CHALLENGER CENTER'S
JOURNEY through the UNIVERSE

Earth Systems Science

This lesson is taken from an education module developed for Challenger Center's *Journey through the Universe* program. *Journey through the Universe* takes entire communities to the space frontier.

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January 2002

Grade Level
5-8

Lesson 1:
Plate Tectonics: Movin' and Shakin'

Lesson Summary

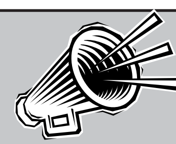
Students are introduced to the causes of, as well as the hazards posed by, plate movements. In Activity 1, students develop an understanding of the theory of plate tectonics. Geologic activity is global and mapping that activity can tell us something about global processes. Students will therefore plot earthquake and volcano locations on a world map. Based on the similarity of their locations, students can draw conclusions about their relationships. Students will discover that this geospheric activity has consequences for life on Earth. In Activity 2, students plan an investigation to simulate, in the laboratory, the exposure of plants to volcanic gases. Their effects on plant growth will be monitored for a few days. Students will produce a report on their findings. Students will discover how volcanoes interact with all of the Earth systems.

Lesson Duration

Two 45 minute class periods and 5 minutes a day for three days for observations and maintenance of experiment.

ESSENTIAL QUESTIONS

- What is the relationship between earthquakes and volcanic eruptions?
- How do volcanic eruptions affect the atmosphere and life on Earth?



OBJECTIVES

Students will be able to:

- Plot the location of 50 earthquakes on a map.
- Plot the location of 50 volcanic eruptions on a map.
- Explore relationships between plate tectonics, earthquakes, and volcanoes.
- Test the effect of different volcanic gases on the growth of plants.

Science Overview

If you look at a world map, you can see that, like pieces of a jigsaw puzzle, the continents appear as if they could fit together almost snugly. For example, the east coast of South America appears to dovetail almost perfectly with Africa. Alfred Wegener, a German meteorologist, responded to this long-noticed feature and other geological puzzles by proposing the "Theory of Continental Drift" in 1912. The theory proposed that the Earth's continents were large movable pieces sliding on the ocean bed. Wegener hypothesized that approximately 200–250 million years ago the continents had formed one huge piece of land, a supercontinent that he called Pangaea, that broke apart into drifting pieces that are the continents that we see today. Wegener's ideas received a great deal of harsh criticism, primarily because he was unable to suggest an adequate mechanism by which the continents could move, nor could his theory be reconciled with real measurements of ocean depth around the continents.

CORE 5-8 STANDARDS

NRC Standards

- STANDARD D1*:* Major geological events, such as earthquakes, volcanic eruptions and mountain building, result from plate movement.
- STANDARD F3*:* Internal and external processes of the earth system cause natural hazards.

Over time, scientists have come to the conclusion that the fundamental concept of surface plates in motion is correct, although Wegener's ideas were wildly inaccurate in important details. The continents are not plates themselves, but are only the upper part of much larger plates. Large portions of the plates are submerged beneath the oceans, and there are some plates that are more or less entirely submerged. The modern "Theory of Plate Tectonics" was developed collaboratively by many scientists in the 1950s and 1960s in response to vast amounts of formerly contradictory and incompatible evidence. Although plate tectonics has enabled enormous strides in understanding and has answered many questions, geophysicists are still researching many important details of the modern theory.

Scientists have identified about 14 major tectonic plates of varying sizes. The exact number of plates is subject to continuing research. It is now believed that the movement of the tectonic plates is driven by convection currents in the Earth's interior. These plates, of varying thickness, extend through the crust and partially into the mantle. They move along on a layer of the mantle that is hot and relatively weak, giving the rock fluid-like properties. It is incorrect to say that this layer is molten, like lava. For comparison, imagine bending a metal bar or stretching a wire. So long as the metal is under stress, it can deform and flow in response to the stress, but it never ceases to be solid matter. Along the boundaries of the Earth's plates, exciting things happen on the planet's surface. Mountains grow, geysers jet, volcanoes erupt, and earthquakes shake. In fact, most earthquakes and active volcanoes (but not all!) are found along plate boundaries.

Earthquakes that occur at plate boundaries are caused by the sudden release of strain that develops within the plates as the plate edges slide against each other. Colliding plates do not move smoothly against or on top of one another, but instead experience friction. Strain, meaning the plates' resistance to being compressed or bent by the stress of the collision, builds up until it is great enough to exceed the frictional forces between the plates. At that point, the plates lurch suddenly and release the energy stored in the strained plates, launching seismic waves outward through the rock that we feel as an earthquake. Earthquakes vary in size, and aftershocks can be felt for days following such an event.

Many volcanoes on the planet are also located where two plates converge, or come together. When two plates converge, one is forced beneath the other in a process called subduction. A portion of the plate that is forced beneath the surface (subducted) may become partially melted, and the molten rock can be forced back towards the surface as magma. Alternatively, rock in the upper plate may be melted by compression as the plate pushes over the subducted plate, also resulting in molten magma that can be pushed up through fractures in the rock of the upper plate. Over time, this rock forces itself through the surface in the form of a volcano, sometimes explosively. As it rises and intrudes into cooler layers of the crust, the magma loses some of its dissolved gases and interacts with the cool solid rock, losing some material, gaining material of different composition from the surrounding crust, and reacting chemically with it. This altered molten material is lava — the different name reflects the fact that lava is compositionally different from the magma from which it is derived, so that lava erupted onto the surface does not faithfully represent the rock composition deep down. The mountains of the Cascade Range, which include Mt. St. Helens, Mt. Rainier, and Mt. Shasta, all were formed by this process.

When lava emerges at the surface, new rock and new land can result from the gradual buildup of material over many successive eruptions of the volcano over thousands or millions of years. The Hawaiian Islands are what are called "shield volcanoes," volcanoes formed by relatively gentle extrusions of lava from the ocean floor over millions of years. Not all types of volcanoes are so gentle and some can erupt violently. In Hawaii, the ongoing eruption of the volcano Kilauea ("keylow- way-uh") adds a few more acres of fresh land to the Big Island of Hawaii every year. The other islands of the Hawaiian chain, extending away to the northwest, are progressively older the farther they are from the currently active volcanoes on the Big Island. Their own volcanoes have been extinct for thousands or millions of years, and those islands slowly are being worn down by wind, weather, and the ocean.

The birth of the youngest land on Earth is not gentle. Active volcanoes may have many effects that are very destructive to the land and life already there:

- Vented gas and fine ash that is "entrained" (carried with it) can be pushed up into the upper atmosphere, creating aerosol clouds of fine particles and droplets of condensed volcanic gases.
- Hot gases can spread at ground level from the volcano, scalding and poisoning living things.
- Liquid rock flows downhill, burning everything living and burying it in rock.
- Volcanic ash and cinder can rain down for miles around, burying land sometimes tens of meters deep.
- Rocks and boulders can be flung great distances by explosions.
- Gas bubbles in the lava can burst explosively, spraying lava up to thousands of meters into the air.
- Sometimes, the rapidly-escaping gas can stir and lift up rock, ash, and other debris on the volcano's slopes, creating a *pyroclastic flow* that pours downhill at high speeds (up to 150 km/hr), grinding away everything in its path.
- Sometimes, moist soils or mountain lakes on the sides of volcanoes can be superheated and poured away as the slopes of the volcano shift, creating a monumentally destructive slide of boiling hot mud called a *lahar* that can sweep away everything from the volcano's slopes, spreading into an apron of mud and devastation.

- Occasionally, a volcanic mountain may explode entirely. Several volcanic islands (e.g., Krakatoa, Thera) have been erased by such events.

While all these effects may be associated with volcanoes, not every volcano will display every one of them, or even most of them. The "style" of a volcano's eruptions, and the destructive effects that follow from it, depend upon where the volcano grows and what is the source of its magma. Most of the world's volcanoes are located along the boundaries of tectonic plates, the fourteen-or-so slowly shifting segments of rock that make up the Earth's surface. In "convergence zones", where one plate is subducted beneath (forced under) another, magma is produced from the partial melting of crustal rock either in the surface of the subducted plate or within the upper plate. In rift zones, magma is believed to rise up from the aesthenosphere, the partially molten layer lying beneath the upper mantle (that lies below the crustal surface rock). And in "hot spot" volcanoes such as the Hawaiian Islands, a locally hotter region of the mantle heats the crust of the ocean bed above it to the point of liquefaction, creating magma that rises up to form a volcano. Different sources of volcanic magma have consequences in the composition, temperature, viscosity ("gooeyness"), dissolved gas quantity, and dissolved gas identity in the magma. These distinctions affect how violent, or gentle, or hot, or gassy, or rapid the volcanic flow may be, and the resulting lavas carry signatures of their source.

Dependence on the Earth Systems

The geosphere is the part of the Earth's system that contains the rocks and minerals, as well as the processes that shape the Earth's surface and the Earth's interior (such as plate tectonics, earthquakes, and volcanoes). The geosphere interacts with the other Earth systems in many ways, including the following:

Hydrosphere

All of the water on Earth and in the air is known as the hydrosphere. On a basic level, the geosphere and the atmosphere provide a home for the hydrosphere. Water rests in lake beds, on ocean floors, and in river valleys, all of which are part of the structure of the geosphere. In most cases, the power of the water and its need to flow has cut away parts of the rock, and created its own place to thrive. Water can cut away at the land in a process called "erosion." Where plates separate, usually in the deep ocean, the midocean ridges are formed by volcanoes erupting along the "spreading center" between the plate edges. The rock at the ridges comes from magma formed in the upper mantle, which is chemically different from convergence-zone volcanic rock. Most of the world's active volcanoes actually occur at the midocean ridges, almost entirely unobserved by human eyes except for their very obvious after-effects.

Atmosphere
Just as erosion can occur from the hydrosphere, it can be a result of atmospheric interactions as well. Wind erosion is a factor in shaping the geosphere. Strong winds may carry dust and grains from one part of the land to another, or work to keep soil and land from building up in one area over another.

An erupting volcano emits huge quantities of gas into the atmosphere. Kilauea in Hawaii emits about 2,000 tons of irritating sulfur dioxide (SO_2) gas each day during periods of sustained eruption. The relative concentrations of volcanic gases can vary considerably from one volcano to the next. Water vapor typically is the most abundant, followed by carbon dioxide and sulfur dioxide. Other principal volcanic gases include hydrogen sulfide, hydrogen chloride, and hydrogen fluoride. A large number of minor and trace gases also are found in volcanic emissions. These gases are released, but come back to the earth in the form of rainwater, which may have a high acid content.

Biosphere
Earth's life system, the biosphere, is greatly affected by the geosphere. Most obviously, the geosphere creates a means by which life on Earth can thrive. It provides a solid surface on which to reside, and is home to much of the plant life on Earth. Geospheric activities also affect the biosphere, as anyone who has survived an earthquake can verify.

Vented gas is a common feature of volcanic lavas. Thus, while the effects are local to the region around the volcano, the common nature of the effect among volcanoes means that volcanic gases are a relatively common, and certainly dangerous, phenomenon affecting the biosphere. Areas downwind of Kilauea have reported a wide range of problems, including reduced visibility from "vog" (volcanic smog), health complaints, and damage to crops.

Volcanic gases may damage plants or may damage their value as food. Starvation reportedly followed a 1783 volcanic eruption in Iceland that contaminated grasses with volcanic gas, leading to the death of livestock that grazed upon it. The effect of volcanic gases on plants can be investigated under controlled circumstances by exposing plants to simulated volcanic gases in the laboratory, providing important data to understanding what humans must do to adapt better to living in a world with volcanoes.

Lesson Plan

Preparation & Management

Create an overhead of the map that is a part of Student Worksheet 1; it shows a map of the Earth with longitude and latitude lines labeled.

Warm-up

1. Show the students the overhead of the map from Student Worksheet 1. Ask students if they know what the horizontal lines on the map are. *(Answer: latitude lines)* Ask students if they know what the vertical lines are. *(Answer: longitude lines)* Ask student if they know the purpose of this grid system. *(Answer: to identify locations on the Earth.)*

2. Show the students how latitude lines and longitude lines are labelled.

Teaching Tip

- *Start at the equator since most students will be familar with this latitude line.*

3. Review or demonstrate to students how to find a location on the Earth from a set of latitute and longitude coordinates. Do a few examples as a class.

Pre-Assessment

Pass out Student Worksheet 1. Provide students with a latitude and longitude coordinate. Ask each student to indicate that location on their map by pointing thier pencil point at it. Circulate around the room and check that each student was able to identify the correct location. Do not move on until every student is able to plot longitude and latitude points.

TEACHER MATERIALS

Warm-Up:
- Overhead of map in Student Worksheet 1

Activity 1:
- Transparency of the plate map
- Ring of Fire Overhead

STUDENT MATERIALS

Warm-Up: (per student)
- Student Worksheet 1

Activity 1: (per student)
- Student Worksheet 1
- Colored crayons or markers (blue & red)
- Transparency of Plate Boundary Map (for every two or three students to share)

Activity 2: (per group of 4)
- Student Worksheet 2
- Source of gaseous CO_2 (compressed-gas cylinder, marble chips in weak hydrochloric acid, or dry ice)
- 4 -5 plant seedlings
- Soil
- 4 -5 large clear plastic soda bottles, with caps
- 2 Campden Tablets
- Plastic packing tape or duct tape
- Various small beakers

ACTIVITY 1: We're Crackin' Up

Preparation & Management

- Make enough overhead transparencies of the Plate Boundary Map for every two or three students to share a copy.
- Make one overhead transparencies of the Ring of Fire Overhead.

Procedures

1. Ask students if earthquakes tend to happen randomly or in one place over and over. *(Answer: they tend to happen in the same general location repeatedly)* Ask students, can you think of any place where earthquakes tend to happen in the United States. *(Answer: California)* Ask students if volcanoes only erupt once or repeatedly. *(Answer: volcanoes tend to erupt repeatedly, until they become dormant)* Ask students, if you had a list of locations of recent earthquakes and volcanoes, would they be scattered all over the Earth or would they occur in concentrated regions? How could we find out? *(Answer: we could mark the events on a map)* Tell students that you just happen to have that information for them!

2. Have students follow the procedures in Student Worksheet 1 to plot the locations of recent volcanoes and earthquakes on the map of the Earth. They should answer the questions in Student Worksheet 1 along the way.

3. Once students have completed forming their hypotheses and plotting the volcanoes and earthquajes on Student Worksheet 1, give them an overhead of the Plate Boundary Map. Have students lay the transparency over their completed map. Ask students if the plate boundaries follow a pattern similar to the pattern they identified.

ACTIVITY 1: We're Crackin' Up

Reflection & Discussion

- Ask students what pattern they identified regarding earthquake locations. *(Answer: earthquakes tend to be concentrated along narrow zones on the Earth's surface)* Ask students what pattern they observed regarding volcanoes. *(Anwser: volcanoes tend to occur around the same patterns as earthquakes)* Ask students to identify the cause of these patterns. *(Answer: students should refer back to the Plate Boundary Map, and realize that the majority of the earthquakes and volcanoes occur along these boundaries)*

- Review or introduce the theory of plate tectonics. Ask students why they think so many earthquakes and volcanoes occure at these plate boundaries. *(Answer: Lead students to the idea that the plate boundaries are not static, they move against each other. This movement causes pressure and stress along the boundaries. That stress is released during earthquakes and volcanoes.)*

- The theory of plate tectonics helps to understand the location of many earthquakes. Plate tectonics can help to predict where 90% of major earthquakes are likely to occur.

- Display the Ring of Fire Overhead, tell students that more than half of the world's active volcanoes encircle the Pacific Ocean to form the "Ring of Fire."

Transfer of Knowledge

Ask students to mark, in pencil, where they believe future volcanoes or earthquakes are likely to occur.

Answer:

In order for students to complete this task successfully, they will have to refer back to the Plate Boundary Map. Students should indicate that future earthquakes and volcanoes are likely along any plate boundary.

ACTIVITY 1: We're Crackin' Up

ASSESSMENT

4 Points
- All earthquake plots are complete and accurate.
- All volcano plots are complete and accurate.
- Student correctly and completely answered all questions on Student Worksheet 1.
- Student accurately predicted future sites of volcanoes and earthquakes as directed in the *Transfer of Knowledge* section.

3 Points
- Student completed 3 of the 4 above criteria.

2 Points
- Student completed 2 of the 4 above criteria.

1 Point
- Student completed 1 of the 4 above criteria.

0 Points
- No work completed.

Placing the Activity Within the Lesson

Review with students what they have learned about the relationship between plate tectonics and earthquake and volcanic activity. Ask students if they think that these activities in the geosphere affect life on Earth. Have them brainstorm how.

ACTIVITY 2: Volcanic Gases

ACTIVITY 2: Volcanic Gases

Teaching Tips

- *Campden Tablets are used in wine making and can be ordered online from a supply house for about $2.00 for 50 tablets. Advise care when using the Campden tablets, especially for people with asthma.*

- *Do not distribute materials to students in advance: The student groups will need to evaluate on their own how much equipment their experiment needs within the limits of the budgeted amount available.*

Preparation & Management

- For the research students will be conducting on volanic gases, they will need in class access to resources on volcanoes, such as books, CDs, or the internet. See the *Supplemental Resource* section for suggestions.

- Assign students into groups of 4.

- If possible, plant samples can be grown in advance in school. Students may have other suggestions, which should be tried if possible.

Procedures

1. Ask students how volcanoes affect life on Earth. *(Answer: they can kill living things)* Ask students how volcanoes can be dangerous to life. *(Answer: lava is so hot it eradicates life in its path)* Ask students if any other material emitted by volcanoes is dangerous? *(Answers: volcanic gas)*

2. Ask students how we could determine the effect of volcanic gases on living things (*Answer: we could do an experiment in which we expose living thing to volcanic gases)* Ask students what type of living things we should use. *(Answer: plants)* Tell the students what type of plants or seedlings you will be providing. Ask students what else they would need. *(Answer: volcanic gases)* How are we going to get volcanic gases? What are they? *(Answer: students will need to research the compostition of volcanic gases)*

ACTIVITY 2: Volcanic Gases

3. STOP and allow students to conduct this research using the reference materials you have provided. Students should complete the "Research" section on Student Worksheet 1. Then they should use that knowledge to complete the "Hypothesize" section on Student Worksheet 1.

Teaching Tips

If time is limited, you can tell students the answers or give them a short article to limit and focus their research.

4. Reconvene and discuss the information students discovered during their research. Although their research should uncover a range of volcanic gas components, the choice of materials for a laboratory simulation will have to be limited on the grounds of availability, cost, and safety. The focus of the investigation will have to be narrowed to consider the effects of just two gases, SO_2 and CO_2.

5. Ask students if we should expose the plants to these gases in the open classroom. *(Answer: no, then we would also be exposing ourselves)* Ask students to brainstorm how we can solve this problem. *(Answer: we can put the plants and the gases in a sealed container)*

6. Point out that large plastic soda bottles can make suitable enclosures in which to keep a controlled atmosphere, because they are almost airtight. Have the class consider how to prepare the soda bottles as enclosures for plants. They may suggest a variety of techniques; post them on the board.
(Answer: Three possible methods are:
(1) Work out a way to insert experimental materials through the bottle's neck.
(2) Cut off the bottom third of the bottle with scissors so that the bottom can be filled with experimental materials and then the top sealed on with tape.
(3) Make a door in the wall of the bottle. When closed, the edges of the door need to be sealed with tape.
Note: Seal access to the bottles with plastic packing tape, not fiber tape or duct tape, so they are still transparent.)

ACTIVITY 2: Volcanic Gases

7. Explain the procedures for introducing carbon dioxide and sulfur dioxide into their bottles. *(Answer: The following advice is offered for introducing the gas to the enclosure:*

   - *Carbon dioxide can be introduced in three ways, all of which depend on the fact that CO_2 is more dense than air and will push the normal air out of the enclosure through its top. After the CO_2 is introduced, immediately cap the bottle to prevent diluting the enclosed atmosphere by gas diffusion.*
     (1) CO_2 can be squirted into the mouth of the bottle with a CO_2 cartridge or lab cylinder. The pitch of the sound emitted will rise as the bottle fills with CO_2. This gives an indication of how much of the gas has been added. With care, it is possible to add different amounts of gas to two bottles to achieve "low" and "high" concentrations.
     (2) CO_2 can be produced using marble chips and weak acid in a beaker at the bottom of the enclosure. Cap the bottle only after the marble chips are completely dissolved to avoid pressurizing the bottle.
     (3) CO_2 can be produced by the sublimation of dry ice chips dropped into the bottle. Cap the bottle only after the dry ice is fully sublimated to avoid pressurizing the bottle.

   - *Sulfur dioxide is used to sterilize baby utensils and home-brew equipment. "Sodium metabisulphite" tablets (Campden Tablets) generate small quantities of sulfur dioxide when added to water. The concentration of SO_2 within the enclosed air can be approximately doubled by using two tablets, even though the actual concentration is not known. (People who have respiratory ailments such as asthma may suffer discomfort if exposed to SO_2, even in these low concentrations.) Like CO_2, SO_2 is more dense than normal air and will push the air out of the bottle neck. Cap the bottle only after the tablets are fully dissolved.)*

8. STOP! Allow student teams to develop their experiment. Each group member should record the procedure on Student Worksheet 1.

9. Check each group's procedure before they begin their experiment. Make sure their experiment is truly designed to test the effects of volcanic gases on their plants. Students should set up a control bottle with normal air, one bottle with sulfur dioxide, and a third bottle with carbon dioxide. (Look for suggestions in the *Teacher Answer Key*)

ACTIVITY 2: Volcanic Gases

10. Allow students to begin their experiment. Students should create a data table to record their results. They will need to monitor and make observations of their plants for three days.

Reflection & Discussion

As a class, have students report the success or failure of their experiments. As each group presents, you may want to have them reflect on the following questions:

- What gases are emitted during eruptions of volcanoes? *(Answer: carbon dioxide and sulfur dioxide amongst others)*
- What gases did you use in your test? *(Answer: carbon dioxide and sulfur dioxide)*
- What effect did these gases have on the growth of your plants? *(Answer: answers will vary although the gases should have a negative effect on the plants)*
- How did you form and test your hypothesis? Did your data support your hypothesis? Explain. *(Answer: answers will vary but students should clearly refer to their original hypothesis)*

Transfer of Knowledge

A small farm community that lives at the base of an active volcano does not understand why all of their crops keep dying, even though the volcano has not erupted recently. Have students explain why this could happen. Have them write their answer on a piece of paper to hand in for assessment.

Answer:
Students should explain that volcanoes emit dangerous gases in addition to lava. These gases, invisible to the naked eye, are actually very harmful to organisms. These gases consist of carbion dioxide and sulfur dioxide and are probably killing the crops, and could possibly be harming livestock.

ACTIVITY 2: Volcanic Gases

ASSESSMENT

4 Points

- On Student Worksheet 2, student research was complete and hypothesis indicated a high level of understanding.
- Student developed a comprehensive experiment to test their hypothesis.
- Student performed the experiment and collected detailed data.
- Student accurately completed the analysis questions, including the *Transfer of Knowledge* question.

3 Points

- Student met 3 of the 4 above criteria.

2 Points

- Student met 2 of the 4 above criteria.

1 Point

- Student met 1 of the 4 above criteria.

0 Points

- No work was completed.

Placing the Activity Within the Lesson

Have students hold a model conference with the other groups in the class, just as professional scientists do, to discuss other ways that the geosphere affects the biosphere.

Lesson Closure

In Activity 1, students learned the cause of earthquakes and volcanoes. They also learned how to use a map of the Earth's plate boundaries to predict future earthquakes and volcano eruptions. In Activity 2, students learned how volcanoes affect not only the geosphere, but the biosphere as well. Ask students what other spheres earthquakes and volcanoes affect. *(Answer: the hydrosphere and the atmosphere - all of them!)*

Supplemental Resources

Additional resources about the effects of dust storms from Africa using SeaWiFS data
http://capita.wustl.edu/Databases/UserDomains/SaharaDust2000/

Alaskan Volcano Observatory, outstanding images and text about all volcanoes in Alaska, the Aleutian Islands, and Kamchatka Peninsula. Regional and local maps. Images of volcanoes, their eruptions, and the effects on the nearby human populations.
http://www.avo.alaska.edu/avo3/atlas/atlindex.htm

An on-line publication about plate tectonics, including considerable material on volcanoes
http:// pubs.usgs.gov/publications/text/dynamic.html

Dramatic black and white picture of eruption and ash cloud.
http://volcano.und.nodak.edu/vwdocs/volc_images/img_st_helens_bw.html

Earth Observation System Volcanology homepage, provides comparative information on a variety of volcanoes under study.
http://volcano2.pgd.hawaii.edu/eos/

Images and data on aerosol index
http://toms.gsfc.nasa.gov/aerosols/aerosols.html

Links to information about Mount St. Helens. Includes details of the 1980 eruption, maps and graphics of the Cascades Volcanoes, monitoring efforts, and more.
http://vulcan.wr.usgs.gov/Volcanoes/MSH/framework.html

Supplemental Resources Continued

Mount Saint Helens homepage

http://volcano.und.nodak.edu/vwdocs/msh/msh.html

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Mt. St. Helens LANDSAT progression of images with additional pictures of selected sites.

http://edcwww.cr.usgs.gov/earthshots/slow/MtStHelens/

Online edition of This Dynamic Earth: the Story of Plate Tectonics, a book published by the US Geological Survey (USGS) through the U.S. Government Printing Office. A downloadable PDF version is available.

http://pubs.usgs.gov/publications/text/dynamic.html/

Narrative of an aircraft encounter with an ash cloud from Redoubt

http://www.geo.mtu.edu/department/classes/ge404/gcmayber/historic.html

Summary of the 1980 eruption event.

http://vulcan.wr.usgs.gov/Volcanoes/MSH/May18/summary_may18_eruption.html

USGS fact sheet on the interaction of airplanes and ash. In pdf format

http://www.avo.alaska.edu/genrl_info/pdfs/usgsfs030_97_ash.pdf

USGS information on volcanic ash and aircraft

http://volcanoes.usgs.gov/Hazards/Effects/Ash+Aircraft.html

USGS source for information on airborne volcanic hazards

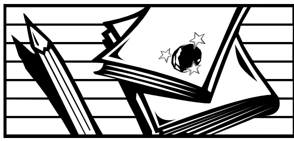
http://volcanoes.usgs.gov/Hazards/What/Tephra/tephra.html

Volcanic ash clouds and aircraft safety

http://www.geo.mtu.edu/department/classes/ge404/gcmayber/

Volcano World page with searchable world map. Students can search for volcanoes by region, country, name, etc. Provides useful information and images from a variety of sources

http://volcano.und.nodak.edu/vwdocs/volc_images/volc_images.html



STUDENT WORKSHEET 1 - WE'RE CRACKIN' UP

Name ________________________________ **Date** __________

Directions:

1. Using a blue crayon, plot the locations of each quake from the Earthquake Table on the map.

2. Is an observable pattern forming? Describe the pattern.

____

3. What percentage of the earthquakes plotted fit your pattern?

____

4. Write a hypothesis attempting to explain the pattern you observed.

____

5. Using a red crayon, plot the locations of each volcano from the Volcano Table on the map.

6. Is an observable pattern forming? Describe the pattern.

____

7. What percentage of the volcanoes plotted fit your pattern?

____

8. Write a hypothesis attempting to explain the pattern you observed.

____

9. When complete, obtain the Plate Tectonic Overhead. Are these boundaries similar to the patterns you identified? Why or why not? What is the true cause of the patterns?

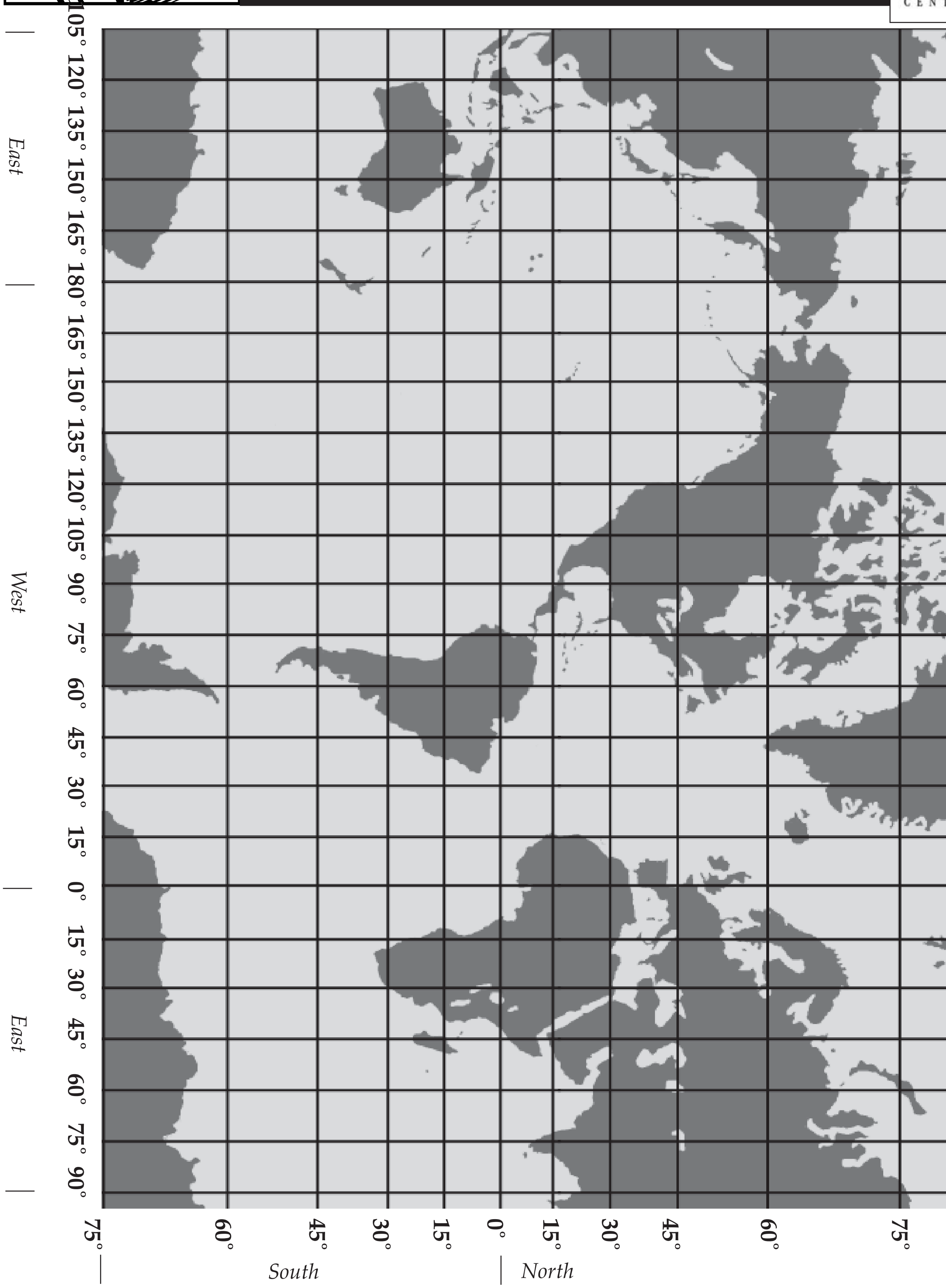
____

10. What is the true cause of the patterns? Hint: Did Earth's continents always look the same?

____

STUDENT WORKSHEET 1 - WE'RE CRACKIN' UP

Name ______________________ Date __________



EARTHQUAKE TABLE

Name **Date** ___________

Date of Earthquake	**Latitude**	**Longitude**
January 19, 1999	5 S	153 E
February 6, 1999	13 S	167 E
March 4, 1999	5 S	122 E
April 5, 1999	6 S	150 E
April 8, 1999	44 N	130 E
May 10, 1999	5 S	151 E
May 16, 1999	5 S	152 E
August 17, 1999	41 N	30 E
September 20, 1999	24 N	121 E
September 30, 1999	16 N	97 W
October 16, 1999	35 N	116 W
November 12, 1999	41 N	31 E
November 15, 1999	1 S	89 E
November 19, 1999	6 S	149 E
November 26, 1999	16 S	168 E
December 6, 1999	57 N	154 W
December 11, 1999	16 N	120 E
January 8, 2000	17 S	174 W
February 25, 2000	20 S	174 E
March 28, 2000	22 N	145 E
April 23, 2000	28 S	63 W
May 4, 2000	1 S	124 E
May 12, 2000	24 S	66 W
August 6, 2000	29 N	140 E
November 16, 2000	4 S	152 E

EARTHQUAKE TABLE

November 16, 2000	5 S	153 E
November 17, 2000	5 S	153 E
December 6, 2000	40 N	55 E
January 1, 2001	7 N	127 E
January 9, 2001	15 S	167 E
January 10, 2001	57N	153 W
January 13, 2001	13 N	89 W
January 26, 2001	23 N	70 E
February 24, 2001	1 N	126 E
June 3, 2001	30 S	179 W
June 23, 2001	16 S	74 W
July 7, 2001	18 S	72 W
August 21, 2001	37 S	180 W
October 12, 2001	13 N	145 E
October 19, 2001	4 S	124 E
December 12, 2001	43 S	125 E
January 2, 2002	18 S	168 E
March 3, 2002	37 N	70 E
March 5, 2002	6 N	124 E
March 31, 2002	24 N	122 E
April 26, 2002	13 N	145 E
June 28, 2002	44 N	131 E
August 19, 2002	22 S	180 W
September 8, 2002	3 S	143 E
October 10, 2002	2 S	134 E
November 3, 2002	64 N	147 W

VOLCANO TABLE

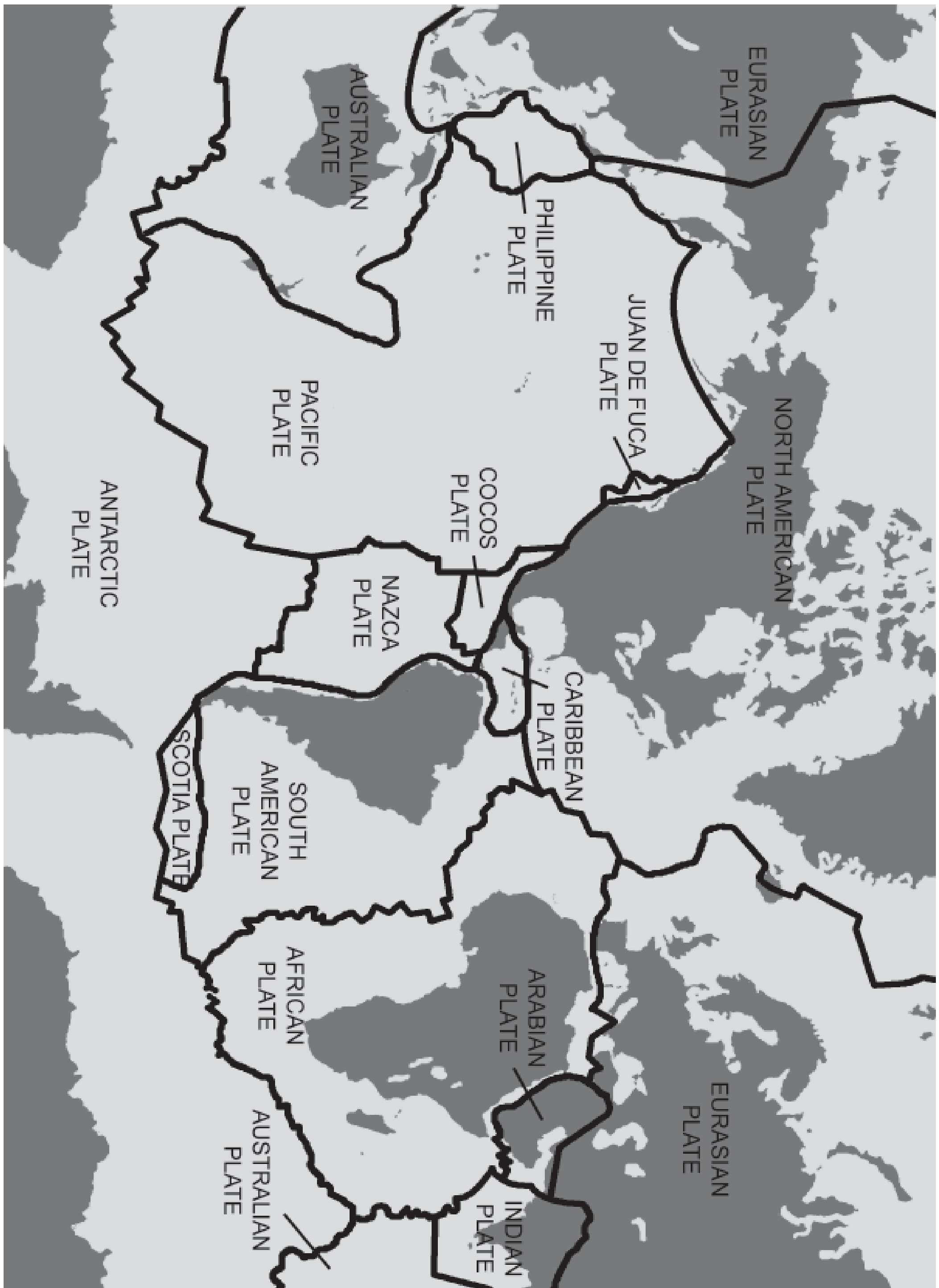
Name ______________________________ Date __________

Date of Volcanic Eruption	Latitude	Longitude
November 11, 2002	7 S	108 E
November 6, 2002	19 N	99 W
November 4, 2002	4 S	152 E
November 3, 2002	0 S	79 W
November 3, 2002	0 S	78 W
October 31, 2002	54 N	159 E
October 31, 2002	4 S	145 E
July 12, 2002	1 S	78 W
July 11, 2002	6 S	149 E
July 9, 2002	55 N	161 E
April 30, 2002	8 S	113 E
April 14, 2002	1 N	125 E
April 2, 2002	34 N	140 E
March 25, 2002	20 N	104 W
March 3, 2002	8 S	110 E
February 27, 2002	56 N	161 E
February 12, 2002	15 N	91 W
January 16, 2002	21 S	56 E
January 13, 2002	10 S	158 E
January 5, 2002	17 N	62 W
July 26, 2001	13 N	124 E
May 10, 2001	13 N	87 W
May 8, 2001	44 N	122 W
April 23, 2001	12 N	86 W

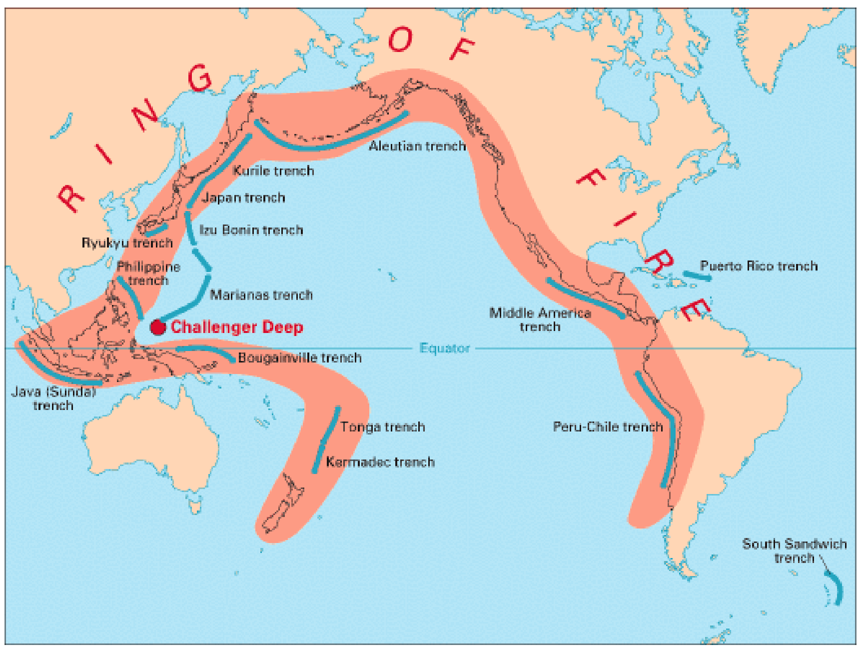
VOLCANO TABLE

April 4, 2001	11 N	85 E
March 20, 2001	52 N	170 W
February 21, 2001	14 N	91 W
February 5, 2001	8 S	114 E
November 8, 2000	42 N	141 E
October 9, 2000	32 N	131 E
August 16, 2000	38 N	140 E
July 20, 2000	23 S	67 W
July 16, 2000	38 S	71 W
March 15, 2000	56 N	161 E
February 26, 2000	64 N	20 W
September 30, 1999	14 N	121 E
September 13, 1999	39 S	176 E
August 26, 1999	30 N	130 E
August 6, 1999	13 N	87 W
July 1, 1999	9 S	123 E
December 18, 1998	64 N	17 W
August 23, 1998	39 N	15 E
August 21, 1998	38 S	177 E
August 18, 1998	38 N	15 E
August 16, 1998	19 N	99 W
July 20, 1998	8 S	110 E
July 10, 1998	40 N	141 E
July 3, 1998	17 N	62 W
July 1, 1998	7 S	108 E
July 1, 1998	46 N	122 W

PLATE BOUNDARY OVERHEAD



RING OF FIRE OVERHEAD



STUDENT WORKSHEET 2 - VOLCANIC GASES

Name ______________________________ Date ____________

Problem: How do volcanic gases affect living things?

Step 1 - Research
Your first task is to research the emissions from volcanoes. Use reference materials such as reference books, CDs, and the internet.

1. Based on your research, what are the most common "volcanic" gases?

____

____

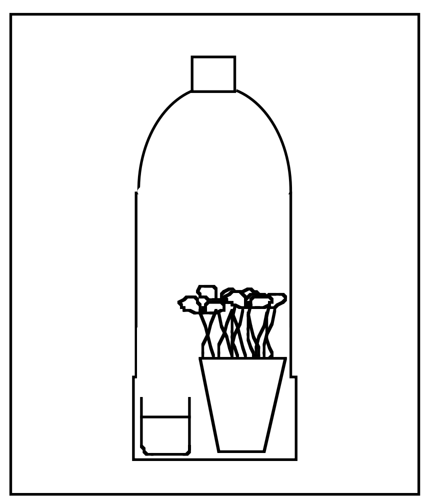
Step 2 - Hypothesize

2. How do you believe volcanic gases will affect living things? (Be specific.)

____

____

Step 3 - Design your experiment in the space below.



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STUDENT WORKSHEET 2 - VOLCANIC GASES

Design a table for your experimental data in the space below.

Analysis

1. What effect did carbon dioxide have on your plants?

____

____

2. What effect did the sulfur dioxide have on your plants?

____

____

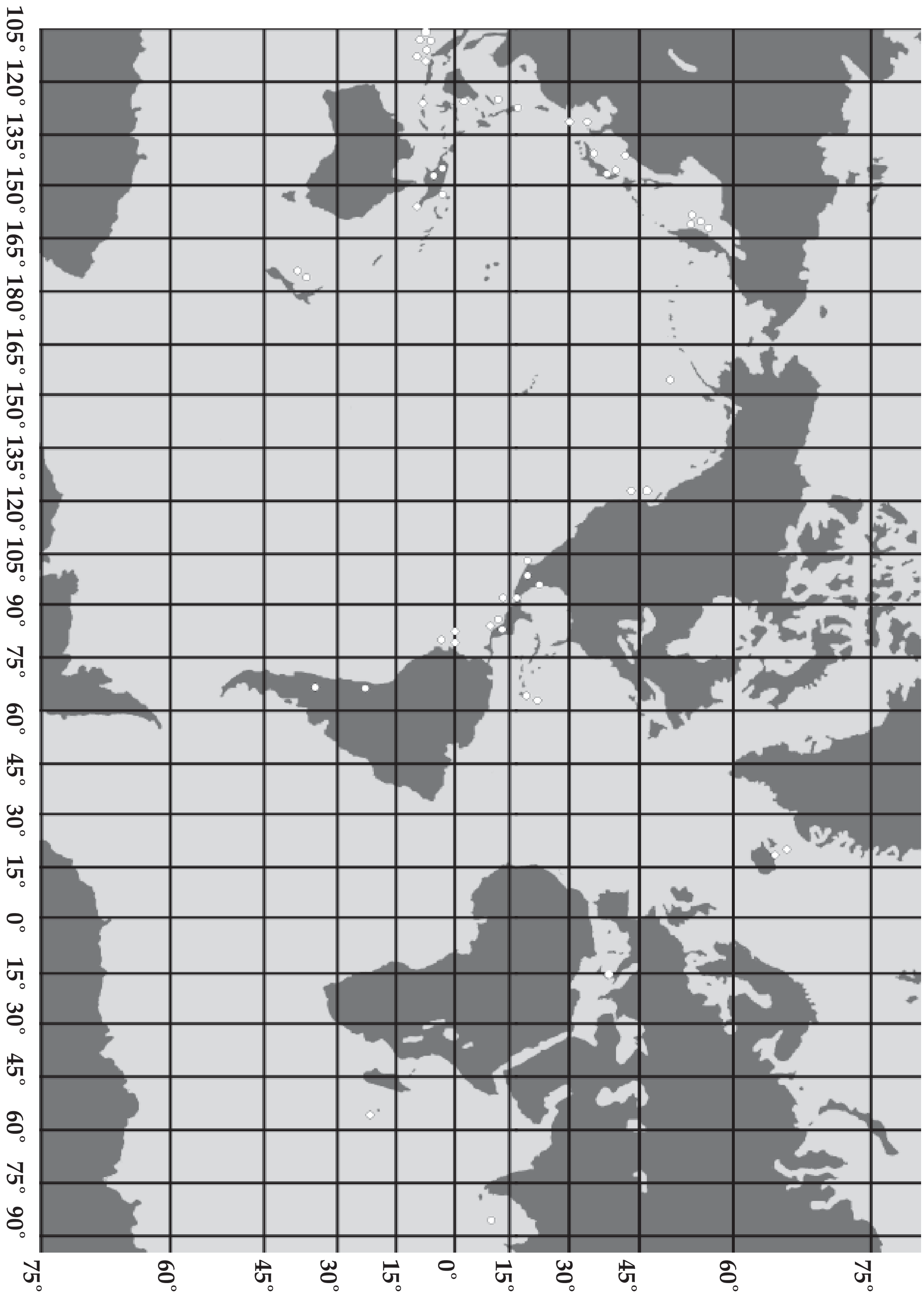
3. Was your hypothesis correct? Explain why or why not.

____

____

Answer Key:
Activity 1 - Earthquakes

Answer Key:
Activity Two - Volcanoes



Answer Key

Activity 1 - We're Crackin' Up

1. Locations plotted on map.

2. The majority of earthquakes appear to occur where land meets the Pacific Ocean.

3. 82% of the earthquakes plotted fit in this pattern.

4. Answers will vary. Students may suggest that it is related to the convergence of the land and ocean.

6. The majority of volcanoes also appear to occur where land meets the Pacific Ocean.

7. 86% of the volcanoes plotted fit in this pattern.

8. Answers will vary. Students may suggest that they are related to earthquakes or that it has something to do with the land converging with the oceans.

9. Yes, the plate boundaries are very similar to the earthquake and volcano patterns. The majority of earthquakes and volcanoes run right along the plate boundaries.

10. The true cause of the earthquakes and volcanoes is movement along the plate boundaries. Earth's continents are continually moving, they have not always looked the same. Tension and stress builds up along these boundaries and is released through earthquakes and volcanoes.

Answer Key

Activity 2 - Volcanic Gases

1. Carbon dioxide and sulfur dioxide are common volcanic gases.

2. Answers will vary. Students should predict that the sulfur dioxide would be harmful in some way to all living organisms. Some students may say that the carbon dioxide is only harmful to animals since plants require it for photosynthesis.

Design your experiment . . .
Answers will vary. Students should indicate three different bottles: a control with normal air, a bottle with carbon dioxide, and bottle with sulfur dioxide. The plan should indicate that the bottles are sealed. Students should also indicate that they will monitor these plants for at least three days. Students should identify what type of data they will be collecting (example leaf color, growth in cm, etc).

Analysis
1. There will be no dramatic effects.

2. The leaves on the plants will turn yellow and the plants will die.

3. Answers will vary. Students must refer to their hypothesis.

Challenger Center Programs

The internationally acclaimed **Challenger Learning Center** Network currently consists of state-of-the-art, innovative educational simulators located at 49 sites across 29 states, Canada, and the United Kingdom. Staffed by master teachers, the core of each Center is a two-room simulator consisting of a space station, complete with communications, medical, life, and computer science equipment, and a mission control room patterned after NASA's Johnson Space Center. See *www.challenger.org* for information.

A joint initiative of Challenger Center for Space Science Education, the Smithsonian Institution, and NASA, ***Voyage — A Journey through our Solar System*** is a space science exhibition project that includes permanent placement of a scale model solar system on the National Mall in Washington, DC, and at locations all over the world. See *www.voyageonline.org* for information.

Space DaySM launches new *Design Challenges* created by Challenger Center each school year. The inquiry-based challenges are designed to inspire students in grades 4-8 to create innovative solutions that could aid future exploration of our solar system. See *www.spaceday.org* for information.

Challenger Center's ***Journey through the Universe*** program provides under-served communities with diverse national resources, including K-12 curriculum materials, teacher workshops, classroom visits by scientists from all over the country, and Family Science Nights. See *www.challenger.org/journey* for information.

The **MESSENGER** spacecraft (MErcury Surface, Space ENvironment, GEochemistry and Ranging) is to be launched in 2004 and go into Mercurian orbit in 2009. Challenger Center is one of the partner organizations charged with MESSENGER education and public outreach activities. See *www.messenger.jhuapl.edu* for information.

Through the Challenger Center **Speakers Bureau, Voyages Across the Universe**, staff members speak to student audiences of 30-1,000, conduct workshops for 100-300 educators, give keynote and featured presentations at conferences, as well as conduct Family Science Nights at the National Air and Space Museum, and other facilities across the nation, for audiences of 300-1,000 parents, students, and teachers. See *www.challenger.org/speakers* for information.

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