocks killed people at Galeras Volcano in Colombia in 1992, and at Mount Etna, Italy, in 1979.

   Pyroclastic flows and surges are lumped together and called "pyroclastic clouds" by Harry Dalton in *Dante's Peak*. These two phenomena are related but slightly different; pyroclastic surges are hot, turbulent clouds of tephra that can surmount ridges and topography easily; pyroclastic flows are dense, turbulent mixtures of tephra and gas that are funneled downslope and in valley bottoms. Pyroclastic flows and surges can travel more than a hundred miles per hour and incinerate or crush most objects in their path. Although most extend only a few miles, a pyroclastic surge at Mount St. Helens in 1980 extended 18 mi (28 km) and killed 57 people. Pyroclastic surges at El Chichon Volcano in Mexico in 1982 killed 2000 people, and pyroclastic flows and surges at Mount Unzen, Japan, in June 1991, killed 43 people. Contrary to the movie, it is unlikely that speeding vehicles could outrun a pyroclastic flow or surge if it is nearby. The pyroclastic flow deposit from the 1912 eruption of Novarupta now within Katmai National Park and Preserve on the Alaska Peninsula formed the famed Valley of Ten Thousand Smokes.

   Lava flows erupted at stratovolcanoes like those in the Pacific Northwest and Alaska are typically slow-moving, thick, blocky, viscous flows. Shield volcanoes that produce basalt like Kilauea Volcano on the island of Hawaii has produced thin, fluid lava flows like those depicted in *Dante's Peak* throughout its history, and almost continuously since 1983. Lava flows destroyed a visitor center at Kilauea in 1989 and overran the village of Kalapana on the volcano's southeast flank in 1991.

2. Can volcanoes be dangerous even when they do not erupt? If so, how?

   Definitely. Many stratovolcanoes have a plumbing system of hot acid water that progressively breaks down hard rock to soft, clay-rich material. As the volcano gradually weakens, large parts may suddenly fail. Resulting water-rich landslides are especially dangerous because they can occur without any volcanic or seismic warning.

   Steam explosions, rock falls, acid hot springs, and significant CO_2 emissions are also possible non-eruptive hazards.

3. In the U.S. and its territories, how can residents who live near volcanoes prepare for future eruptions?

   Residents can obtain copies of USGS volcano-hazard reports and preliminary hazard assessments to determine whether they live or work in areas at risk from volcanic activity and what kinds of hazards they face. Everyone should plan how they and their family will respond to a natural disaster, including unrest or eruptive activity at nearby volcanoes. Preparation might include knowing where to go when family members are separated, where to go for emergency housing, what emergency supplies to keep on hand, and how to be self sufficient for several days, as recommended by local emergency management agencies. Residents who live within 160 km (100 mi) of a volcano should also find out what their local officials are doing to prepare their community for the possibility of renewed volcanic activity. Lastly, enjoy the scenic, recreational, and inspirational benefits of living near an active volcano!

Name ____________________________________ Date ______________ Period _____

Supervolcano

The docudrama *Supervolcano* dramatically explores the effect of a large caldera-forming eruption at Yellowstone National Park in Wyoming. Answer the questions below and shed light on issues related to volcanism at Yellowstone.

1. What is the chance of another catastrophic volcanic eruption at Yellowstone?

2. What is a "supervolcano"?

3. What would happen if a "supervolcano" eruption occurred again at Yellowstone?

4. Is Yellowstone monitored for volcanic activity and if so, why?

5. Do scientists know if a catastrophic eruption is imminent at Yellowstone? If so, how?

6. How far in advance could scientists predict an eruption of the Yellowstone volcano?

7. Can some of the pressure at Yellowstone be released by drilling into the volcano? If so, how?

8. Could the Yellowstone volcano have an eruption that is not catastrophic? Is so, when? Can you describe it?

9. Because Yellowstone is so geologically active, are there other potential geologic hazards in Yellowstone? If so, what are they?

Supervolcano Key

(based on http://volcanoes.usgs.gov/yvo/2005/docudrama.html)

The docudrama *Supervolcano* dramatically explores the effect of a large caldera-forming eruption at Yellowstone National Park in Wyoming. The scale of the portrayed eruption is similar to the eruption of the Huckleberry Ridge Tuff at Yellowstone 2.1 million years ago. The movie is realistic insofar as depicting what could happen if an eruption of this magnitude were to occur again. Although the drama is set in the future, it does an acceptable job of addressing some of the issues scientists would grapple with if Yellowstone showed signs of an impending eruption. The questions and answers below shed light on issues related to volcanism at Yellowstone.

1. What is the chance of another catastrophic volcanic eruption at Yellowstone?

   Although it is possible, scientists conclude that the probability of another catastrophic eruption at Yellowstone is extremely small. Given Yellowstone's history, the annual probability of another caldera-forming eruption could be calculated as 1 in 730,000 or 0.00014 percent. However, this number is based simply on averaging the two intervals between the three major past eruptions at Yellowstone —hardly enough information to make a defensible statistical forecast. This probability is roughly similar to that of a large (1 km [~3,280 ft]) asteroid hitting the Earth. In summary, although it is possible, it is highly unlikely.

2. What is a "supervolcano"?

   The term "supervolcano" refers to a volcanic system capable an eruption of magnitude 8 on the Volcano Explosivity Index, meaning that more than 1,000 km^3 (240 mi^3) of magma (partially molten rock with crystals, dissolved gases, and liquid rock) are erupted. The most recent such event on Earth occurred 74,000 years ago at the Toba Caldera in Sumatra, Indonesia.

3. What would happen if a "supervolcano" eruption occurred again at Yellowstone?

   Such a giant eruption would devastate everything within hundreds to thousands of miles. It would have widespread regional effects from falling ash, volcanic gas, and aerosol clouds causing disruption of lives and communities throughout the United States. The ash and gas cloud would circle the globe causing changes in global climate for years to decades. The surrounding states of Montana, Idaho, and Wyoming would be affected, as well as other places in the U.S. and the world. Such eruptions usually form calderas, broad volcanic depressions created as the ground surface collapses because of withdrawal of partially molten rock (magma) below. Fortunately, the chances of this sort of eruption at Yellowstone are exceedingly small in the next few thousands of years.

4. Is Yellowstone monitored for volcanic activity?

   Yes. The Yellowstone Volcano Observatory (YVO), a partnership between the U.S. Geological Survey (USGS), Yellowstone National Park, and the University of Utah, closely monitors volcanic activity at Yellowstone. The YVO website features real-time data for earthquakes, ground deformation, streamflow, and selected stream temperatures. Additionally, YVO scientists collaborate with scientists from around the world to study the Yellowstone volcano and better understand how it works.

5. Do scientists know if a catastrophic eruption is imminent at Yellowstone? If so, how?

   There is no evidence that a catastrophic eruption at Yellowstone is imminent, and such events are unlikely to occur in the next few centuries. Scientists have also determined no indication of an imminent smaller eruption of lava.

6. How far in advance could scientists predict an eruption of the Yellowstone volcano?

   The science of forecasting a volcanic eruption has significantly advanced over the past 25 years. Most scientists think that the buildup preceding a catastrophic eruption would be detectable for weeks and perhaps months to years. Precursors to volcanic eruptions include strong earthquake swarms and rapid ground deformation and typically take place days to weeks before an actual eruption. Earthquake activity can sometimes begin to rise subtly many months prior to an eruption. Scientists at YVO closely monitor the Yellowstone region for such precursors. They expect that the buildup to larger eruptions would include intense precursory activity far exceeding those that have been typically observed at multiple spots within the Yellowstone volcano. As at many caldera systems around the world, small earthquakes, ground uplift and subsidence, and gas releases at Yellowstone are commonplace events that do not lead to eruptions. Smaller eruptions or steam explosions may have no precursory signals at all.

7. Can you release some of the pressure at Yellowstone by drilling into the volcano? If so, how?

   No. Scientists agree that drilling into a volcano would be of questionable usefulness. Notwithstanding the enormous expense and technological difficulties in drilling through hot, mushy rock, drilling is not likely to have much effect. At near magmatic temperatures and pressures, minerals crystallizing from the natural fluids that are present at those depths would rapidly seal any hole.

8. Could the Yellowstone volcano have an eruption that is not catastrophic? Is so, when? Can you describe it?

   Yes. Over the past 640,000 years since the last giant eruption at Yellowstone, approximately 80 relatively non-explosive, lava-flow eruptions have occurred. This would be the most likely kind of future eruption. If such an event were to occur today, activities would be disrupted in Yellowstone National Park, but few lives would be threatened. The most recent volcanic eruption at Yellowstone, a lava flow on the Pitchstone Plateau, occurred 70,000 years ago.

9. Because Yellowstone is so geologically active, are there other potential geologic hazards in Yellowstone? If so, what are they?

   The heat and geologic forces fueling the massive Yellowstone volcano affect the park in many ways. Yellowstone's many geysers, hotsprings, steam vents, and mudpots are evidence of the heat given off by magma many miles beneath the surface. These hydrothermal (hot water) features are mostly benign, but rarely can be the sites of a type of eruption (phreatic or steam explosions driven by the flash of water to steam in a pressured environment) and pose a hydrothermal hazard. Earthquakes, another example of active geologic forces, are quite common in Yellowstone, with 1,000–3,000 occurring annually. Most of these are quite small, although significant earthquakes have shaken Yellowstone, such as the 1959 magnitude 7.5 Hebgen Lake earthquake, the largest historical earthquake in the intermountain region, and the 1975 magnitude 6.1 earthquake near Norris Geyser Basin. The many earthquakes and gas and steam explosions in the past 10,000 years at Yellowstone have not led to volcanic eruptions.

Activity III. A Day in the Life of a Volcano Observatory

Grade Level 7–11

Setting Two classrooms or one large room

Time 2–3 hours
Depending on the number of students in the class and the length of a class period, it may take as much as 4 hours to complete this activity. The activity can be broken down into different days; it need not be continuous until complete.

Vocabulary (see Glossary)
andesite, basaltic andesite, geologist, geology, geophysicist, glaciology, hydrology, incandescence, incandescent, phreatic, plume, proglacial lake, radar, volcanic (or magmatic) gases, volcanologist

Correlations to Alaska State Department of Education (2006) Science Performance Standards (Grade Level Expectations)
A1—Science as Inquiry and Process
SA[6-11] Students develop an understanding of the processes and applications of scientific inquiry.
SA1[6-11] Students develop an understanding of the processes of science used to investigate problems, design and conduct repeatable scientific investigations, and defend scientific arguments.
SA2[6-11] Students develop an understanding that the processes of science require integrity, logical reasoning, skepticism, openness, communication, and peer review.
SA3[6-11] Students develop an understanding that culture, local knowledge, history, and interaction with the environment contribute to the development of scientific knowledge, and local applications provide opportunity for understanding scientific concepts and global issues.

E1—Science and Technology
SE[6-11] Students develop an understanding of the relationships among science, technology, and society.
SE1[6-11] Students develop an understanding of how scientific knowledge and technology are used in making decisions about issues, innovations, and responses to problems and everyday events.
SE2[6-11] Students develop an understanding that solving problems involves different ways of thinking, perspectives, and curiosity that lead to the exploration of multiple paths that are analyzed using scientific, technological, and social merits.
SE3[6-11] Students develop an understanding of how scientific discoveries and technological innovations affect and are affected by our lives and cultures**.**

F1—Cultural, Social, Personal Perspectives, and Science

SF[6-11] Students develop an understanding of the dynamic relationships among scientific, cultural, social, and personal perspectives.

SF1[6-11] Students develop an understanding of the interrelationships among individuals, cultures, societies, science, and technology.

SF2[6-11] Students develop an understanding that some individuals, cultures, and societies use other beliefs and methods in addition to scientific methods to describe and understand the world.

SF3[6-11] Students develop an understanding of the importance of recording and validating cultural knowledge.

Overview

Through this “table top” volcanic activity scenario and exercise, students will learn how the Alaska Volcano Observatory (AVO) functions when there is an increase in volcanic activity at an Alaskan volcano. Students will play the roles of managers and scientists at AVO, interagency partners, the media, and the public during a volcanic event. A guided discussion will follow the exercise and allow students the chance to discuss how they functioned as a group and fulfilled their individual duties.

Background

AVO is a joint program of the U.S. Geological Survey (USGS), the Geophysical Institute of the University of Alaska Fairbanks (UAFGI), and the State of Alaska Division of Geological and Geophysical Surveys (ADGGS). AVO was formed in 1988, and uses Federal, State, and university resources to monitor and study Alaska's hazardous volcanoes, to predict and record eruptive activity, and to mitigate volcanic hazards to life and property.

AVO offices are in Anchorage and Fairbanks, Alaska. The Anchorage office is at the USGS, and is the primary point of information dissemination during crises. Fairbanks offices are concentrated at the UAFGI, which serves as the data collection point for most seismic and satellite data. AVO is staffed by the equivalent of a few dozen full-time scientists, technicians, and administrators and supports several graduate students. Managerial responsibility for AVO rests with the Scientist-in-Charge, a USGS employee in Anchorage, and the Coordinating Scientist in Fairbanks, a UAFGI or ADGGS employee.

AVO has three primary objectives:

- To conduct monitoring and other scientific investigations in order to assess the nature, timing, and likelihood of volcanic activity
- To assess volcanic hazards associated with anticipated activity, including kinds of events, their effects, and areas at risk
- To provide timely and accurate information on volcanic hazards, and warnings of impending dangerous activity, to local, state, and Federal officials and the public

An important component of AVO's program is to conduct research into how volcanoes work. The scope of this research includes:

- Basic geological mapping to determine eruptive histories of active volcanoes
- Geochemical characterization and modeling of diverse magmatic systems
- Investigation of hydrologic hazards associated with eruptions of snow and ice-clad volcanoes
- Documentation and analysis of eruptive processes
- Geophysical exploration of the interiors of volcanoes and mechanisms of eruption
- Development of new instrumentation to aid in prediction and interpretation of volcanic unrest

Results of these studies contribute significantly to the quality of volcanic hazards assessments and to the continual improvement of AVO's monitoring and forecasting capabilities.

For more information see:

- About AVO webpage
  http://www.avo.alaska.edu/about/

Also for detailed information about AVO specific interagency response during volcanic activity, specifically episodes including ash fall, see pages 6–17 in:

- Madden, John, Murray, T.L., Carle, W.J., Cirillo, M.A., Furgione, L.K., Trimpert, M.T., and Hartig, Larry (signatories), 2008, Alaska interagency operating plan for volcanic ash episodes, 52 p.
  PDF http://www.avo.alaska.edu/pdfs/cit3996_2008.pdf

The scenario used in this activity reflects the sequence of events in autumn 2006 described below.

As autumn arrived in Alaska in 2006, a phreatic eruption from a volcano not considered active in the Holocene (last ~ 10,000 years) surprised AVO and residents of south-central Alaska. In September, AVO received several citizen telephone reports of a dark plume, fed by what appeared to be two sources, rising from the area near Cape Douglas in lower Cook Inlet. Satellite analysis indicated the source of the plumes to be roughly between closely spaced Douglas and Fourpeaked volcanoes. Subsequent data analysis concluded that Fourpeaked, within the northeast corner of Katmai National Park and Preserve on the Alaska Peninsula, 7.5 mi (12 km) southwest of Mount Douglas was the source of the plume. The drifting cloud produced by these rising plumes persisted throughout the night, reaching a minimum altitude of 6,100 m (20,000 ft) based on radar data, but drifting only 20 km (12 mi) downwind in an unusually calm and clear atmosphere over south-central Alaska. The sizes and styles of past eruptions are not well constrained, however, past eruptions of andesite and dacite indicate that eruptions of Fourpeaked can be explosive, possibly producing plumes that reach in excess of 10 km (33,000 ft) above sea level and local ash fall. For the next several weeks, AVO was involved in a significant response to this activity.

For a complete description of AVOs response and activity at the volcano see:

- Neal, C.A, McGimsey, R.G., Dixon, J.P., Manevich, Alexander, and Rybin, Alexander, 2009, 2006 volcanic activity in Alaska, Kamchatka, and the Kurile Islands—Summary of events and response of the Alaska Volcano Observatory: U.S. Geological Survey Scientific Investigations Report 2008-5214, 102 p. PDF http://pubs.usgs.gov/sir/2008/5214/pdf/sir20085214.pdf

Objectives

By playing roles in a volcanic activity scenario students will understand what Observatory staff do, as well as how and why. For one or more class periods, one or more students will be assigned to, or choose to, play the roles of Observatory geophysicists, geologists, and the Scientist-in-Charge (which may also be the role of the instructor). Additional students will play the roles of emergency managers, the public, and the media. In these roles, students will work through an Observatory exercise concerning reported activity of a volcano on the Alaska Peninsula. The scenario presented in this exercise closely matches the order of events that took place in autumn of 2006 when Fourpeaked volcano had a phreatic eruption (an explosion involving water flashing to steam at depth), which caused a significant plume observed by individuals in Homer on the Kenai Peninsula.

Students will answer a series of questions the worksheet provided. These questions aim to have students describe their roles, and how well (or poorly) their tasks were carried out. The worksheet also may be used to generate class discussion instead of written response. Students will be able to identify the roles of individual specialists within the Observatory and additionally identify career paths for students who would like to study volcanoes.

Materials

— *The Finer Points* worksheet
— *Briefing* and *Discussion* information handouts
— chalk or dry erase board (optional)
— digital projector, laptop(s) or other computers with internet access (optional) available

Procedure

I. Set up

1. To conduct this exercise you may need an additional, supervised classroom area. Students playing different roles will be having simultaneous conversations, which should take place in different locations. The use of the internet, a digital overhead projector and computer, and chalk or dry erase board will be useful in both classrooms.

2. For simplicity in this scenario, staff from the Federal Aviation Administration (FAA) and National Weather Service (NWS) will not be included. They are AVOs closest, and in many respects, most crucial interagency partners. Be sure to include the involvement of these two agencies in the discussion following the scenario as mentioned in *The Finer Points* post scenario discussion guide / worksheet.

3. For the sake of simplicity, there is no Coordinating Scientist role in this scenario.

4. There are many unit measurements in this exercise. In some cases, conversions are provided, in other cases they are not. This reflects the complexity of information gathered and used by AVO.

5. Although the Observatory releases their information products to emergency managers, the media, public, and land managers at the same time, it is rare that representatives from all these agencies would be present for a Briefing at one time (as in the scenario portrayed here).

6. This scenario uses a now old aviation color code. For information about the new code and development of the new code please see:
   - Gardner, C.A., and Guffanti, M.C., 2006, U.S. Geological Survey's alert notification system for volcanic activity: U.S. Geological Survey Fact Sheet 2006-3139, 4 p.
     PDF http://pubs.usgs.gov/fs/2006/3139/fs2006-3139.pdf (12.14 MB)

II. Assign Roles

1. Assign a student or small groups of students each of the following roles:
   One person each
   - Observatory Scientist-in-Charge (SIC) (may be played by instructor)
   - Observatory Information Manager (may be played by instructor)
   - National Park Superintendent

   One or more people each
   - Geophysicists (geodesists, seismologists, and satellite remote sensors)
   - Geologists (geochemists, petrologists, hydrologists, and glaciologists)
   - Emergency Managers (includes Homeland Security, Borough Emergency Managers, and Village Public Safety Officers)
   - Members of the public
   - Media (TV, print, web-based, and radio)

   Note It may be best to assign or let students choose their roles and distribute the first set of materials (Discussion 1 only) the day before you plan to start the scenario. Additionally, class discussion and (or) the completion of the worksheet may best take place after the scenario has been completed. It may take up to 4 hours to complete this activity in full, but it does not need to be carried out in one continuous session.

2. The materials presented here are broken into four discussion periods. The teacher or designee will begin the scenario by reading Discussion 1 and sharing the materials (as an overhead, handout, or digital presentation) in the Volcano Activity Narrative.

3. Everyone receives a page (or more) of specific and guiding information about their assigned/chosen role. The Observatory staff should receive updates from the teacher (distribute the appropriate information to the right character at the allotted time) prior to the next Discussion held. Students will have to incorporate this information into a series of Discussions, which should last no longer than 15 minutes. During these Discussions, the Observatory staff should develop an Activity Statement—a brief description of the activity at the volcano for a general audience. In essence, each

Discussion period will serve as a way for the Scientist-in-Charge (SIC) to hear from all his or her staff to develop this statement, have it reviewed, and approved. The Activity Statement must include the use of the aviation level of concern color code.

Green	No eruption anticipated. Volcano is in quiet, "dormant" state.
Yellow	An eruption is possible in the next few weeks and may occur with little or no additional warning. Small earthquakes detected locally and (or) increased levels if volcanic gas emissions.
Orange	Explosive eruption is possible within a few days and may occur with little or no warning. Ash plume(s) bot expected to reach 25,000 feet above sea level. Increased numbers of local earthquakes. Extrusion of lava dome or lava flows (non-explosive eruption) may be occurring.
Red	Major explosive eruption expected within 24 hours. Large ash plume(s) expected to reach at least 25,000 feet above sea level. Strong earthquake activity detected even at distant monitoring stations. Explosive eruption may be in progress.

Aviation Level of Concern Color Code

4. The Observatory SIC and the Information Manager are responsible for the generation and distribution of this Activity Statement to the media, emergency managers, and the Park Superintendent during Briefings. Each Briefing is designed so the media, emergency managers, and the Park Superintendent receive the Activity Statement from the Information Manager and ask questions about the contents of the statement. It is up to individual staff or the SIC whether or not the Observatory staff needs to be present, in whole or individually, at Briefings.

5. While Discussions are occurring, non-Observatory staff should NOT be present, and while Briefings are occurring, the Observatory Information Manager should try to limit the time the media, emergency managers and the Park Superintendent are at the "Observatory" and contact with the SIC and Observatory staff.

6. Media will be tasked with writing articles (or producing radio or TV broadcasts, etc.) for the public—likely, in a room they will share with the members of the public and other non-Observatory staff. It may be best for each group to have their own section of this room in which to work. The media will need to develop and disseminate (or show) their products while the Observatory is having their Discussions. The Media can print and distribute a news story, hold a press conference for the public, or have a mock news briefing with the public watching or a similar event.

7. The students should advance through their assignments with 15-minute long Discussions (Observatory only) including Activity Statement development, and 5 minutes for Briefings (some Observatory and non-Observatory staff with limitations described previously).

8. If the teacher/educator is not a member of the "cast":
   - Try to participate in the Discussion and Briefings as little as possible. The students' characters and their attachment to their position may become more pronounced. You may serve as a moderator in the event that no student or students take this lead.
   - During Discussions and Briefings allow and encourage the students to draw and show figures and graphs to illustrate their points and, if necessary, get attached, concerned, worried, or downright frustrated in their roles!

9. Upon completion of the last Briefings, lead a class discussion, using *The Finer Points* worksheet as a guide and have the students focus on what did and did not work, and how they felt as the professional trying to accomplishing their job, etc. A big test is to determine if the public received accurate information about the activity at each point an Activity Statement was generated. Having the public describe to the Observatory what they thought was going on could be eye opening!

Extensions

1. Have students discuss how the new Aviation Color Code and Volcanic Alert Level would be used in this scenario. A description of this newer system can be used.
   - Gardner, C.A., and Guffanti, M.C., 2006, U.S. Geological Survey's alert notification system for volcanic activity: U.S. Geological Survey Fact Sheet 2006-3139, 4 p.
     PDF http://www.avo.alaska.edu/pdfs/fs2006-3139.pdf (12.14 MB)

2. Instead of a discussion, have the students individually or within their identified groups answer the discussion points in a report, poster, or presentation.

References Cited

Alaska State Department of Education and Early Development, 2006, Standards and grade level expectations, March 2006: State of Alaska website, accessed October 2009 at http://www.eed.state.ak.us/tls/assessment/GLEHome.html.

Neal, C.A, McGimsey, R.G., Dixon, J.P., Manevich, Alexander, and Rybin, Alexander, 2009, 2006 volcanic activity in Alaska, Kamchatka, and the Kurile Islands—Summary of events and response of the Alaska Volcano Observatory: U.S. Geological Survey Scientific Investigations Report 2008-5214, 102 p. (Available at http://pubs.usgs.gov/sir/2008/5214/pdf/sir20085214.pdf.)

AVO website references in order of appearance in the exercise

Cape Douglas from Main Street, Homer, Alaska, September 17, 2006. Photograph taken by Lanny Simpson, Alaska High Mountain Images, used with permission. http://avo.alaska.edu/images/image.php?id=11078.

Location map of Fourpeaked and Douglas volcanoes, Image created by Seth Snedigar and J.R. Schaefer, Alaska Volcano Observatory/Alaska Division of Geological & Geophysical Surveys, dated September 18, 2006. http://www.avo.alaska.edu/image.php?id=11079.

Image from the King Salmon NEXRAD weather radar showing the volcanic cloud at Fourpeaked Mountain volcano on September 17, 2006, at 12:40 ADT (20:40 UTC). Image dated September 19, 2006. This image was produced by David Schneider, U.S. Geological Survey/Alaska Volcano Observatory, using data and software provided by the NOAA National Climatic Data Center. http://www.avo.alaska.edu/image.php?id=11086.

Image showing the total amount of sulfur dioxide in the atmosphere over Fourpeaked Mountain volcano on September 17, 2006, as measured by the Ozone Monitoring Instrument (OMI) on NASA's Aura satellite. Image created by the volcanic emissions group at the University of Maryland Baltimore County, Baltimore, Md., USA, dated September 19, 2006 (S.A. Carn, N.A. Krotkov, A.J. Krueger, and K. Yang). OMI was built by a Dutch/Finnish collaboration and managed by KNMI and NIVR in the Netherlands. http://www.avo.alaska.edu/image.php?id=11085.

Image from Puff volcanic ash dispersion model showing the predicted position of the volcanic cloud at 15:00 ADT (23:00 UTC) from Fourpeaked Mountain volcano on September 17, 2006. Image taken by Peter Webley, Alaska Volcano Observatory/University of Alaska Fairbanks, Geophysical Institute, dated September 20, 2006. http://www.avo.alaska.edu/image.php?id=11087.

Terminus of Fourpeaked Glacier. Notice the dark-colored sediment issuing from an elongate tunnel in the ice that is distinctly different than the color of the proglacial lake. Photograph taken by K. Wallace, U.S. Geological Survey/Alaska Volcano Observatory, September 20, 2006. http://avo.alaska.edu/images/image.php?id=11102.

Photograph taken during the helicopter observation flight between 19:40 and 20:30 local time, looking NNW. SE Ridge in the foreground, top of the "headwall" at the extreme right of the photograph and both plumes in the background. Photograph taken by Guy Tytgat, Alasak Volcano Observatory/University of Alaska Fairbanks, Geophysical Institute, September 20, 2006. http://avo.alaska.edu/images/image.php?id=11132.

Headwall of Fourpeaked Glacier NE of the summit of Fourpeaked volcano. Waterfalls were issuing from beneath the ice at the top of the headwall at an elevation of 5,000 ft (1,900 ft below the summit). A convective vapor plume was rising above the cloud deck between the summit (obscured by clouds) and the headwall region. Photograph taken by K.L., Wallace, Alaska Volcano Observatory/U.S. Geological Survey, September 20, 2006. http://avo.alaska.edu/images/image.php?id=11099.

Newly installed temporary broadband seismometer (bottom) and time-lapse camera (top) located about 6 km (4 mi) NW of Fourpeaked summit. Photograph taken by Rick Wessels, U.S. Geological Survey/Alaska Volcano Observatory, September 25, 2006. http://avo.alaska.edu/images/image.php?id=11429.

Steaming on the uppermost section of the northern flank of Fourpeaked volcano. Photograph taken by Jennifer Adleman, U.S. Geological Survey/Alaska Volcano Observatory, November 4, 2006. http://avo.alaska.edu/images/image.php?id=12359.

Thermal image of chain of vents at Fourpeaked summit from 6.4 km (4 mi) NNW of summit. Black arrows on inset map show approximate field of view. FLIR image created by Rick Wessels, U.S. Geological Survey/Alaska Volcano Observatory, September 24, 2006. http://avo.alaska.edu/images/image.php?id=11462.

Terminus of Fourpeaked Glacier. Notice the dark-colored sediment issuing from an elongate tunnel in the ice that is distinctly different than the color of the proglacial lake. Photograph taken by K. Wallace, U.S. Geological Survey/Alaska Volcano Observatory, September 20, 2006. http://avo.alaska.edu/images/image.php?id=11102.

Fumaroles on west side of Fourpeak Volcano. Photograph taken by Cyrus Read, Alaska Volcano Observatory/U.S. Geological Survey, September 24, 2006. http://avo.alaska.edu/images/image.php?id=11205.

Photograph of flowage deposit of ice and debris on the NW flank of Fourpeaked volcano. The debris/ice flow originated from a glacial outbreak flood caused by melting of summit glacial ice by volcanic processes on September 17, 2006. View is looking to the west, down slope. Rick Wessels, Alaska Volcano Observatory (AVO), points to large ice block in the flowage deposit. Photograph taken by K.L. Wallace, Alaska Volcano Observatory/U.S. Geological Survey, dated, September 25, 2006. http://avo.alaska.edu/images/image.php?id=11677.

AVO staff member getting ready to sample the thin debris flow deposit on the surface of the ice field north of Fourpeaked volcano. The debris flow originated from a glacial outbreak flood caused by melting of summit glacial ice by volcanic processes on September 17, 2006. View is looking to the east, southeast. Photograph taken by K.L. Wallace, U.S. Geological Survey/Alaska Volcano Observatory, dated September 25, 2006. http://avo.alaska.edu/images/image.php?id=11659.

USGS Aviation Color Code and Volcanic Alert Level, 2006. http://www.avo.alaska.edu/color_codes.php.

Glossary

Andesite – A gray to black volcanic rock with between about 52 and 63 weight percent silica (SiO_2). The low-end silica value rock is also known as **basaltic andesite**.

Geologist – One who is trained in and works in any of the geological sciences.

Geology – The study of the planet Earth—the materials of which it is made, the processes that act on these materials, the products formed, and the history of the planet and its life forms since its origin.

Geophysicist – One who studies the geophysical properties of the Earth, or applies physical measurement to geological problems.

Glaciology – The study of all aspects of snow and ice; the science that treats quantitatively the whole range of processes associated with all forms of solid water. Glaciology is the study of existing glaciers and ice sheets, and of their physical properties.

Hydrology – The science that deals with global water (both liquid and solid), its properties, circulation, and distribution on and under the Earth's surface and in the atmosphere, from the moment of its precipitation until it is returned to the atmosphere through evapotranspiration or is discharged into the ocean.

Incandescence – The emission of visible light by a body caused by its high temperature.

Incandescent – Produced by incandescence.

Phreatic – A volcanic explosion of steam, mud, or other material that is not incandescent; it is caused by the heating and consequent expansion of groundwater due to an underlying igneous heat source.

Plume – A volcanic plume is a mixture of particles and gas emitted by an eruption. Plumes may reach heights of several thousand meters (tens of thousands of feet) during large eruptions.

Proglacial lake – A lake formed just beyond the frontal margin of an advancing or retreating glacier or ice sheet, generally at or near its lower end.

Radar (radio detection and ranging) – An electronic detection device or active system for locating or tracking a distant object by measuring elapsed circuit time of travel of ultra-high frequency radio waves of known propagation velocity emitted from a transmitter and reflected back by the object to or near the point of transmission in such a way that range, bearing, height, and other characteristics of the object may be determined.

Volcanic (or magmatic) gases – Magma contains dissolved gases that are released into the atmosphere during eruptions. Gases also are released from magma that either remains below ground (for example, as an intrusion) or rises toward the surface. The most abundant gas typically released into the atmosphere from volcanic systems is water vapor (H_2O), followed by carbon dioxide (CO_2) and sulfur dioxide (SO_2). Volcanoes also release smaller amounts of others gases, including hydrogen sulfide (H_2S), hydrogen (H_2), carbon monoxide (CO), hydrogen chloride (HCL), hydrogen fluoride (HF), and helium (He).

Volcanologist – A volcanologist is a person who studies volcanoes, lava, magma, and related geological and geophysical phenomena.

Source of Glossary Definitions

Bates, R.K., and Jackson, J.A., eds., 1987, Glossary of Geology, (3rd ed.): Falls Church, Va., American Geological Institute, 571 p.

U.S. Geological Survey, 2010, Volcano Hazards Program—USGS photo glossary of volcanic terms: U.S. Geological Survey website. (Available at http://volcanoes.usgs.gov/images/pglossarys/index.php.)

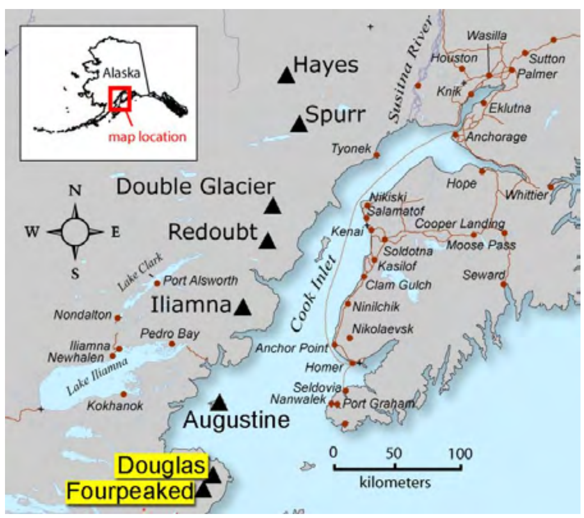
Stein, Jess, ed., 1982, The Random House College Dictionary, revised edition: New York, Random House, Inc.

U.S. Geological Survey, 2010, Volcano Hazards Program—Volcanic gases and their effects: U.S. Geological Survey website. (Available at http://volcanoes.usgs.gov/hazards/gas/index.php.)

Volcano Activity Narrative

It is September 17, a fine, crisp Sunday evening, and beginning at ~8:15 PM and over the next several hours, AVO received reports of two discrete plumes (seen in the image) rising from the Cape Douglas area on the Alaska Peninsula within Katmai National Park and Preserve. Based on photo comparisons, the plume reached approximately 20,000 ft above sea level.

Cape Douglas from Main Street, Homer, Alaska, September 17, 2006. Photograph by Lanny Simpson, Alaska High Mountain Images, used with permission.



Location map of Cape Douglas emphasizing Fourpeaked and Douglas volcanoes (AVO website).

Name ______________________________ Date ____________ Period _____

Scientist-in-Charge (SIC)

You are *The Boss*, the ultimate decision maker in the Observatory. You must manage your staff, take into consideration all data, activities, and assessments, and plan how to use your resources efficiently. You are directly responsible for the performance of the Observatory and for the accuracy, relevance, and timeliness of the information produced by the Observatory through a system of Activity Statements—a brief description of the activity at the volcano for a general audience and must include use of the Level of Concern Color Code.

Green	No eruption anticipated. Volcano is in quiet, "dormant" state.
Yellow	An eruption is possible in the next few weeks and may occur with little or no additional warning. Small earthquakes detected locally and (or) increased levels if volcanic gas emissions.
Orange	Explosive eruption is possible within a few days and may occur with little or no warning. Ash plume(s) bot expected to reach 25,000 feet above sea level. Increased numbers of local earthquakes. Extrusion of lava dome or lava flows (non-explosive eruption) may be occurring.
Red	Major explosive eruption expected within 24 hours. Large ash plume(s) expected to reach at least 25,000 feet above sea level. Strong earthquake activity detected even at distant monitoring stations. Explosive eruption may be in progress.

Level of Concern Color Code

To deal with the reporting of volcanic activity you will lead Observatory staff in 15-minute Discussions during which you must asses the situation and complete a well-written and brief Activity Statement with which your staff will concur. You must make sure that the Activity Statement gets to:

- Observatory staff
- Emergency Managers (includes Homeland Security, Borough Emergency Managers, and Village Safety Officers)
- Park Superintendent
- Media (TV, print, web-based news, and radio)

To accomplish this, each Discussion is followed by a 5-minute Briefing. During this Briefing the non-Observatory staff will be invited into the Observatory and the Observatory Information Manager will convey your Activity Statement to them in the manner you see fit (print, digital presentation, orally, poster). The Observatory Information Manager will try to limit the access non-Observatory staff has to the Observatory scientists and yourself. It is up to you to decide if your staff must be present at the Briefing.

Remember you are in charge. You are the responsible party in the event the Activity Statement does not go out, or is flawed. You can and may assign the task to another individual, but you must see and approve the statement before it goes out.

You periodically will be given information pertaining to the time you will coordinate the next Activity Statement.

SIC

Discussion 1 (September 17–19)

1 This Activity Statement needs to include all that you know right now without causing panic. Your information product needs to include the Observatory plans for dealing with this activity in the future. People who need the information you are generating likely do not know anything about Fourpeaked or Douglas volcanoes, not even where they are!

2 You also need permission from the Park Superintendent to conduct any fieldwork at Fourpeaked or Douglas volcanoes and you should notify him or her of increased volcanic activity!

✂--

SIC

Discussion 2 (September 20–23)

1 Today, September 21, you spoke with the Park Superintendent. You explained to the Park Superintendent the fieldwork you needed to do immediately. To access remote areas of the region, your staff will need to travel in small aircraft.

2 You also offered to get someone from the Observatory to the Park headquarters next week to provide a briefing to their staff.

3 You want your staff to inform the Park Superintendent the day before you fly, where you intend to fly, with whom, and what you intend to do. Eventually you may not need to do so, but for the first flights, you think it is best to do so. This gives the Park Superintendent an opportunity to note any sensitive areas and demonstrates that you respect their mission too.

4 In this Activity Statement, show what you have learned since the last statement. Continue to discuss a course of future action.

✂--

SIC

Discussion 3 (September 24 – 26)

1. Continue to re-evaluate the information you receive, and determine how you can describe it best to your audience. Describe what the Observatory and the volcano have done and what the Observatory will do.

✂--

SIC

Discussion 4 (September 27‒)

1. Develop a scenario or a set of scenarios describing the timing and likelihood of an eruption and the course of action (or plan) the Observatory is taking to continue to refine that list. Logically fit this into your Activity Statement.

Name ______________________________ Date ____________ Period _____

Information Manager

You work closely with the boss, the Scientist-in-Charge (SIC), the ultimate decision maker in the Observatory. You and the SIC must cooperatively develop a series of Activity Statements during 15-minuute long Observatory Discussions. Activity Statements are a brief description of the activity at the volcano for a general audience and must include use of the Level of Concern Color Code. Following each Discussion is a 5-minute Briefing. During the Briefing, the non-Observatory staff will be invited in by you.

- Emergency managers (includes Homeland Security, Borough Emergency Managers, and Village Safety Officers)
- Park Superintendent
- Media (TV, print, web-based, and radio)

You will convey the Activity Statement to them in the manner you and the SIC agree upon (print, digital presentation, orally, poster). You will try to limit the access non-Observatory staff has to the Observatory scientists and yourself.

You must make sure the Activity Statement is factual, well written, spoken and (or) illustrated, brief, and to the point. You must answer questions about it from the Briefing attendees. If you do not know the answer you should find it out and get back to the person who asked you the question during the next break or earlier.

Green	No eruption anticipated. Volcano is in quiet, "dormant" state.
Yellow	An eruption is possible in the next few weeks and may occur with little or no additional warning. Small earthquakes detected locally and (or) increased levels if volcanic gas emissions.
Orange	Explosive eruption is possible within a few days and may occur with little or no warning. Ash plume(s) bot expected to reach 25,000 feet above sea level. Increased numbers of local earthquakes. Extrusion of lava dome or lava flows (non-explosive eruption) may be occurring.
Red	Major explosive eruption expected within 24 hours. Large ash plume(s) expected to reach at least 25,000 feet above sea level. Strong earthquake activity detected even at distant monitoring stations. Explosive eruption may be in progress.

Level of Concern Color Code

You should know what kind of graphic tools (maps, diagrams, photographs, or video) are available in the event one of the groups you distribute the Activity Statement to wants to generate an article, website, or news story about it. You should stress the facts and not let your audience generate a panic situation in nearby communities.

Remember, your boss, the SIC, is the responsible party in the event the Activity Statement is not released or it is done poorly, but he or she can and may assign this task to another individual. However, he or she must see and approve the statement before it goes out.

You will be given guiding questions and information for you to use during each 15-minute long Observatory Discussion.

Information Manager

Discussion 1 (September 17 – 19)

1 This Activity Statement needs to include all that you know right now without causing panic and it needs to include the plans the Observatory has for dealing with this activity in the future. People who need the information you are generating likely do not know anything about Fourpeaked or Douglas volcanoes, not even where they are!

2 On September 18
- Two pilots reported smelling sulfur while flying at an altitude of 11,000–12,000 ft above sea level, ~200 mi west of Anchorage
- A heavy sulfuric smell and ash in the air were reported from two lodges in the Park
- One of your staff was able to collect a sample of ash fall on top of the glacier at Fourpeaked

3 On September 19, another lodge in the Park reported ash fall.

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Information Manager

Discussion 2 (September 20–23)

1 Show progress in this Activity Statement, both in volcano activity and new information learned since the last statement. Include information on earthquake, other geophysical, satellite, or any other information, if available.

2 On September 20, residents in a nearby community reported ash fall.

3 On September 21, you received reports from a nearby community of a “mushroom cloud” like formation near Fourpeaked.

Information Manager

Discussion 3 (September 24–26)

1. You received a call on September 25, from a pilot in a community near Fourpeaked. They wanted AVO to know that the waterfalls at the headwall of Fourpeaked Glacier and the sediment flowing into the lake at the foot of the glacier are normal occurrences that they have seen many times over their tens of years of flying in the area.

2. Continue to re-evaluate the information you are receiving and determine how you can best describe it to your audience. Describe what the Observatory and the volcano have done and what the Observatory will do.

✂---

Information Manager

Discussion 4 (September 27-)

1 Develop a scenario or a set of scenarios describing the timing and likelihood of an eruption, or if an eruption has occurred, and the course of action (or plan) the Observatory is taking to continue to monitor the volcano. Logically fit this into your Activity Statement.

Name ___________________________________ Date ______________ Period _____

Media

This could be the story that makes or breaks your career! You are a budding new journalist and this kind of "killer" volcanic eruption could jettison you career into stardom! CNN, BBC, NPR, FOX, they will all be seeking you out if you get this one right! You could do a radio show, a blog, an on-line news report, or an actual printed newspaper article… the possibilities seem endless.

It is not likely that you will have loads of time to spend at the Observatory; they generally do not want you hanging out, no matter how much you would just love to be a fly on the wall. Periodically, throughout the eruption you will receive brief statements that you hope describe what is going on. You will have an opportunity to question the Observatory staff. Make the most of it, and be pushy, you want this story!

1. Do the Activity Statements you are given answer all your questions? Those questions that you think the public has?
2. Are there informative and exciting photographs, graphs, plots, figures that you can see or use?
3. Can you snag an interview with a scientist, how about the Scientist-in-Charge?
4. What about emergency managers and Park officials, what are they doing to plan?
5. How many people died? Were any planes downed by the eruption? What are the dangers that the current activity poses to people?

You are also tasked with writing articles (or producing radio or television broadcasts or presentations) for the public. You will need to develop and disseminate your products while the Observatory is developing those brief statements for you. You could try to have the public available for a Q&A with you, write and distribute a story you hope they will read (catchy title!), or have a news-like segment with your adoring fans watching.

You will be given some leading questions to consider during each Briefing.

Media

Briefing 1

1. Was there an eruption? If not, then what happened?
2. What does the Observatory know about this volcano specifically?
3. What kinds of fieldwork are scientists at the Observatory conducting? Do they have pictures of the volcano or of Observatory staff at work?
4. What is the color code level and why?

✂---

Media

Briefing 2

1. Did the plume(s) have ash in them? What kinds of gases were in the plumes?
2. Were there any earthquakes when those plume(s) formed?
3. Are there any pictures of the holes these plumes are coming from?
4. Was anyone hurt? Did this plume affect air traffic?
5. What is the color code and why, and what are the associated hazards to people on the ground and in the air?

✂---

Media

Briefing 3

1. Was there ash fall and if so, where?
2. What were those plume(s) made of?
3. Are there any pictures of the holes these plumes are coming from?
4. Was anyone hurt? Did this plume affect air traffic?
5. What is the color code and why, and what are the associated hazards to people on the ground and in the air?

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Media

Briefing 4

1. So what is likely to happen at the volcano, what are staff at the Observatory doing?
2. Can we expect another event such as this one, and if so, when?
3. Are there any pictures of the holes these plumes are coming from or other features of this volcano?
4. Were flights cancelled or diverted due to the eruption?
5. What is the color code and why, and what are the associated hazards to people?

Name ____________________________________ Date ______________ Period _____

Geophysicists

You study earthquakes, satellite imagery, ground deformation, and other phenomena that could indicate how a volcano may be behaving physically and what it could do in the future. Almost all of your studies require some kind of instrument be in place on the ground at a volcano so you can assess its activity or some satellite image to show a particular feature that indicates activity.

This is an odd event for you to respond to because of the complete lack of instruments on the ground at this volcano! In all likelihood, you really want be asked at some point to come up with plans to install some geophysical devices on the volcano. In order to further your needs, you must design this network taking into consideration the phenomena that can be measured or visualized from other sources of data and determine how to build the best network possible under seasonal constraints. This area is covered with glacial ice and the only bare rock tends to make difficult spots to land a helicopter. Once winter sets in, you will not be able to access the volcano easily.

The Scientist-in-Charge (SIC) of the Observatory, your boss, will lead a series of 15-minute long Discussions where he or she is gathering information to generate an Activity Statement—a brief description of the activity at the volcano for a general audience and must include use of the Level of Concern Color Code.

Green	No eruption anticipated. Volcano is in quiet, "dormant" state.
Yellow	An eruption is possible in the next few weeks and may occur with little or no additional warning. Small earthquakes detected locally and (or) increased levels if volcanic gas emissions.
Orange	Explosive eruption is possible within a few days and may occur with little or no warning. Ash plume(s) bot expected to reach 25,000 feet above sea level. Increased numbers of local earthquakes. Extrusion of lava dome or lava flows (non-explosive eruption) may be occurring.
Red	Major explosive eruption expected within 24 hours. Large ash plume(s) expected to reach at least 25,000 feet above sea level. Strong earthquake activity detected even at distant monitoring stations. Explosive eruption may be in progress.

Level of Concern Color Code

This is your opportunity to present new data and to lay out your network plans and image interpretations. Each Discussion is followed by a Break. During a Break, the Observatory Information Manager will present the Activity Statement to a group of people who need to know what is going on.

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Geophysicists

Discussion 1 (September 17–19)

1. Satellite images from the evening of September 17 show a cloud originating near Fourpeaked and Douglas volcanoes and persisting throughout the night. Satellite imagery does not indicate any ash in the cloud, which traveled as far as 12 mi to the northeast. No thermal anomalies or areas on the ground that appear unusually warm or hot, were detected.

2. On September 18, you notice that the anomalies and plume reported are more likely from Fourpeaked than from Douglas.

✂---

Geophysicists

Discussion 2 (September 20–23)

You have some data to add during Discussions at specific points in time. These data sets are as follows and should be shared during the noted Discussion period.

On September 20, while working on seismic stations at Augustine volcano, you were able to take the helicopter to Fourpeaked

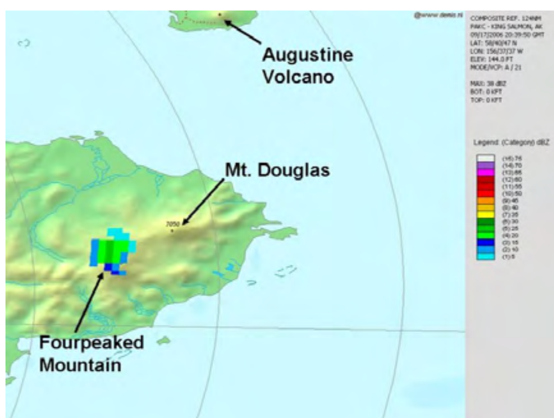
1. You obtained an ash sample

2. You also observed two steam plumes above Fourpeaked. The two steam plumes appeared, vigorous, similar in size, white (no evidence of ash), and were rising to ~11,000 ft. Shown in photograph below (photograph taken by Guy Tytgat, Alaska Volcano Observatory/University of Alaska Fairbanks Geophysical Institute, September 20, 2006).

3. You detected a strong smell of rotten eggs as you approached Fourpeaked from the north. There is discoloration (gray) of the snow around the vent(s) from possible ash fall near the volcano in different direction, but the darkest snow (most ash deposits) was on the northwest side of the volcano.

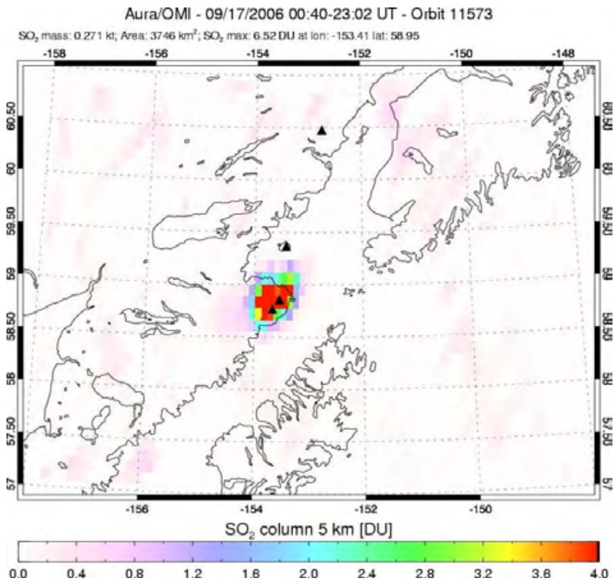
4. You also observed flow on the surface of the glacial ice on the northwest side of the mountain. The flow looked like mud coming out of the glacial crevasses and extending for quite a distance down the glacier. Shown in photograph below (photograph taken by Guy Tytgat, Alaska Volcano Observatory/University of Alaska Fairbanks Geophysical Institute, September 20, 2006).

5. On September 20, you received an image from the closest weather radar station showing the volcanic cloud at Fourpeaked volcano on September 17 at 12:40 PM local time.



The color scheme shows a scale of radar reflectivity (from light blue-low, to dark green-moderate), which corresponds to greater numbers and (or) sizes of particles in the atmosphere. The figure shows retrospective analysis of radar data showing a signal above Fourpeaked volcano beginning at 12:00 noon on September 17. The cloud stayed over or near the vent for the entire time (that is, it was not observed drifting away). Remind your colleagues that the radar detects reflectors and cannot determine the cloud composition. This means that it can see, but not distinguish between large water droplets, ice particles, or coarse ash (like mm size [0.04 in.] [AVO website]).

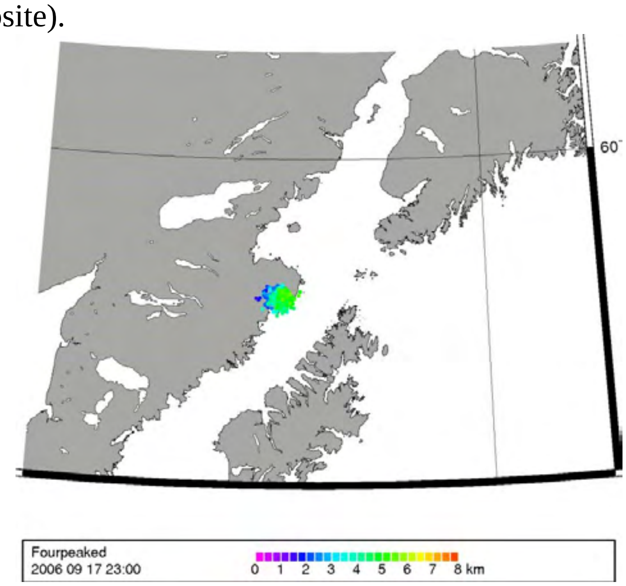
Also on September 20, colleagues emailed you an image showing the amount of sulfur dioxide in the atmosphere over Fourpeaked volcano at 3 PM on September 17.



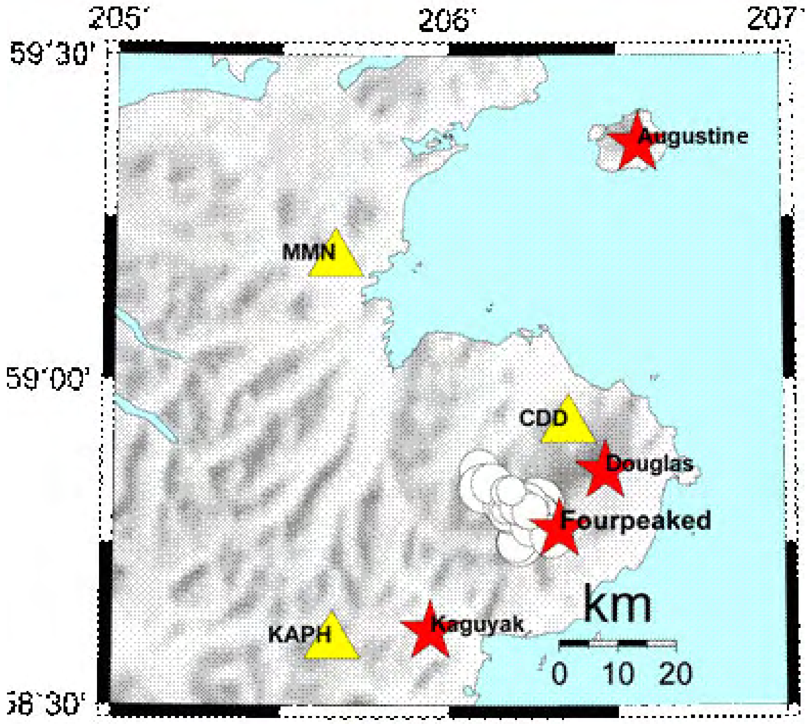
This image was created using data from the Ozone Monitoring Instrument (OMI) on NASA's EOS Aura satellite. This image confirms that the plume was volcanic! Nothing else you know of could produce approximately 300 tons of sulfur dioxide into the atmosphere except a volcano (AVO website).

6. Based on the satellite and weather radar data you now have, you ran the Puff volcanic ash dispersion model for the same time as the SO_2 OMI image you got from your colleagues in Maryland.

   The Puff-generated image shows the predicted position of a volcanic cloud at 3 PM local time from Fourpeaked volcano on September 17. The Puff prediction showed the ash cloud to be 5 to 6 km above sea level (asl). The color scheme at the bottom of the image shows the altitude scale (asl) for the ash cloud from 0 km (purple) to 8 km (red) (AVO website).

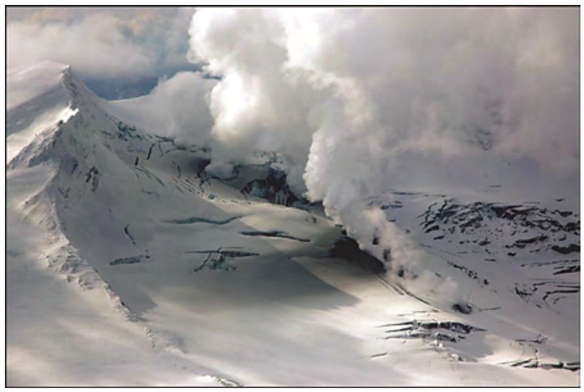


7. On September 21, you notice that a small swarm of earthquakes was detected on the regional seismic network from 11:48 AM to 3:50 PM on September 17.



Sixteen of the earthquakes (white circles) were large enough to show up on stations in nearby Katmai, Oil Point, Augustine (yellow triangles), and in Kodiak (not pictured). The earthquake magnitudes were between 0.8 and 1.8 and were clustered to the northwest of the Fourpeaked summit. The red stars are volcanoes (AVO website).

8. On September 23, you went on a gas flight (a small airplane flight to make observations and use equipment to determine the types and amount of volcanic gases coming from the volcano). You saw a linear series of vents to the north and just below the summit of Fourpeaked. Gas was abundant. You measured carbon dioxide (CO_2), and you measured and could smell sulfur dioxide (rotten egg smell—SO_2), and hydrogen sulfide (striking a match smell—H_2S). Shown in photograph below (Photograph taken by P. Cervelli, U.S. Geological Survey/Alaska Volcano Observatory, September 23, 2006).



Geophysicists

Discussion 3 (September 24 – 26)

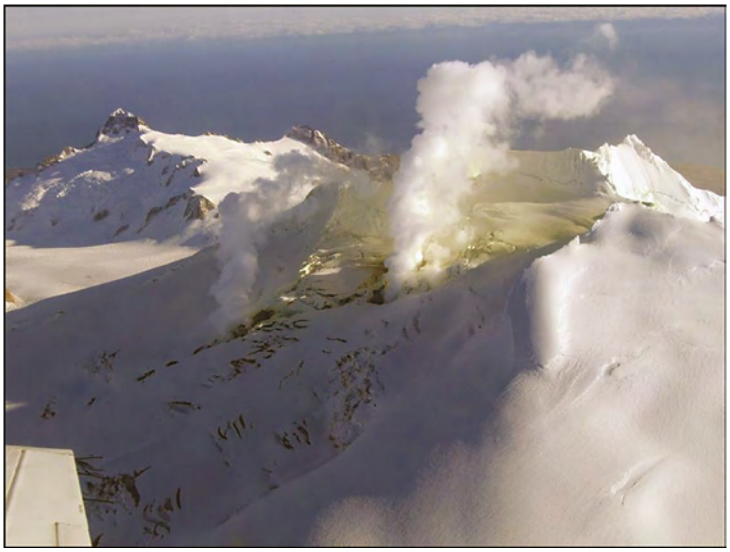
1. On Monday and Tuesday, September 24–25 you were one of the AVO staff in a helicopter visiting the Fourpeaked area and have the following to report:

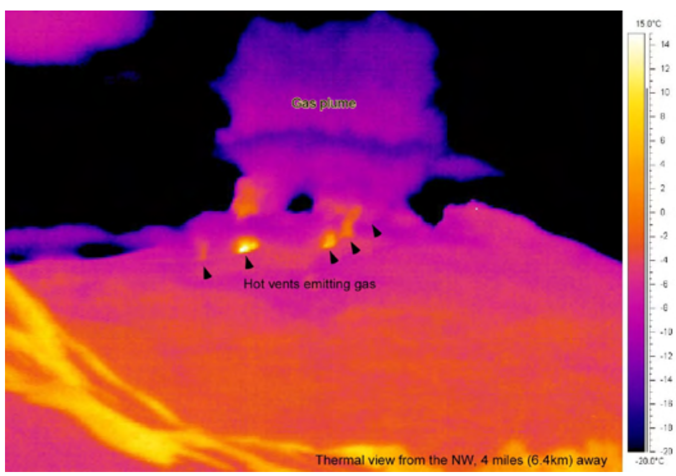
   - The nearest, but inoperable, seismometer (used to detect earthquakes) was repaired and a new station was installed 7 mi east of the volcano. Both instruments are now sending data to AVO.

   - A campaign (non-telemetered) seismometer was installed 4 mi northwest of the summit (shown in the photograph below). This station recorded earthquake information on-site but could not automatically relay it to AVO facilities. Scientists would have to travel back to this site to retrieve the digital data storage card to view the data. (Photograph taken by R. Wessels, U.S. Geological Survey/Alaska Volcano Observatory, September 25, 2006.)

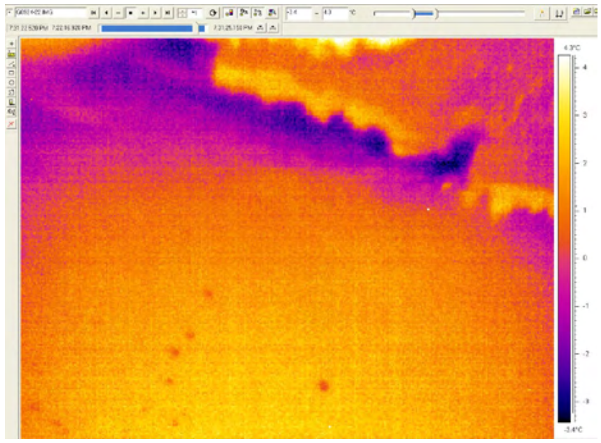
   - Using a hand-held gas detection instrument you determined that gases emanating from a source of magma beneath the volcano were all present.

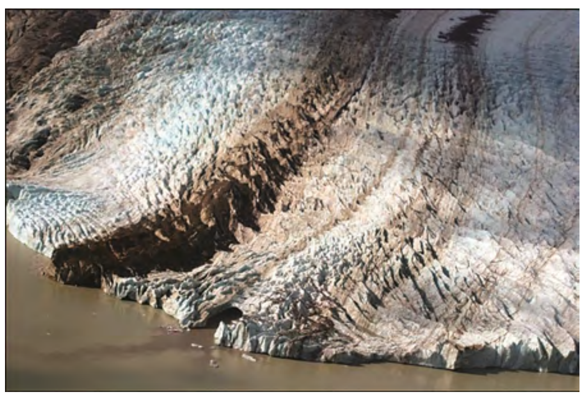
- Along the 1 km long crack on the side of the summit glacier discrete vents are emitting gas. Using your Forward Looking Infrared Radiometer (FLIR), you determined these are the hottest surface areas along the crack and they reach temperatures ~ 12°C (54°F). The color of the feature in the photograph corresponds to the color on the temperature scale shown in the FLIR images. The FLIR produces an image whose color scale correlates to the surface temperatures within the shot Dark purple to black features generally are the coldest and white to yellow features are the hottest. (Photograph taken by J. Adleman, November 4, 2006 (top) and FLIR by R. Wessels, September 24, 2006 (bottom), both of U.S. Geological Survey/Alaska Volcano Observatory).





- Additionally, you used the FLIR to look at the water draining from inside a lobe of glacial ice (of the Fourpeaked Glacier), which drains into a proglacial lake and the end of the lobe. The geologists thought that the water might have been warm and anomalous. You determined that it was cool. Note the cool purple imaged water emanating from the glacier; seen below in the FLIR (R. Wessels, U.S. Geological Survey/Alaska Volcano Observatory, September 24, 2006) and visible photograph below (R. Wessels, U.S. Geological Survey/Alaska Volcano Observatory, September 20, 2006).





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Geophysicists

Discussion 4 (September 27 -)

1 Develop a scenario or a set of scenarios describing the timing and likelihood of an eruption (if you believe it was an eruption) or similar explosion or event and the course of action (or plan) the Observatory is taking to continue to refine that list. Logically fit this into your Activity Statement.

Name ____________________________________ Date ______________ Period _____

Geologists

You study rocks, the products of current and previous volcanic eruptions, and the processes by which magma moves, erupts, and changes landforms at the Earth's surface. Working with you are volcanic gas, hydrology, and glaciology specialists. You also usually wind up flying in small planes to make visual observations and magmatic gas measurements. Your studies also require mapping, access to the ground (usually by helicopter), laboratory analysis, and assessment of any studies previously completed on the volcano in question.

This is an odd volcano to you because it has been poorly studied and there is no evidence of historic activity. In all likelihood, you will be asked to come up with plans to visit the volcano and look for evidence of historic or prehistoric eruptions. To plan your fieldwork, and the appropriate laboratory work to undertake, you must take into consideration information gathered by geophysicists and satellite remote sensors. This volcano is covered by glacial ice and the only bare rock tends to make difficult spots to land a helicopter to install instruments on the ground. Once winter sets in, you will not be able to access the volcano easily and geologic evidence will be buried by snow.
The Scientist-in-Charge (SIC) of the Observatory, your boss, will lead a series of 15-minute long Discussions where he or she is gathering information in order to generate an Activity Statement—a brief description of the activity at the volcano for a general audience and must include use of the Level of Concern Color Code.

Green	No eruption anticipated. Volcano is in quiet, "dormant" state.
Yellow	An eruption is possible in the next few weeks and may occur with little or no additional warning. Small earthquakes detected locally and (or) increased levels if volcanic gas emissions.
Orange	Explosive eruption is possible within a few days and may occur with little or no warning. Ash plume(s) bot expected to reach 25,000 feet above sea level. Increased numbers of local earthquakes. Extrusion of lava dome or lava flows (non-explosive eruption) may be occurring.
Red	Major explosive eruption expected within 24 hours. Large ash plume(s) expected to reach at least 25,000 feet above sea level. Strong earthquake activity detected even at distant monitoring stations. Explosive eruption may be in progress.

Level of Concern Color Code

This is your opportunity to present new data and to lay out your plans and interpretations. Each Discussion is followed by a Briefing. During a Briefing, the Observatory Information Manager will be presenting the Activity Statement to a group of people who need to know what is going on.

You have some data to add during Discussions at specific points in time. These data sets should be shared during Discussion periods.

Geologists

Discussion 1 (September 17–19)
Upon learning of the observed and possibly volcanic cloud, you and colleagues began to gather all the known information about Fourpeaked and Douglas volcanoes—those volcanoes are located closest to the plume observed and reported by people in Homer on the Kenai Peninsula in southcentral Alaska. From Wood and Kienle (1990) you learned that:

> Fourpeaked Mountain consists of small isolated volcanic exposures surrounded by the Fourpeaked Glacier. The exposures are along ridge crests and cliff faces on the sides of ridges that radiate out from the ice-covered summit. Lava flows are interlayered with volcanic agglomerate in the isolated exposures.
>
> Orientation of lava flows suggests the present summit of Fourpeaked is probably the vent for Fourpeaked volcano. Extensive hydrothermal alteration of rocks in this area is consistent with this vent location.
>
> Fourpeaked is known only from limited reconnaissance studies. The lavas are porphyritic andesite.
>
> and
>
> Mount Douglas is a dissected stratovolcano covered by ice of the Spotted Glacier. The summit of the volcano is marked by a crater with a small (160-m wide) crater lake. An active fumarole field on the north side of the crater keeps the area free of ice. A black scum floating on the lake in 1980 was probably sulfide minerals of some sort (consistent with a lake temperature of 25°C [77°F] [and a pH of 1 measured in 1982]).
>
> Much of the volcano has been subjected to glacial erosion, but a ramp of lava flows on the northwest flank is relatively uneroded. Most of the volcano is ice-covered, but isolated outcrops of lava flows (high-silica andesite) are in the ice. Reconnaissance geologic surveys suggest that the lavas extend to elevations lower than glacier's, but this has not been confirmed on the ground.
>
> No historic activity has been reported for Mount Douglas; however, the presence of unglaciated lava flows and the active fumaroles indicate recent activity.

Reference Cited
Wood, C.A., and Kienle, Jürgen, eds., 1990, Volcanoes of North America—United States and Canada: Cambridge University Press, p.77-78, Contribution by S.E. Swanson.

You also know:

Andesite is a volcanic rock with ~ 56–64 weight percent silica and consists of large-grained crystals in a fine-grained groundmass.

Porphyritic texture displays minerals in two distinct size populations.

Agglomerate is a volcanic rock consisting of rounded and angular fragments fused together.

Fourpeaked and Douglas volcanoes are not monitored seismically. There are seismometers around the Katmai group of volcanoes, about 50 mi (80 km) to the southwest, and around Augustine volcano, 40 mi (64 km) to the north.

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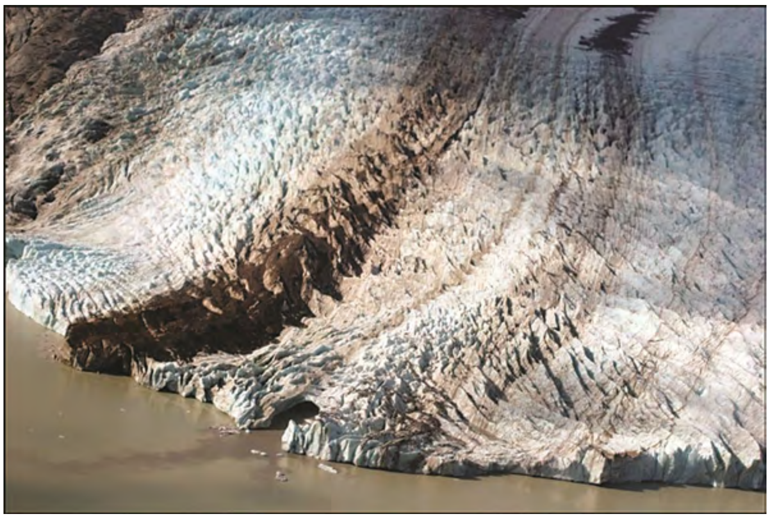
Geologists

Discussion 2 (September 20–23)
On September 20, you and other AVO staff were in a small plane visiting the Fourpeaked area and have the following to report:

1. At the terminus of Fourpeaked Glacier, dark-colored sediment is issuing from an elongate tunnel in the ice, shown in photograph below (photograph taken by K Wallace, U.S. Geological Survey/Alaska Volcano Observatory, September 20, 2006).



2. Looking toward the north-northwest, the southeast ridge of Fourpeaked volcano has distinct, white steam plumes, shown in photograph below (photograph taken by Guy Tytgat, U.S. Geological Survey/Alaska Volcano Observatory, September 20, 2009).

3. Looking due west at the flanks of Fourpeaked volcano, there are deposits of dirty, lobe-shaped flows and what is probably ash fall on top of the glacial ice.

4. You observed the headwall of Fourpeaked Glacier just northeast of the summit of Fourpeaked volcano. Waterfalls were issuing from beneath the ice at the top of the headwall at an elevation of 5,000 ft (1,900 ft below the summit), shown in photograph below (taken by K. Wallace, U.S. Geological Survey/Alaska Volcano Observatory, September 20, 2009).

5. There is a strong sulfuric smell just east-southeast of the summit of Fourpeaked at ~ 6,500 ft above sea level.

6. A glaciologist on your staff calculated the elevation difference between a topographic map from 1951 and elevation data from satellite imagery from 2000 for Fourpeaked. The total ice loss (the most likely reason for the difference in elevation) on the volcano is ~10.8 km^3 (2.6 mi^3) between the years.

7. These are your preliminary observations of the sample retrieved from Fourpeaked by your geophysicist colleague on September 20.
   - The sample consists of coarse material and crystal fragments
   - The coarse material appears to be primarily crystal fragments, some altered rock, and possibly some dark rock or glassy material.
   - The crystal fragments look sharp and broken, rather than rounded or smooth.
   - You did not see anything that looks obviously like glassy, bubble-filled ash in the coarse material.
   - You did see a lot of pyrite (very metallic, gold colored, cubic, and striated faces—although the grains are very tiny.)
   - You warn that these observations are preliminary!

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Geologists

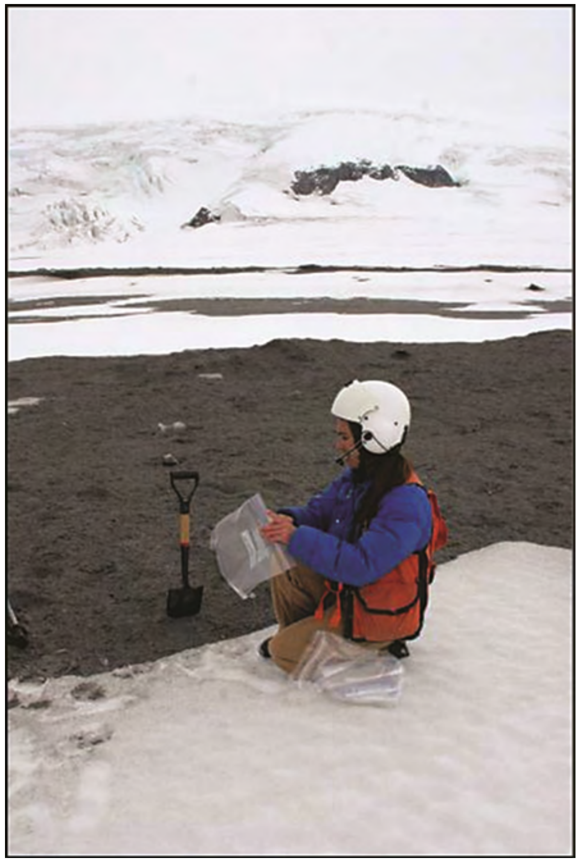
Discussion 3 (September 24–26)
AVO geologists and other staff were on a gas measuring and observation flight on September 24. You crisscrossed the plume 20 times!

1. You had good views of the entire line of vents in the ice. You noted that the lower two pits were circular, the middle segment was elongate or maybe multiple, now coalesced vents, and it had multiple, vigorous steam sources and a fresh ring of ash around it. The upper region had at least three steam sources offset from the linear trend. There was no incandescence, although an outcrop of orange altered rock gave you a scare! Shown in the photograph below (taken by C. Read, U.S. Geological Survey/Alaska Volcano Observatory, September 24, 2009).

2. You also noted fresh snow since the September 20.

On Monday and Tuesday, September 24–25, geologists and other AVO staff were in a helicopter visiting the Fourpeaked area and have the following to report:

1. You were able to land on Fourpeaked glacier and you sampled the lobe shaped flows noticed on an earlier trip; shown in the photographs below (taken by K. Wallace U.S. Geological Survey/Alaska Volcano Observatory, September 25, 2006).



You collected samples from the lobate muddy surface flow and observed giant chunks of the glacier that may have been ripped up during the formation of these flows.

You were able to look at the riverbanks along the Douglas River and did not see any deposits corresponding to volcanic eruptive activity in the last few thousand years anywhere nearby.

Geologists

Discussion 4 (September 27-)

1. Describe the timing and likelihood of an eruption, explosion, or event based on your findings from the last observations. Use historical and local information to make your report. Describe the timing and focus of the next set of observations/data collections that will be performed.

Name ___________________________________ Date ______________ Period _____

Emergency Managers
(Homeland Security, Borough Emergency Managers, Village Public Safety Officers)

You have the responsibility for communicating and implementing procedures, precautions and instructions, to the public in the event of a natural disaster or other emergency situation. This includes any volcanic activity within the state.

You must obtain accurate information regarding all volcanic activity before, during, and after a volcanic eruption. Your most likely source, but not your only source, for this information is the Alaska Volcano Observatory (AVO). You are also concerned with any information the media is releasing to the public. Information may be inaccurate, and you must be prepared to handle the questions and concerns the public. You may need to communicate with Federal, State, or local land managers in the event the activity affects regions within these land management units.

You will not have loads of time to spend at the Observatory learning every detail of the eruption or activity at hand. Periodically, throughout the eruption you will receive brief statements describing the volcanic activity. This may include information including forecasts of what activity is expected. You will periodically have an opportunity to question the Observatory staff. You have certain issues that must be dealt with.

1. What, exactly, is happening now, what will happen in the near future (when?) and what will the effects be?
2. What is the Observatory doing to mitigate the situation?
3. Will you need to order an evacuation, prepare residents for ash fall, mud flows, loss of communications, and transportation systems? Will there be power outages?
4. Is the volcano in a National Park? If so, what is the Park Superintendent doing about the local concerns?

You are tasked with providing guidance to the public. You will need to develop and disseminate your products while the Observatory is developing those brief statements for you. You could try to have the public available for a Q&A with you. Write and distribute a set of instructions you hope they will read, or have a press conference.

You will be given some leading questions to consider during each Briefing.

Emergency Managers

Briefing 1

1. Was there an eruption, explosion or other type or volcanic event?
2. What are the hazards to ground and air populations based on the activity that has already occurred?
3. What does the Observatory staff think will happen in the immediate future, how about in the long term?
4. What are staff of the Observatory doing to study this event and project what will happen next?

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Emergency Managers

Briefing 2

1. Did the plume(s) have volcanic ash and (or) magmatic gases in them?
2. Were there any earthquakes when those plume(s) formed?

✂---

Emergency Managers

Briefing 3

1. Did ash fall anywhere nearby or distant from the volcano?
2. What were those plume(s) made of—steam, magmatic gases, rock shards?

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Emergency Managers

Briefing 4

1. So what is likely to happen at the volcano, what is the Observatory doing?
2. What can we expect to be our main concerns for the next days, to weeks, or months?

Name ___________________________________ Date ______________ Period _____

Park Superintendent

You are the head of the National Park in which there are several active volcanoes. You keep in close communication with the Alaska Volcano Observatory (AVO) for two reasons. One is to hear about any volcanic activity that may lead to an eruption from a volcano within the lands you manage. The other reason is that the Observatory must have your permission to work within the Park.

You have the responsibility for communicating and implementing procedures, precautions, and instructions to Park staff and visitors in the event of a natural disaster or other emergency. This includes any volcanic activity within the Park. You and your staff also have an interpretive responsibility if the activity becomes a visitor attraction!

You must obtain consistently and quickly thorough and accurate information regarding all volcanic activity before, during, and after a volcanic eruption and any related work the Observatory may do within the Park. Your most likely source, but not your only source, for this information is the Alaska Volcano Observatory (AVO). You are also concerned with any information the media is releasing to the public. Even if it is inaccurate, you must be prepared to handle the questions and concerns this information will generate from the public. You may need to communicate with Federal, State, or local emergency managers in the event the activity affects communities within the Park.

You will not have loads of time to spend at the Observatory learning every detail of the eruption or activity at hand. Periodically, throughout the eruption you will receive brief statements describing the volcanic activity. This may include information including forecasts of what activity is expected. You will periodically have an opportunity to question the Observatory staff. You have certain issues that must be dealt with.

1. What, exactly, is happening now, what will happen in the near future (when?) and what will the affects be?
2. What is the Observatory doing to mitigate the situation?
3. Will you need to order an evacuation of staff? Will you need to order an evacuation of visitors? Will you need to prepare staff/visitors for ash fall, mudflows, loss of communications and transportation systems? Will there be power outages?
4. Is the volcano going to affect communities within or near the Park? What are emergency managers’ concerns?

You will be given some leading questions and information to consider during each Briefing.

Park Superintendent

Briefing 1

1. Was there an eruption, explosion, or other type or volcanic event?
2. What are the hazards to ground and air populations based on the activity that has already occurred?
3. What does the Observatory staff think will happen in the immediate future, how about in the long term?
4. What are staff of the Observatory doing to study this event and project what will happen next?

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Park Superintendent

Briefing 2

1. Did the plume(s) have ash in them? Were there any earthquakes when those plume(s) formed?

2. Today, September 21, you spoke with the Observatory Scientist-in-Charge (SIC) about the fieldwork your staff needs to do to research the activity that occurred. The SIC also offered to get someone from the Observatory down here next week to provide a briefing to your staff.

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Park Superintendent

Briefing 3

1. Did ash fall anywhere nearby or distant from the volcano?
2. What were those plume(s) made of—steam, magmatic gases, rock shards?

✂---

Park Superintendent

Briefing 4

1. What is likely to happen at the volcano, what is the Observatory doing?
2. What can we expect to be our main concerns for the next days, weeks, or months?

Name ____________________________________ Date ______________ Period _____

The Public

What on Earth is going on? A volcanic eruption? In Alaska? Where? What should you do? Is it going to affect you, your daily routine? Do you need to prepare, plan, leave? You consider what resources are available to you: an observatory, the media, and government. You want to know what happened, what is likely to happen in the near future, and when, and what to do. You listen for any kind of public meetings, reports from friends and neighbors about what they heard, and what they say on the news.

At the very least, you would like to keep a journal about the experience! Maybe someday someone would want to read it. Photographs would not hurt either. So, you will make this your task—write down what you learn about this possible volcanic eruption practically in your own backyard!

Name ___________________________________ Date ______________ Period _____

The Finer Points

1. How did you feel information from each Alaska Volcano Observatory (AVO) subgroup (Scientist-in-Charge [SIC], Information Manager, Geologists, Geophysicists) was used to develop Activity Statements?

2. Was there equal value placed on each data set, or were some more important than others? Were there individuals or subgroups of AVO staff that were better at making themselves heard?

3. Did the media get all the information they wanted? Did their story reflect the statements made by the Observatory?

4. Did the emergency managers get the information they needed and wanted in a timely manner? Were their directions to the public a true reflection of what needed to happen?

5. Did the Park Superintendent get the information he or she needed and wanted in a timely manner? Was their permission sought for work done at the volcano? Were their directions to staff and visitors a true reflection of what needed to happen?

6. Who spoke with whom? Did the media, emergency managers or Park Superintendent get to talk with anyone at the Observatory other than the Information Manager? Should they have?

7. This activity has few rules. Did the media, emergency managers, or Park Superintendent manage to get "into" the Observatory during discussions, and when they were there, did they manage to talk with anyone?

8. How did each person feel throughout the process: ignored, worried, angry, frustrated, or excited? Did your feelings have an effect on how you completed your job or a specific task?

9. In the end, did the public have the correct information in a timely and appropriate manner?

10. How could things have been improved?

11. Imagine if this volcanic activity continued for weeks or months, or maybe even years. What kinds of changes do you imagine may take place in your procedures if you have to maintain them 24/7 indefinitely? What sorts of issues would a long explosive eruption in this part of Alaska raise for residents, businesses, and others?

12. The three AVO products shown below reflect the activity at Fourpekaed for the period you handled in the activity. AVO has several types of reports:

    - Weekly Update—Issued on Fridays, reports on all Alaskan volcanoes
    - Information Release or Statement—Issued on significant changes at an Alaskan volcano
    - Status Report—Issued daily, reports on restless Alaskan volcanoes

    AVO also uses two products when there is a change in color code at a volcano. One product is a Volcanic Activity Notice (VAN) and the other is a Volcano Observatory Notice to Aviation (VONA).

    The included Weekly Updates and Status Reports have been abbreviated to show only Fourpeaked information. Complete reports included information for Cleveland and Veniaminof volcanoes, also at elevated levels of activity.

    Additionally, a volcano can only be listed as GREEN in the Level of Concern Color Code if it is seismically monitored. Fourpeaked was not previously seismically monitored and therefore the Level of Concern Color Code was **Not Assigned.**

    How do the four reports made by your Observatory scenario compare to those made by AVO?

ALASKA VOLCANO OBSERVATORY
Information Release
Monday, September 18, 2006 2:20 PM AKDT (2220 UTC)

DOUGLAS VOLCANO (CAVW#1102-27-)
58°51'18" N153°32'31" W, Summit Elevation 7021 ft (2140 m)
Current Level of Concern Color Code: **Not Assigned**

FOURPEAKED VOLCANO (CAVW#1102-26-)
58°46'12" N153°40'19" W, Summit Elevation 6903 ft (2104 m)
Current Level of Concern Color Code: **Not Assigned**

On Sunday, September 17, AVO received several reports of two discrete plumes rising from the Cape Douglas area, about 200 miles (320 km) southwest of Anchorage, beginning at approximately 8:15 PM AKDT (0415 UTC, September 18) and continuing until darkness. Analysis of satellite images shows that the plumes originated in the area of Fourpeaked Glacier, located between Fourpeaked and Douglas volcanoes. Photographs of the plumes show that they reached up to approximately 20,000 ft (6,000 m) above sea level.

Satellite images show a cloud originating from Fourpeaked glacier area and persisting throughout the night. The cloud does not show an ash signature. The cloud traveled up to 12 miles (20 km) to the northeast.

Fourpeaked and Douglas volcanoes are not monitored seismically. Seismometers around the Katmai group of volcanoes, about 50 miles (80 km) to the southwest, and around Augustine volcano, 40 miles (64 km) to the north, did not record any unusual seismic activity. Based on the absence of an ash signature in the cloud in satellite data, a significant volcanic eruption did not occur. The origin of the two plumes is still unknown.

Poor weather in the area today prevents further visual observations. AVO will continue to monitor the area via satellite and local pilot reports. AVO will attempt an overflight of the area later this week.

Mount Douglas, a 2,140 m (7,020 ft) high stratovolcano, is located on the northern tip of the Alaska Peninsula, 320 km (200 mi) southwest of Anchorage. The summit of Mount Douglas has a small lake-filled crater, and an active fumarole field on the northeast crater wall. In 1982, the crater lake had a temperature of 25 degrees C (77 degrees F) and a pH of 1. Although Mount Douglas is dissected and eroded, lava flows on the northwest flank are relatively uneroded. Douglas has not experienced eruptive activity within historical times; the most recent eruption was in the early Holocene.

Fourpeaked Mountain lies within the northeast corner of Katmai National Park and Preserve on the Alaska Peninsula, 7.5 miles (12 km) southwest of Mount Douglas. It is the likely vent for Fourpeaked volcano, a stratovolcano that is mostly surrounded (and covered) by Fourpeaked Glacier. Small isolated volcanic exposures along ridge crests and cliff faces radiate out from the ice-covered summit. The last volcanic activity at Fourpeaked was probably greater than 10,000 years ago. No recent volcanic or hydrothermal activity has been identified.

ABBREVIATED COLOR CODE KEY (contact AVO for complete description):
GREEN volcano is dormant; normal seismicity and fumarolic activity occurring
YELLOW volcano is restless; eruption may occur
ORANGE volcano is in eruption or eruption may occur at any time
RED significant eruption is occurring or explosive eruption expected at any time

ALASKA VOLCANO OBSERVATORY
Information Release
Wednesday, September 20, 2006 2:25 PM AKDT (2225 UTC)

FOURPEAKED VOLCANO (CAVW#1102-26-)
58°46'12" N153°40'19" W, Summit Elevation 6903 ft (2104 m)
Current Level of Concern Color Code: **YELLOW**

On Sunday evening, September 17, AVO received numerous reports of a large unusual cloud rising to heights of 20,000 ft (6,000 m) above sea level from the Cape Douglas area, about 200 miles (320 km) southwest of Anchorage and about 80 miles (140 km) northwest of Kodiak. Since our Monday, September 18 Information Release, additional data and observations of the September 17 event have been compiled from several new sources. These data confirm that the source of the large cloud observed Sunday evening was volcanic. Thus, AVO is increasing the Level of Concern Color Code for Fourpeaked volcano from "Not Assigned" to **YELLOW**

The exact location of the source is still unknown. Satellite and radar data suggest a source low on the flank of Fourpeaked volcano and we are assigning this activity to Fourpeaked based on this data. However, this location has not yet been confirmed by visual observations.

New details of Sunday's event have been added since Monday afternoon:

Retrospective analysis of data from the NEXRAD Doppler radar in King Salmon show an unusual cloud starting at 12:00 PM AKDT (2000 UTC) on September 17. The maximum cloud height determined by radar during the first hour of the event was 20,000 ft (6,000 m). The radar return from the cloud continued until at least 9:45PM AKDT (0545 UTC).

A cloud of sulfur dioxide gas released during the eruption was observed by colleagues at the University of Maryland Baltimore County over Cape Douglas/Fourpeaked region on September 17, 2006 at 3:00PM AKDT (2300 UTC) using data collected by the Ozone Monitoring Instrument (OMI) on NASA's Aura satellite.

Puff particle dispersion modeling showed that the cloud would have spread west to east as it moved northwards over the subsequent day. This is consistent with pilot reports received by AVO on the afternoon of Monday, September 18, that described a strong sulfur smell in the Stony River Valley, 300 km (180 miles) northwest of the Fourpeaked area, and from additional OMI sulfur dioxide observations of the cloud.

Although satellite data did not detect ash during this event, AVO received reports of a trace of ashfall at Nonvianuk Lake outlet (110 km, about 70 miles, west-northwest of the volcano) and near Homer (about 95 miles northeast of the volcano).

Although poor weather in the area has prevented visual observations, NEXRAD data over the past two days have not detected any further emissions. AVO staff will attempt both fixed-winged and helicopter overflights this afternoon to locate the possible vent areas and document any changes. AVO continues to monitor satellite data for further signs of activity.

Fourpeaked Mountain lies within the northeast corner of Katmai National Park and Preserve on the Alaska Peninsula, 7.5 miles (12 km) southwest of Mount Douglas. It is the likely vent for Fourpeaked volcano, a stratovolcano that is mostly surrounded (and covered) by Fourpeaked Glacier. Small isolated volcanic exposures along ridge crests and cliff faces radiate out from the ice-covered summit. The last volcanic activity at Fourpeaked was probably greater than 10,000 years ago. No recent volcanic or hydrothermal activity has been identified.

ABBREVIATED COLOR CODE KEY (contact AVO for complete description):
GREEN volcano is dormant; normal seismicity and fumarolic activity occurring
YELLOW volcano is restless; eruption may occur
ORANGE volcano is in eruption or eruption may occur at any time
RED significant eruption is occurring or explosive eruption expected at any time

ALASKA VOLCANO OBSERVATORY
Current Status Report
Thursday, September 21, 2006 12:45 PM AKDT (2045 UTC)

FOURPEAKED VOLCANO (CAVW#1102-26-)
58°46'12" N153°40'19" W, Summit Elevation 6903 ft (2104 m)
Current Level of Concern Color Code: **YELLOW**

AVO staff conducted both fixed-wing and helicopter overflights in the Cape Douglas area Wednesday afternoon and confirmed the source of volcanic activity reported on Sunday, September 17 to be Fourpeaked volcano.

Weather clouds partly obscured the summits of Douglas and Fourpeaked volcanoes yesterday, however a strong sulfur smell was noted immediately downwind (east) of Fourpeaked volcano and two white vapor plumes rose through the cloud deck as high as 2000 feet (610 m) above the approximate summit of the volcano (6903 ft, 2100 m).

Analysis of photographs and other data is ongoing. AVO continues to monitor Fourpeaked using satellite images. There is currently no real-time seismic network on the volcano and AVO is unable to track local earthquake activity that may indicate volcanic unrest.

ALASKA VOLCANO OBSERVATORY
Current Status Report
Friday, September 22, 2006 12:10 PM AKDT (2010 UTC)

FOURPEAKED VOLCANO (CAVW#1102-26-)
58°46'12" N153°40'19" W, Summit Elevation 6903 ft (2104 m)
Current Level of Concern Color Code: **YELLOW**

Satellite images of Fourpeaked volcano have been obscured by clouds over the past day.

AVO continues to monitor Fourpeaked using satellite images. There is currently no real-time seismic network on the volcano and AVO is unable to track local earthquake activity that may indicate volcanic unrest.

ALASKA VOLCANO OBSERVATORY
Weekly Update
Friday, September 22, 2006 12:45 PM AKDT (2045 UTC)

FOURPEAKED VOLCANO (CAVW#1102-26-)
58°46'12" N153°40'19" W, Summit Elevation 6903 ft (2104 m)
Current Level of Concern Color Code: **YELLOW**

AVO raised the Level of Concern Color Code for Fourpeaked volcano from "Not Assigned" to **YELLOW** on Wednesday, September 20. A large steam explosion near the summit of Fourpeaked volcano occurred on Sunday, September 17 beginning at approximately 12:00 noon AKDT (2000 UTC, September 18). Photographs and NEXRAD weather radar show that the plume reached up to approximately 20,000 ft (6,000 m) above sea level. Satellite images showed a cloud originating from Fourpeaked volcano, and persisting throughout the night. No ash or thermal anomalies have been detected in satellite images. The plume was visible on NEXRAD until 9:45 PM AKDT September 17 (0545 September 18 UTC). AVO staff conducted both fixed-wing and helicopter overflights in the Cape Douglas area September 20 and confirmed the source of volcanic activity to be Fourpeaked volcano.

A small but distinct SO_2 cloud over the area was detected by researchers from the Univ. of Maryland-Baltimore County using a new NASA satellite-based UV sensor (the Ozone Mapping Instrument, or OMI) at 3:00 PM AKDT (2300 UTC) September 17. Puff windfield modeling showed that the plume would have spread west and then moved north over the next day or so. This is consistent with pilot reports received by AVO on September 18 that described a strong sulfur smell in the Stony River Valley, ~200 miles west of Anchorage. Subsequent passes of the OMI have also shown an SO_2 cloud whose position is consistent with Puff modeling. AVO has received several accounts of very light ashfall, in Homer and near Nonvianuk Lake in Katmai National Park, that are also consistent with Puff modeling.

There is currently no real-time local seismic network on the volcano. The closest seismometer is 40 miles (64 km) to the north. A small swarm of tectonic earthquakes was detected on the regional seismic network from 11:48 AM to 3:50 PM AKDT (19:48 to 23:50 UTC) September 17. No explosion signals were detected seismically, but the infrasound array at the University of Alaska-Fairbanks picked up a signal from the Fourpeaked area with an origin time consistent with the other data.

There have been no known historical eruptions of Fourpeaked and no known geologic evidence for activity in the last 10,000 years. These factors and the lack of close-in seismic monitoring limit AVO's ability to forecast likely future activity. A helicopter flight is scheduled for this weekend to make geologic observations, collect samples, and install telemetered seismometers. AVO continues to monitor Fourpeaked using satellite images.

ALASKA VOLCANO OBSERVATORY
Current Status Report
Saturday, September 23, 2006 12:55 PM AKDT (2055 UTC)

FOURPEAKED VOLCANO (CAVW#1102-26-)
58°46'12" N153°40'19" W, Summit Elevation 6903 ft (2104 m)
Current Level of Concern Color Code: **YELLOW**

Satellite images of Fourpeaked volcano have been obscured by clouds over the past day. A fixed-wing mission to sample gases at Fourpeaked and Cook Inlet volcanoes is in progress.

AVO continues to monitor Fourpeaked using satellite images. There is currently no real-time seismic network on the volcano and AVO is unable to track local earthquake activity that may indicate volcanic unrest.

ALASKA VOLCANO OBSERVATORY
Current Status Report
Sunday, September 24, 2006 12:30 PM AKDT (2030 UTC)

FOURPEAKED VOLCANO (CAVW#1102-26-)
58°46'12" N153°40'19" W, Summit Elevation 6903 ft (2104 m)
Current Level of Concern Color Code: **YELLOW**

On Saturday, September 23, AVO flew an observation flight over Fourpeaked volcano. Relatively good weather permitted the first look at the volcano's summit since the event of September 17. Observers saw a linear series of vents running north from the summit for about 1 km. Most of these vents were vigorously emitting steam and other volcanic gases. In the immediate vicinity of the vents, the glacier had been disrupted. Gas measurements indicated abundant quantities of sulfur dioxide, hydrogren sulfide, and carbon dioxide. The sulfur species could be smelled easily by the observers on the flight at distances of up to 50 km from the Fourpeaked summit.

There are three field missions in progress at Fourpeaked today: (1) the installation of seismic instrumentation; (2) geologic observations; and (3) airborne thermal and gas measurements.

AVO continues to monitor Fourpeaked using satellite images. There is currently no real-time seismic network on the volcano and AVO is unable to track local earthquake activity that may indicate volcanic unrest.

ALASKA VOLCANO OBSERVATORY
Current Status Report
Monday, September 25, 2006 1:30 PM AKDT (2130 UTC)

FOURPEAKED VOLCANO (CAVW#1102-26-)
58°46'12" N153°40'19" W, Summit Elevation 6903 ft (2104 m)
Current Level of Concern Color Code: **YELLOW**

Aerial observations over the weekend indicate that unrest continues at Fourpeaked volcano. A series of pits and elongate openings through glacial ice high on the north flank of the volcano are emitting significant amounts of volcanic gas and steam. Channels and debris fans on the ice field indicate that outbursts of water have occurred. A helicopter is in the area today to make additional geologic and thermal observations and to install a time-lapse camera and one or two seismic stations near the volcano.

ALASKA VOLCANO OBSERVATORY
Information Release
Monday, September 25, 2006 3:35 PM AKDT (2335 UTC)

FOURPEAKED VOLCANO (CAVW#1102-26-)
58°46'12" N153°40'19" W, Summit Elevation 6903 ft (2104 m)
Current Level of Concern Color Code: **YELLOW**

On September 17, an explosion of ash, gas, and steam from Fourpeaked Mountain 320 km (200 mi) SW of Anchorage on the Alaska Peninsula marked the onset of unrest at this long-dormant, ice-clad volcano. AVO elevated the level of concern color code to **YELLOW** on September 20. Since then, AVO has gathered aerial and ground-based information and also initiated installation of geophysical instrumentation to better track activity at Fourpeaked. Based on our observations and limited geologic understanding of the volcano, it is possible that significant eruptive activity could occur in the coming days to weeks.

Over the weekend and continuing today, AVO flew a variety of missions to Fourpeaked volcano. The main findings are as follows: (1) Observers saw a linear series of vents running north from the summit for about 1 km (0.6 mi). Most of these vents were vigorously emitting steam and other volcanic gases. In the immediate vicinity of the vents, the glacier had been disrupted and showed signs of subsidence. (2) Gas measurements reveal that emission rates of sulfur dioxide, hydrogren sulfide, and carbon dioxide were all high. The sulfur dioxide emission rate was roughly equivalent to that measured at Augustine before its January 2006 eruptions. A distinct sulfur smell was evident up to 50 km (30 mi) from Fourpeaked's summit. (3) Marked scouring of a glacier flowing west from the summit indicates flooding, probably from the September 17th event. (4) Thermal measurements of 60 degrees C (140 degrees F) where recorded at the vents, though the abundant steam was likely obscuring hotter areas.

All evidence, including the ash emission of September 17th, the abundant volcanic gases, the presence of new vents at the summit, and the disruption and floods occurring at and below the summit glaciers, suggest the presence of new magma at shallow levels beneath the volcano. Because AVO has had no instrumentation network on Fourpeaked, we do not have the geophysical measurements necessary to provide independent evidence for the presence of new magma.

Fourpeaked volcano is not known to have erupted in the last 10,000 years, though geological investigations have been limited and ice covers much of the area. Because of this, the range of sizes and styles of past eruptions is not well-constrained. However, the composition of the volcano indicates that eruptions of Fourpeaked can be explosive, possibly producing plumes that reach in excess of 10 km (33,000 ft) above sea level and local ashfall.

Based on all currently available evidence, AVO believes that an eruption from Fourpeaked in the next days to weeks is possible. Given below are some possible future scenarios for the current unrest at Fourpeaked, listed in order, with the most likely scenario listed first:

1. A small to moderate eruption will occur, which may produce ash plumes exceeding 10 km (33,000 ft) above sea level. Lava flows may also occur.
2. No eruption occurs. Unrest gradually subsides to background levels.
3. A large eruption will occur, which would produce ash plumes exceeding 10 km (33,000ft) above sea level, and possible widespread ash fall.

Even minor volcanic activity can result in floods, debris flows, and lahars (volcanic mud flows) into the nearby drainages. These can occur without obvious signs of volcanic activity like ash plumes or loud explosions. Thus, the local area is considered especially hazardous.

AVO has begun constructing a network of geophysical monitoring instruments at Fourpeaked. Over the last two days, two seismometers were installed between 10 and 20 km (6 -12 mi) from the summit. These instruments give AVO volcanic earthquake detection capability, but do not provide enough information for short-term forecasts of volcanic eruptions. Additional seismometers will be installed in the coming days. If conditions permit, these instruments will be closer to the summit and should provide better forecasting capability. AVO also plans the installation of web cameras and instruments for measuring ground deformation.

AVO will continue to monitor the volcano with satellite data, observation flights, and new geophysical data streams as they become available.

ALASKA VOLCANO OBSERVATORY
Current Status Report
Tuesday, September 26, 2006 12:45 PM AKDT (2045 UTC)

FOURPEAKED VOLCANO (CAVW#1102-26-)
58°46'12" N153°40'19" W, Summit Elevation 6903 ft (2104 m)
Current Level of Concern Color Code: **YELLOW**

Aerial and ground observations yesterday indicate that volcanic unrest continues. A series of pits and elongate openings through glacial ice high on the north flank of the volcano are vigorously emitting volcanic gas and steam. Channels and debris fans on the ice field indicate that outbursts of water have occurred.

Limited seismic data from the area of Fourpeaked volcano are now being received at AVO. As weather allows, AVO will install additional instrumentation and conduct further geologic investigations near the volcano.

ALASKA VOLCANO OBSERVATORY
Current Status Report
Wednesday, September 27, 2006 12:25 PM AKDT (2025 UTC)

FOURPEAKED VOLCANO (CAVW#1102-26-)
58°46'12" N153°40'19" W, Summit Elevation 6903 ft (2104 m)
Current Level of Concern Color Code: **YELLOW**

Cloudy and rainy conditions have prevented any new visual or satellite observations of Fourpeaked. The limited seismic data now being received at AVO do not indicate significant volcanic activity.

As weather allows, AVO will install additional instrumentation and conduct further geologic investigations near the volcano.

Activity IV. Activities to Consider Before, During, or After a Volcanic Eruption

Grade Level 6–11

Setting varies

Time varies

Correlation to Alaska State Science Standards
varies

Overview
Several of the activities within this guidebook may be prioritized in the event of increased volcanic activity or current volcanic eruption(s) in Alaska. Additional, dynamic resources also are available on-line and in print in the event of a forecasted or actual volcanic eruption in Alaska or elsewhere.

Background
During volcanic eruptions in Alaska, the Alaska Volcano Observatory (AVO) has developed activity web pages that are updated every few hours to reflect the ongoing or forecasted activity at one or more of Alaska's volcanoes. AVO also posts associated satellite, seismic and other monitoring data, images from staff and the public, and other pertinent information that can be useful for activities and classroom discussion, as well and safety and emergency planning.

In addition, AVO staff conducts media interviews and press conferences during periods of heightened activity and volcanic eruption(s). There is typically an increase in the amount of media coverage (blogs, documentaries, news reports and articles, radio spots etc.) related AVO and the heightened activity or erupting volcano during this time.

AVO's interagency partners such as the NOAA National Weather Service, Federal Aviation Administration, and Alaska State Department of Homeland Security and Emergency Services, among others, also post pertinent information, and monitoring data and tools on-line and conduct media interviews. These tools and media documentation can augment activities in this guidebook and Earth science curriculum.

A list of *Common Websites Used During Volcanic Episodes in Alaska* is included. This is a general list and additional websites and sources for current information will be included—so stayed tuned for additional postings on the AVO website and other agency websites, and media references for additional resources. AVO places links associated with the activity of a specific volcano on the AVO website activity web page under the heading, "Links." This website is a great resource for you and your students and all of your colleagues and families, as well.

Additionally, many of Alaska's active volcanoes are on public land managed by a Federal, State or local agencies. These land managers often place pertinent information on their own websites. The boroughs and city municipalities in which these volcanoes and nearby communities reside place pertinent information on their websites.

Objective

By learning about a current or forecasted volcanic eruption(s) in Alaska and elsewhere, students will gain perspective on the wide variety of data, interagency organization, and personal responsibility and preparedness needed to remain safe and to learn from these dynamic, and rather frequent, volcano events.

Materials

- access to on-line, print, and radio media, and podcasts and on-line resources such as the AVO website and those of its interagency partners
- materials specific to prioritized guidebook activities mentioned below

Suggested Procedures

A. Research, Present, and Review

1. Assign students to complete a paper, poster, podcast, or digital presentation about the ongoing activity. You can assign or students can select a different topic to research and discuss during daily or weekly classroom periods. Students can also discuss how their individual family is preparing for the event of an ash fall.

B. Prioritized Activities

1. It may be worthwhile to prioritize some of the activities in the guidebook to inform students about possible volcanic hazards and preparedness planning that may be most pertinent in the event the community is affected by the heightened activity or eruption(s). Suggested, prioritized activities are listed in order of appearance in the guidebook. The activities in Chapter 5 Alaska's Volcanoes and You! may be the most valuable for communities that may be directly affected by heightened activity or eruption(s).

    Chapter 1 Alaska Plate Tectonics
    Activity II Plate Tectonics Mapping

    Chapter 2 Alaska's Igneous Rocks
    Activity III Comparison of Hawaiian, Cascade, and Alaskan Volcanic Rocks

    Chapter 3 Eruption!
    Activity I Eruption 1, 2, 3

    Chapter 4 Alaska's Volcanic Landforms and Features
    Activity I Volcanic Landforms and Features Information Search

    Chapter 5 Alaska's Volcanoes and You!
    Activity I We need all the assistance you have…
    Activity II What is the Plan?
    Activity III Volcanic Ash Fall in Your Community

    Chapter 6 Climate and Volcanic Eruptions
    Activity III Globally Averaged Temperature and Volcanic Eruptions

C. Ash fall deposit collection

1. AVO has thorough ash fall collection instructions posted on its website. It may be a great outside activity for students to complete after an ash fall. Be sure that all other medial, emergency, and safety needs and precautions are met prior to conducting this activity.
   - AVO Procedures for Collecting and Returning Ash Samples from Modern Volcanic Eruptions
     http://www.avo.alaska.edu/ashfall.php

2. You can use the ash-deposit collection instructions to collect your own "ash" by using a household granular substance in place of volcanic ash when a real ash fall is unavailable, or to practice with practice during heightened activity, but before a likely ash fall occurs. If you decide to use a human food item such as corn meal or flour in place of real ash, be sure not to conduct your collection experiment outside where the remaining food items may be an attractant for wildlife.

Extension 1

1. Encourage students to write fictional or non-fiction stories about volcanic eruptions, and describe what they would do if they were a volcanologist studying this eruption.

2. Give students time to work in groups to illustrate, present, or write about how they would work as a team to solve a specific mystery at an Alaskan volcano.

Websites Commonly Used During Volcanic Episodes in Alaska

GENERAL PREPARDNESS
Alaska Homeland Security and Emergency Management: http://www.ak-prepared.com/

USGS Volcanic Ash—What it can do and how to prevent damage
http://volcanoes.usgs.gov/ash/

ASHFALL WARNINGS, MARINE ADVISORIES
NOAA National Weather Service (NWS) Alaska Aviation Weather Unit (AAWU):

- PIREPS (Pilot Reports) http://aawu.arh.noaa.gov/pireps/webPirep.htm
- Ashfall and Marine Advisories http://www.arh.noaa.gov/ and through the Center Weather Service Unit (CWSU) http://cwsu.arh.noaa.gov/

WIND TRAJECTORIES
NOAA Air Resource Laboratory: HYSPLIT
http://www.arl.noaa.gov/ready/traj_alaska.html

RADAR
NOAA National Doppler Radar Sites http://radar.weather.gov/

AIRBORNE VOLCNAIC ASH
Volcanic Ash Advisory Centers (VAAC) http://www.ssd.noaa.gov/VAAC/vaac.html

- Alaska VAAC - http://aawu.arh.noaa.gov/
- Oakland VAAC - http://www.wrh.noaa.gov/zoa/oceanSIG.php
- Washington VAAC http://www.ssd.noaa.gov/VAAC/messages.html

HEALTH – ASH IMPACTS
Alaska Department of Environmental Conservations—Division of Air Quality: Air Quality Advisories & Alerts http://www.dec.state.ak.us/air/am/aq_sr.htm

Alaska State Health and Social Services

- Public Health http://www.hss.state.ak.us/dph/
- Epidemiology: Volcano Facts http://www.epi.hss.state.ak.us/volcanoes/default.htm

AIR TRAFFIC CLOSURES
Federal Aviation Administration (FAA)—Flight Restrictions http://tfr.faa.gov/tfr2/list.jsp

MARINE SAFETY
U.S. Coast Guard (USCG): http://www.uscg.mil/d17/

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