Geology: Just Touching the Surface

Grade Level: 4th Grade
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Length of Unit: Eleven Lessons - Approximately 18 Days

I. ABSTRACT

In this unit, students will explore patterns of change in the earth's layers through hands-on experiments and activities, as well as case studies of geologic phenomena. Students will learn about volcano types, volcanic activity, and plate movement and its effects. Students will be exposed to the plate tectonic theory and its implications on geologic history. They will observe the effects of geologic activity on human life based through case studies. Students will also gain new perspective on the decisions humans make in their choice of location. Throughout the unit, students will examine models of the earth as well as models of geologic phenomena. They will observe how the models represent real-world situations, and will also identify limitations of each model.

The unit will conclude with a performance task that, upon giving students scientific data (seismic readings, temperature readings, and pictures of the landmark), asks them to identify the geologic landmark of a hypothetical area. By using their knowledge in a practical way, students will enjoy a memorable and intellectually rewarding activity

II. OVERVIEW

A. Concept Objectives
   1. Students will know that change can create recognizable patterns (TEKS 4.6).
   2. Students will know that certain past events affect present and future events (TEKS 4.10).
   3. Students will understand the plate tectonic theory and how it explains geologic phenomena.
   4. Students will know how layers of the earth interact with each other in a way that supports the law of matter.
   5. Students will understand that humans are affected by changes on the earth's surface, in both positive and negative ways.

B. Content from the *Core Knowledge Sequence*
   1. The Earth's crust; mantle; core (105)
   2. Movement of crustal plates (105)
   3. Earthquakes (105)
   4. Volcanoes (105)
   5. Hot springs and geysers (105)
   6. Theories of how the continents and oceans were formed; Pangaea and continental drift (105)
   7. Volcanic mountains; folded mountains; fault-block mountains; dome-shaped mountains (105)
   8. Know how to gather information from different sources, and write short reports presenting the information in his or her own words (87)

C. Skill Objectives
   1. Students will identify patterns of change (TEKS 4.6A).
   2. Students will identify and observe effects of events that require time for changes to be noticeable (TEKS 4.10A).
   3. Students will analyze, review, and critique scientific explanations, including hypotheses and theories, as to their strengths and weaknesses using scientific evidence and information (TEKS 4.3A).

4. Students will represent the natural world using models and identify their limitations (TEKS 4.3C).
5. Students will evaluate the impact of research on scientific thought, society, and the environment (TEKS 4.3D).
6. Students will analyze and interpret information to construct reasonable explanations from direct and indirect evidence (TEKS 4.2C).
7. Students will communicate valid conclusions (TEKS 4.2D).
8. Students will construct simple graphs, tables, maps, and charts to organize, examine, and evaluate information (TEKS 4.2E).

III. BACKGROUND KNOWLEDGE

A. For Teachers
   1. *What Your 4th Grader Needs to Know* edited by E.D. Hirsch
   2. *Core Knowledge Sequence*
   3. *Volcanoes: Crucibles of Change* by Richard V. Fisher, Grant Heiken, & Jeffrey B. Hulen

B. For Students
   1. Grade 1 - Science - What's Inside the Earth
   2. Grade 3 - Geography - Spatial Sense

IV. RESOURCES (Provide a list of key resources-literature selections, activity books, AV materials, etc.-that are critical in teaching this unit.)

A. "In the Path of a Killer Volcano". Documentary Guild, Nova. Boston: WGBH Boston Video, 1993, ISBN 1578070392

B. "Volcanoes: Fire from Within". Earth Science Series. Lucerne Films, 2001, LM0214-EN-VID. Available on http://www.digitalcurriculum.com.

V. LESSONS (Each day's lesson is designed to be approximately 45 minutes in length.)

Lesson One: The Mystery of Lake Nyos - An Introduction to Geology

A. *Daily Objectives*
   1. Concept Objective
      a. Students will understand that humans are affected by changes on the earth's surface, in both positive and negative ways.
   2. Lesson Content
      a. Volcanoes
   3. Skill Objective
      a. Students will analyze and interpret information to construct reasonable explanations from direct and indirect evidence.

B. *Materials*
   1. Appendix A - Lake Nyos Reading - one copy per student
   2. KWL chart

C. *Key Vocabulary*
   1. geology - the study of the earth and its layers

D. *Procedures/Activities*
   1. Pass out Lake Nyos Reading (Appendix A) to the students. Read the passage aloud, while students follow along.
   2. Upon completion, have students discuss what they think happened to the village of Nyos. Students may discuss in pairs, groups, or as a class. Continue

discussion for about 10 minutes. Ask students if anything could have been done to prevent this village's mysterious death.

3. Continue the discussion by suggesting (if students haven't) that the case of Lake Nyos has to do with volcanoes. Ask: "Why should we learn about volcanoes? How do we learn about volcanoes?"
4. Introduce the following essential questions of the unit:
   How and why does the earth change?
   Why is it important for us to know?
   How do we know what the earth was like in the past?
   How do we predict what it will be like in the future?
5. Present KWL chart to the class. Complete parts K and W, and continue to add to the chart as the unit progresses. Make sure the chart is placed prominently in the classroom.

E. *Assessment/Evaluation*

1. Have students journal about today's lesson. Students may select from one of the following prompts, writing a page as a reflection on today's introduction.
   I wonder…
   I predict…
   I hope…
   It surprised me to learn that…
   I want to learn…
2. The journaling activity may be completed as a homework assignment. Have students turn in their reflections for a daily participation grade.

Lesson Two: Mt. Pinatubo Case Study

A. *Daily Objectives*

1. Concept Objectives
   a. Students will understand that humans are affected by changes on the earth's surface, in both positive and negative ways.
   b. Students will know that change can create recognizable patterns.
   c. Students will know that certain past events affect present and future events.
2. Lesson Content
   a. Volcanoes
3. Skill Objective
   a. Students will identify and observe effects of events that require time for changes to be noticeable.

B. *Materials*

1. Appendix B - Mt. Pinatubo Case Study - one copy per student
2. "In the Path of a Killer Volcano" video

C. *Key Vocabulary*

1. dome volcano - a volcano made when magma comes out of the earth slowly, making a dome out of lava.
2. composite volcano - a steep volcanic cone that is made from lava and volcanic eruptions.
3. shield volcano - a gently sloping volcano that looks like a flattened dome and is made out of lava flows.

D. *Procedures/Activities*

1. Introduce Mt. Pinatubo eruption of 1991. Tell students they will learn abou the Mt. Pinatubo eruption of Spring 1991 in the Philippines. Show the Philippines

on a map. Explain that much of the land is used for farming, and that many of its citizens (Filipinos) are poor. The United States had two military bases near Mt. Pinatubo in 1991 (Subic Bay Naval Base, 25 mi. from volcano, and Clark AFB, 10 mi. from volcano). The 10 million people of the Philippines were affected by the eruption.

2. Tell the students that they will see video clips of Mt. Pinatubo in 3 parts: before, during, and after the volcanic explosion. In the first part, they should pay close attention to the events that helped scientists predict that there would be an eruption.
3. Pass out Appendix B to all students. Inform them that they will be completing the worksheet during and after the video clips.
4. Show "In the Path of a Killer Volcano", before-eruption footage. (Start at 4:40, Stop at 13:15.) Stop to explain that scientists were concerned about making the wrong predictions. If they kept predicting a greater explosion and nothing happened, people would be angry at them for having to evacuate. But worse, if they predicted that the volcano would not explode and it did, millions of people might have died.
5. Show during-eruption footage. (Start at 32:00, Stop at 40:24.) Stop to explain that when scientists realized that the cinder-block walls of their scientific station at the military base would not protect them from the hot ash and lava of the exploding Mt. Pinatubo, they fled farther away to safety. Even though volcanologists want to learn all they can about the earth's changes, they will be able to help us more in the future if they survive their investigations!
6. Show after-eruption footage. (Start at 45:00, Stop at 49:00.) If time allows, show mud flow clips (Start 50:00, Stop 52:08.) Explain other effects of the Mt. Pinatubo eruption. Mud flows continued to destroy farmland and left many Filipinos homeless for months. The U.S. military withdrew from the Philippines since their bases were destroyed. A crater and lake now lie where the 1991 eruption occurred on Mt. Pinatubo.
7. Students are given time (~10 minutes max.) to finish Appendix B worksheet.

E. *Assessment/Evaluation*

1. Use the worksheet to assess students' understanding of the Mt. Pinatubo eruption and its effects on the earth.

Lesson Three: Types of Volcanoes and Eruptions

A. *Daily Objectives*

1. Concept Objectives
   a. Students will know that change can create recognizable patterns.
   b. Students will know that certain past events affect present and future events.
   c. Students will understand that layers of the earth interact with each other in a way that supports the law of matter.
2. Lesson Content
   a. Volcanoes
3. Skill Objective
   a. Students will identify and observe effects of events that require time for changes to be noticeable.
   b. Students will identify patterns of change.

B. *Materials*

1. Appendix C - Types of Volcanoes and Volcanic Explosions - one copy per student
2. "Volcanoes: Fire from Within" video

C. *Key Vocabulary*
   1. magma - melted rock underneath the earth's surface.
   2. ash - tiny particles of blasted rock.
   3. lava - magma that has reached the surface of the earth.
   4. lava flow - when lava pours out onto the earth from a crack or vent.
   5. igneous rock - rock that is created from volcanic eruptions (lava)
   6. metamorphic rock - rock that is made of either igneous or sedimentary rock, but has been changed by other forces in the earth.

D. *Procedures/Activities*
   1. Review what students know about volcanoes. Revisit the KWL chart to refresh students' prior knowledge. Ask students if all volcanoes are alike. Are some volcanoes different than others?
   2. Tell students that today, they will be viewing a video that explains how there are many different types of volcanoes.
   3. Pass out Appendix C, "Types of Volcanoes and Volcanic Explosions". Inform students that they will be completing the worksheet during and after the video.
   4. Students watch video as they complete the worksheet. Stop at 9:47-10:00 to discuss volcano types and their distinguishing characteristics. Throughout the volcanic explosions portion, pause at each explosion drawing so students can quickly sketch each. (Strombolian, Plinian, Glowing Cloud, and Paroxysmal.)
   5. Allow extra time (~10-15 minutes) for students to complete their study sheets.
   6. With any additional time in the period, review volcano types and explosions, with the use of charts. Answer students' questions, revisit the KWL chart, and informally assess for students' understanding.

E. *Assessment/Evaluation*
   1. Use the Appendix C worksheet to assess students' understanding of volcano types and explosions.

Lesson Four: The Story of a Volcano

A. *Daily Objectives*
   1. Concept Objectives
      a. Students will know that change can create recognizable patterns.
      b. Students will know that certain past events affect present and future events.
      c. Students will understand that layers of the earth interact with each other in a way that supports the law of matter.
   2. Lesson Content
      a. Volcanoes
   3. Skill Objectives
      a. Students will identify patterns of change.
      b. Students will identify and observe effects of events that require time for changes to be noticeable.
      c. Students will construct simple graphs, tables, maps, and charts to organize, examine, and evaluate information.

B. *Materials*
   1. Appendix D - The Volcano - one copy for each student
   2. White sheet of blank paper - one for each student

C. *Key Vocabulary*
   1. conduit - a passage for magma to go through in a volcano.
   2. crater - a circular hole or depression formed by a volcanic explosion or collapse.
   3. fissure - a crack on the slope of a volcano.

4. extinct - a word to describe volcanoes that haven't erupted in a very long time and probably won't again.

D. *Procedures/Activities*

1. Introduce the lesson by explaining to students that they will be learning about the life of a volcano.
2. Pass out a blank sheet of white paper to each student. Students will fold their paper into 6 sections.
3. Write the following steps and draw a visual for each step in the life of a volcano:
    1. Magma rises to the surface from under the earth.
    2. Magma goes up the conduit due to pressure from heat.
    3. Magma, hot air, and gas burst out of the Earth's crust and create an area called a crater and a cone top.
    4. Magma outside the Earth is called lava. It flows on the land. Lava cools and hardens as igneous rock.
    5. The side of the volcano cracks -air, magma come out to form fissures.
    6. Eventually, the lava outside the Earth and magma within the Earth harden. The volcano becomes extinct.
4. Students create the story on their own sheets. Students use teacher's examples as they create their own visuals, and may color their visuals if time allows.
5. Pass out Appendix D (The Volcano) to each student. Students use their story of a volcano to complete the Volcano worksheet.

E. *Assessment/Evaluation*

1. Use the Appendix D worksheet to assess students' understanding of a volcano, its parts and process.

Lesson Five: The Positive and Negative Effects of Volcanoes (possibly two days)

A. *Daily Objectives*

1. Concept Objectives
    a. Students will know that change can create recognizable patterns.
    b. Students will know that certain past events affect present and future events.
    c. Students will understand that layers of the earth interact with each other in a way that supports the law of matter.
    d. Students will know that humans are affected by changes on the earth's surface, in both positive and negative ways.
2. Lesson Content
    a. Volcanoes
    b. Hot springs and geysers
3. Skill Objectives
    a. Students will identify patterns of change.
    b. Students will identify and observe effects of events that require time for changes to be noticeable.
    c. Students will construct simple graphs, tables, maps, and charts to organize, examine, and evaluate information.
    d. Students will communicate valid conclusions.

B. *Materials*

1. Appendix E - "What's Inside a Volcano?" Song - one copy for each student
2. Unopened soda bottle
3. Chart paper for T-Chart
4. Blank paper (or card stock) for poster advertisement

C. *Key Vocabulary*

1. geyser - a spring that shoots up hot water and steam from inside the earth.

2. hot spring - a spring that has warm water.
3. fertile - having things needed to make plants grow.

D. *Procedures/Activities*

1. Introduce today's lesson by passing out Appendix E, "What's Inside a Volcano?" song, to review the parts and process of a volcano.
2. Introduce the concept of geysers and hot springs. Use the unopened soda bottle to demonstrate how geysers and hot springs work. Over a bucket or receptacle to catch any liquid, shake the bottle so that it will fizz out when opened. Open the bottle and tell the students that, like the bottle, geysers and hot springs erupt gases and water. Unlike the bottle, heat creates the pressure to cause the liquid to rise.
3. Explain the effects of geysers and hot springs: fertile soil, energy, tourism, etc.
4. Using chart paper, create a T-chart for the class discussion on positive and negative effects of volcanoes. Guide students as they offer contributions. Positive effects may include: loamy soil, fertile land for growing crops, help for scientists to learn about the inside of the Earth, help to preserve history (ash-covered towns like Pompeii), tourism, energy. Negative effects may include: disasters, home destruction, death of people and plants.
5. Introduce poster advertisement activity. Students will create a poster advertisement, both promoting visits to a volcanic landmark and warning tourists to the possible negative effects. Students will choose either a volcano, geyser, or hot spring for their landmark to advertise. Students might want to create this poster from the point of view of a government agency, chamber of commerce, or tourist agency.
6. Students should create a sketch and plan before they receive their poster materials. End product should be colored and neat.
7. Poster advertisements might take an extra class period to complete. Assignment can be made optional as homework, or can be completed entirely in class.

E. *Assessment/Evaluation*

1. Informally assess understanding of positive and negative effects during class discussion. During students' work time, informally assess students' understanding. Evaluate the posters upon completion.

Lesson Six: Layers of the Earth and Quiz (allow two days)

A. *Daily Objectives*

1. Concept Objective
   a. Students will understand that layers of the earth interact with each other in a way that supports the law of matter.
2. Lesson Content
   a. The Earth's crust; mantle; core
3. Skill Objectives
   a. Students will construct simple graphs, tables, maps, and charts to organize, examine, and evaluate information.
   b. Students will analyze, review, and critique scientific explanations as to their strengths and weaknesses using scientific evidence and information.
   c. Students will represent the natural world using models and identify their limitations.
   d. Students will analyze and interpret information to construct reasonable explanations from direct and indirect evidence.

B. *Materials*

1. Plums (one for each pair of students) - can also be substituted with peaches
2. Toothpicks (approx. 4 for every plum)

3. File folder labels (or strips of paper) - approx. 4 for every plum
4. Knives (one for each pair of students)
5. Appendix F - Earth's Layers - one copy for each student
6. Appendix G - Volcanoes and Layers of the Earth Quiz

C. *Key Vocabulary*

1. mantle - the layer of the earth below the crust and above the core
2. crust - the top layer of the earth, or the surface.
3. inner core - the center layer of the earth.
4. outer core - the layer underneath the mantle, above the inner core.
5. limitations - shortcomings or differences.

D. *Procedures/Activities*

1. Introduce the lesson by teaching that scientists look inside the earth to explain what happens on the surface. Because of measurements and patterns, scientists are pretty sure about what the inside of the earth is like.
2. Pass out a copy of Appendix F to each student. Complete the diagram as a class, discussing the Earth's layers and introducing them one by one. Introduce the idea of limitations - how is the picture not like Earth? Why can't it be exactly the same?
3. Pass out model materials: plums, knives, toothpicks, and labels. Instruct students to dissect the plum, creating a cross-section model of the earth's layers. Students will use toothpicks and labels to mark each layer of the earth, as it is modeled on the plum.
4. Students present their Earth's layers cross-sections to the rest of the class and explain why they cut their plum the way they did. Students should also explain the similarities and limitations of their plum models.

E. *Assessment/Evaluation*

1. Informally assess students' understanding of layers through the plums and presentations.
2. Use Appendix G (Quiz) to evaluate students' understanding of volcanoes and earth layers. Quiz should take up one complete class period.

Lesson Seven: Plate Movement

A. *Daily Objectives*

1. Concept Objectives
   a. Students will know that change can create recognizable patterns.
   b. Students will know that certain past events affect present and future events.
   c. Students will know that humans are affected by changes on the earth's surface, in both positive and negative ways.
2. Lesson Content
   a. Movement of crustal plates
3. Skill Objectives
   a. Students will identify patterns of change.
   b. Students will identify and observe effects of events that require time for changes to be noticeable.
   c. Students will represent the natural world using models and identify their limitations.
   d. Students will construct simple graphs, tables, maps, and charts to organize, examine, and evaluate information.

B. *Materials*

1. Appendix H - Plate Movement Slide Show - teacher use

2. Appendix I - Plate Movement Chart - one copy for each student
3. 1 package of graham crackers
4. 1 square of aluminum foil
5. 1 piece of Styrofoam
6. 1 bowl of water
7. 1 cup of peanut butter

C. *Key Vocabulary*

1. convergent boundary - a fault where two plates push together.
2. divergent boundary -a fault where two plates spread apart.
3. transform boundary - a fault where two plates rub in opposite directions.
4. subduction - an action that occurs at a convergent boundary where one plate goes underneath another plate.
5. fault - a crack in the earth's surface where two plates come together.

D. *Procedures/Activities*

1. If an LCD projector is available, use a computer to show the slide show. If not, print out the slide show images onto transparencies and show on an overhead projector.
2. Introduce lesson by reviewing layers of the earth. Introduce the idea that these layers are not always still. Humans on the earth have observed the crust's movement for years. Today students will learn about ways in which the crust moves. Introduce faults to students.
3. Pass out Appendix I, Plate Movement Chart, to each student. Show the slide show to students, monitoring their progress as they complete the chart. During the slide show, present each type of plate movement, along with an example, its effects, and the direction in which the plates involved move.
4. After students have finished chart, perform graham cracker demonstration. During each demonstration, students should use hand movements to reinforce visual cues they are receiving from the demonstrations. Convergent boundary hand motions can have hands coming together; transform boundaries can have hands rubbing together; divergent boundaries can have hands spreading apart. Use graham crackers to demonstrate different plate movements, as follows below:
5. To present subduction, use a graham cracker square, a piece of Styrofoam, and a square of aluminum foil. Lay the graham cracker and the piece of Styrofoam end to end on the foil. (In this case, the Styrofoam is an oceanic plate, and the cracker is a continental plate.) Push the pieces together. Explain that, just as the cracker rises up above the Styrofoam, continental plates rise up above oceanic plates in subduction.
6. To present convergent boundaries, use two graham cracker squares. Dip the ends of both crackers into a bowl of water. Put the crackers on the foil, with the damp ends almost touching. Push the crackers together. Explain that, just as the ends of the crackers go up when they come together, mountains are created when plates are pushed together in a convergent boundary.
7. To present transform boundaries, break a piece of graham cracker into two squares. Put them back together side by side. Push the pieces in opposite directions. Explain that, just as the crackers slide past each other and create a lot of friction, plates that rub together in the same way are very destructive. This is an example of a transform boundary.
8. To present divergent boundaries, spread peanut butter on the aluminum foil piece. Lay two graham crackers adjacent to each other on the peanut butter. Push down on the crackers and move the crackers away from each other.

Explain that, just as the peanut butter in the middle rose as the crackers moved, new earth (or magma) rises between plates when they spread apart. This is an example of a divergent boundary, and can be seen in the Mid-Atlantic Ocean.

9. Encourage students to share this demonstration with their families at home. Follow up demonstration by revisiting KWL chart and filling more of it in.

E. *Assessment/Evaluation*

1. Informally assess students' understanding as they fill out the chart during slide show.
2. Check for understanding through asking class for hand movements for each type of plate movement.

Lesson Eight: Loma Prieta Case Study

A. *Daily Objectives*

1. Concept Objectives
   a. Students will know that certain past events affect present and future events.
   b. Students will know how layers of the earth interact with each other in a way that supports the law of matter.
   c. Students will understand that humans are affected by changes on the earth's surface, in both positive and negative ways.
2. Lesson Content
   a. Earthquakes
3. Skill Objectives
   a. Students will identify and observe effects of events that require time for changes to be noticeable.
   b. Students will represent the natural world using models and identify their limitations.
   c. Students will evaluate the impact of research on scientific thought, society, and the environment.
   d. Students will analyze and interpret information to construct reasonable explanations from direct and indirect evidence.
   e. Students will construct simple graphs, tables, maps, and charts to organize, examine, and evaluate information.

B. *Materials*

1. Appendix J - A Major Road Block - one copy for each student
2. Jar with a lid - one for each group of about 4 students
3. Wide-point pen or marker - one for each group
4. Rubber band - one for each group
5. Masking tape
6. Scissors - teacher use
7. Strip paper or strips of wax paper - ~1 ft. for each group

C. *Key Vocabulary*

1. seismograph - an instrument that measures vibrations in the earth's layers.
2. Richter Scale - a way of measuring the intensity of earth's vibrations.
3. intensity - strength of force.

D. *Procedures/Activities*

1. Pass out Appendix J sheet to each student. Read aloud Loma Prieta case study with the class. Have students discuss the questions at the end of the case study. After discussion, prompt students to further thought by asking, "How do people know what happened at Loma Prieta? How do people predict earthquakes?"
2. Perform a demonstration of a flat-line seismic reading. Fill a jar with water and put the lid back on. Put a 12-inch strip of paper on a table or desk, and put the jar

on one side of the paper. Using a rubber band, attach a marker or pen to the jar so that the tip touches the paper. Tape the marker or pen to the jar for additional support. Hold the free end of the paper, pushing it close to the jar. Then quickly pull the paper straight out from under the jar.

3. Explain how this demonstration is like a seismograph. Pass out materials to students and have groups perform the demonstration.
4. Discuss the Richter Scale and the effects of varying intensities of seismic readings. Draw varying intensities of seismic readings for students to see. Students can copy examples of varying intensities on their strip papers.
5. Wrap up lesson by tying seismic readings back to Loma Prieta case study. Revisit KWL chart and add to it accordingly.

E. *Assessment/Evaluation*

1. Informally assess student understanding through questioning and observations of students' strip papers.

Lesson Nine: Mountain Formations

Note: *At any time from this lesson through the rest of the unit, it is recommended that students be exposed to either a field trip to a local geologic landmark, or that a speaker from the community present information on geology. Local university professors are excellent resources and can offer highly engaging class visits. Enrichment opportunities can either be used during the unit, or as a culminating activity.*

A. *Daily Objectives*

1. Concept Objectives
   a. Students will know that change can create recognizable patterns.
   b. Students will know that certain past events affect present and future events.
   c. Students will know how layers of the earth interact with each other in a way that supports the law of matter.
2. Lesson Content
   a. Movement of crustal plates
   b. Volcanic mountains; folded mountains; fault-block mountains; dome-shaped mountains
3. Skill Objectives
   a. Students will identify patterns of change.
   b. Students will identify and observe effects of events that require time for changes to be noticeable.
   c. Students will represent the natural world using models and identify their limitations.
   d. Students will analyze and interpret information to construct reasonable explanations from direct and indirect evidence.
   e. Students will communicate valid conclusions.

B. *Materials*

1. One piece of cloth - teacher use
2. Appendix K - Mountain Slide Show - teacher use
3. Appendix L - Mountain Assessment - one copy per student

C. *Key Vocabulary*

1. folded mountain - a mountain made from two plates colliding, where the plates both bend upward.
2. fault-block mountain - a mountain made from two plates colliding, but the plates are too strong to bend, so they break upward.

3. dome-shaped mountain - a mountain made from magma and heat beneath the earth's surface causing the top layer of crust to rise in a dome-shape.

D. *Procedures/Activities*

1. Review previous lesson, asking students to recall vocabulary: fault, boundaries, seismograph, Richter scale, etc. Go over the concept of plate movement and its effects.
2. Introduce lesson through asking students, "How do you think mountains are made? Where do they come from?" Students should come up with several various hypotheses. Encourage a variety of answers.
3. Present the vocabulary of the lesson. Inform students that there are four major types of mountains: volcanic mountains, folded mountains, fault-block mountains, and dome-shaped mountains. Students should be familiar with the concept of volcanic mountains.
4. Use cloth to introduce the idea of folded mountains. Push ends of the cloth together. Just as the cloth folds more and more as they are pushed together, so do some plates. Give the Appalachian Mountains as an example. Ask students to identify the type of plate movement that causes folded mountains.
5. Introduce fault-block mountains by asking students to recall the graham cracker demonstration. Just like folded mountains, fault-block mountains occur on convergent boundaries. The difference is the strength (hardness) of the plates. An example of fault-block mountains is the Tetons in Wyoming.
6. Introduce dome-shaped mountains by discussing how magma can create pools underneath the surface of the earth, pushing rock layers up and creating a dome. An example of dome-shaped mountains is the Black Hills in South Dakota.
7. Present the mountain slide show. Prepare students for the slide show by telling them to look for whether they think the pictures show old mountains or new mountains. Students should try to identify the type of mountain in the picture. As the pictures are shown, ask students to show a thumbs up if they think it is a new mountain, thumbs down for an old mountain.
8. Pass out Appendix L, mountain assessment sheet, for independent practice.
9. With any additional time, continue filling out the KWL chart.

E. *Assessment/Evaluation*

1. Informally assess students' understanding during slide show (thumbs up/thumbs down, oral identification.)
2. Evaluate students' understanding through the mountain assessment sheet.

Lesson Ten: Continental Drift and Quiz (allow two days)

A. *Daily Objectives*

1. Concept Objectives
   a. Students will know that change can create recognizable patterns.
   b. Students will know that certain past events affect present and future events.
   c. Students will understand the plate tectonic theory and how it explains geologic phenomena.
   d. Students will know how layers of the earth interact with each other in a way that supports the law of matter.
2. Lesson Content
   a. Movement of crustal plates
   b. Theories of how the continents and oceans were formed; Pangaea and continental drift
3. Skill Objectives

a. Students will identify patterns of change.
b. Students will identify and observe effects of events that require time for changes to be noticeable.
c. Students will analyze, review, and critique scientific explanations, including hypotheses and theories, as to their strengths and weaknesses using scientific evidence and information.
d. Students will represent the natural world using models and identify their limitations.
e. Students will analyze and interpret information to construct reasonable explanations from direct and indirect evidence.
f. Students will communicate valid conclusions.
g. Students will construct simple graphs, tables, maps, and charts to organize, examine, and evaluate information.

B. *Materials*
1. Copy of a world map - teacher use
2. "Spreading Zones" map (showing earth's plates) - one copy per student
3. Blue construction paper - one per student
4. Appendix M - Earthquakes and Plate Movement Quiz - one copy per student

C. *Key Vocabulary*
1. continental drift - the theory that movement of plates on the earth's surface caused continents to move towards or away from each other.
2. Pangaea - the idea of what the earth's seven continents were when they were all joined together, making one large continent.
3. Plate Tectonic Theory - the theory that the earth's crust is broken into plates, which move. The movement causes continents to move, volcanoes to erupt, and oceans to spread.

D. *Procedures/Activities*
1. Introduce lesson by showing students a map of United States, focusing on California. Mention California's movement along the San Andreas fault (transform boundary). Tell students that the movement is very slow.
2. To illustrate, have students line up along one side of the classroom. Have them take one-inch steps, timed 5 seconds apart. After one minute, have students sit down.
3. Ask students, "How long would it have taken to go all the way across the classroom at that rate?" "How long would it take to walk to your home?"
4. Mention to students that, unlike the demonstration, plates move at a matter of inches (or less) every year. At that rate, it would take thousands of years to move even a short distance. Ask students, "If plates move that slowly, how long do you think it took for the earth to look the way it does today? What do you think it looked like millions of years ago?"
5. Using a cut-out version of world map, fit the continents together to introduce the concept of Pangaea. Return the pieces to the original world map form.
6. Pass out a copy of a "spreading zones" map and blue paper to students. (Spreading zones maps show the plates of the earth's crust, along with their movement directions. Students cut out the zones and move the continents to predict possible movements or changes in the continents due to continental drift.
7. After students have the opportunity to explore possibilities, discuss continental drift's implications as a class. Introduce Plate Tectonic Theory. Ask what that might mean about things that lived millions of years ago.

8. Students share their ideas of possible continental formations of the future. Encourage students to take home their puzzle pieces to share with their families.

E. *Assessment/Evaluation*

1. Informally assess students' understanding of continental drift and the Plate Tectonic Theory through class presentations and students' puzzles.
2. On the second day, administer Appendix M (quiz). Allow entire class period for completion of the assessment.

Lesson Eleven: Wrapping It Up - The Performance Task

A. *Daily Objectives*

1. Concept Objectives
    a. Students will know that change can create recognizable patterns.
    b. Students will know that certain past events affect present and future events.
    c. Students will know how layers of the earth interact with each other in a way that supports the law of matter.
    d. Students will understand that humans are affected by changes on the earth's surface, in both positive and negative ways.
2. Lesson Content
    a. Movement of crustal plates
    b. Earthquakes
    c. Volcanoes
    d. Hot springs and geysers
    e. Volcanic mountains; folded mountains; fault-block mountains; dome-shaped mountains
    f. Know how to gather information from different sources, and write short reports presenting the information in his or her own words.
3. Skill Objectives
    a. Students will identify patterns of change.
    b. Students will identify and observe effects of events that require time for changes to be noticeable.
    c. Students will evaluate the impact of research on scientific thought, society, and the environment.
    d. Students will analyze and interpret information to construct reasonable explanations from direct and indirect evidence.
    e. Students will communicate valid conclusions.
    f. Students will construct simple graphs, tables, maps, and charts to organize, examine, and evaluate information.

B. *Materials*

1. Appendix N - Landform #1 - one copy for every 5th pair in the class
2. Appendix O - Landform #2 - one copy for every 5th pair in the class
3. Appendix P - Landform #3 - one copy for every 5th pair in the class
4. Appendix Q - Landform #4 - one copy for every 5th pair in the class
5. Appendix R - Landform #5 - one copy for every 5th pair in the class
6. Appendix S - Performance Task Teacher Kit - teacher use
7. Blank white paper - one for each pair

C. *Procedures/Activities*

1. Revisit KWL chart and wrap up what students have learned through the unit. Tell students that, now that they have learned so much about geology, they are ready to become geologists.

2. Introduce performance task (See VI, Culminating Activity for background information.) Divide class into pairs for performance task. Show students teacher-created example. Explain expectations, show rubric, and show landform examples.
3. Pass out landform assignments to each pair. There are 5 options, so a variety of landforms will be explored. Each pair will work on just one landform. Teacher should assign landforms to various groups. Allow each group to investigate their landform packet with their partner.
4. Over the next few days, allow students to work on their performance task. On day two, students should be taking notes on their packet, as well as starting a rough draft of their pamphlet/brochure. On day three, students should finish their rough draft. On day four, students should complete their pamphlet final drafts. Presentations should be made on day five to the entire class.

D. *Assessment/Evaluation*
1. Use Appendix S, performance task rubric, to evaluate students' understanding of geology and their comprehension of the unit's objectives.

VI. CULMINATING ACTIVITY

A. Using Appendices N-S, administer the performance task to the class. Students should have approximately one week to work on the performance task with their partners. The scenario for the performance task can be given as follows:
You are a scientist working on a nearby area to investigate its geologic history. This place has an important geologic landmark. You have been given historical observations, seismic readings, relief maps, and pictures of the area. Your task is to determine what the landmark is and to make a prediction about what could happen to the area in the future. You should also explain to the people living near this landmark the benefits and dangers of building and living in this area.
You must present your findings by creating a pamphlet that interprets the seismic readings, explains relief maps and pictures to identify the landform, explains the reason for previous geologic activity and what happened, compares positive and negative effects of the landform, and predicts future geologic activity. As an extension, you may propose plans to ensure public safety. You will show your pamphlet to a small audience of peers and justify your decisions.

B. On the fifth day, have student pairs present their pamphlets to the rest of the class. Additional options for presentation could be to invite parents, other teachers, or guests to listen to the presentations, and split up the class into smaller groups for presentation. Students will be evaluated according to the performance task rubric, which should be introduced along with the performance task.

C. As suggested earlier, any possible guest speakers or field trips can aid in giving students information and experiences that will help to enhance their understanding of geology. These can be done either during the unit or after the performance task.

VII. HANDOUTS/WORKSHEETS

A. Appendix A: Lake Nyos Reading
B. Appendix B: Mt. Pinatubo Case Study
C. Appendix C: Types of Volcanoes and Volcanic Explosions
D. Appendix D: The Volcano
E. Appendix E: "What's Inside a Volcano?" Song
F. Appendix F: Earth's Layers
G. Appendix G: Volcanoes and Layers of the Earth Quiz
H. Appendix H: Plate Movement Slide Show
I. Appendix I: Plate Movement Chart

J. Appendix J: A Major Road Block
K. Appendix K: Mountain Slide Show
L. Appendix L: Mountain Assessment
M. Appendix M: Earthquakes and Plate Movement Quiz
N. Appendix N: Landform #1
O. Appendix O: Landform #2
P. Appendix P: Landform #3
Q. Appendix Q: Landform #4
R. Appendix R: Landform #5
S. Appendix S: Performance Task Teacher Kit

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G. http://topozone.com/map.asp?lat=36.74111&lon=-103.99306 Topographical Maps
H. http://Vulcan.wr.usgs.gov/Volcanoes/NewMexico/Capulin/VisitVolcano/framework.html
I. http://www.nps.gov/cavo/ Mt. Capulin websites
J. http://www.volcano.si.edu/world/volcano.cfm?vnum=0204-01=&VErupt=Y&VSources=Y&VRep=Y&VWeekly=N&volpage=erupt
K. http://www.hrw.com/science/si-science/earth/tectonics/volcano/volcano/region02/Africa_w/Cameroon/var.html
L. http://www.cameroonconsul.com/images/mount.jpg
M. http://www.ucol.mx/volcan/historia_volcan.htm
N. http://volcano.und/nodak.edu/vwdocs/current_volcs/colima/colima.html
O. http://www.geo.wvu.edu/~jtoro/geol101/Outline-2.html
P. http://pirate.shu.edu/~schoenma/mountains.htm
Q. http://sunsite.utk.edu/samba/gifs/gis004hp2.gif
R. http://www.appalachianstudies.org/gallery/album01/Blue_Ridge_Mountains_between_Pisgah_and_Bryson_City_4
S. http://www.deafhoosiers.com/sci/SOARHIGH/lithosphere/EarthLandforms.html
T. http://www.cs/Dartmouth.edu/whites/Washington.html
U. http://Vulcan.wr.usgs.gov/LivingWith/VolcanicPast/Places/volcanic_past_new_hampshire.html
V. http://www.peakbagger.com/peak.aspx?pid=6960
W. http://www.mountwashington.com

Appendix A

A Geological Mystery

It was night time in Cameroon. On August 21, 1986, a farmer named Hadari was sleeping with his family in their home. They lived on a hill, right above a large lake. About a mile away below the lake was a village called Nyos. Some people in the village said the lake used to be a volcano, but Hadari and everyone else in his village had never seen or heard anything to make them worry about it.

Suddenly, Hadari woke up to a loud rumbling sound. He and his family rushed out of the house. Outside, they saw a cloud of mist rise from the lake and cover the valley where the village was. Frightened, Hadari and his family moved to a higher place and spent the night there.

When they woke up, they were terrified. The village of Nyos had become a graveyard: 1,200 people were dead. Nearby, 500 people in two other villages had died mysteriously at the same time.

Three thousand cows were scattered around the valley below the lake, all dead, but no flies or vultures could be seen near them--every living thing near the lake was dead.

What happened? How could this have been stopped? Mysteries like these have given scientists around the world many reasons to learn about geology and how our earth works.

Appendix B

Name _____

Mt. Pinatubo Case Study

1. When did the eruption of Mt. Pinatubo happen? _____

2. Where is Mt. Pinatubo? _____

3. List at least 3 signs that Mt. Pinatubo was about to erupt:

   1) _____

   2) _____

   3) _____

Extra credit: _____

4. What instruments (special tools) and clues did scientists use to try to predict whether Mt. Pinatubo
   was about to erupt?

_____

_____

5. List at least 3 things that happened during the explosion of Mt. Pinatubo:

   1) _____

   2) _____

   3) _____

Extra credit: _____

6. Who was affected by the Mt. Pinatubo eruption?

_____

7. List at least 3 effects of the Mt. Pinatubo eruption (on land, people, animals, etc.):

   1) _____

   2) _____

   3) _____

Extra credit: _____

Name _____

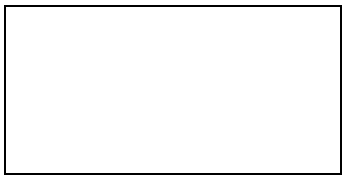
Types of Volcanoes and Volcanic Explosions

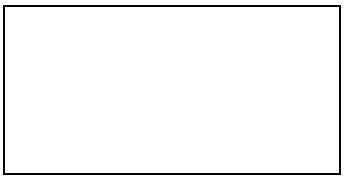
1. Name at least 3 volcanoes:

1) _____ 2) _____ 3) _____

List the 3 major types of volcanoes and draw a **QUICK** sketch of each type:

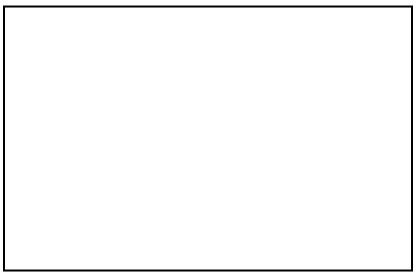
_____ _____ _____





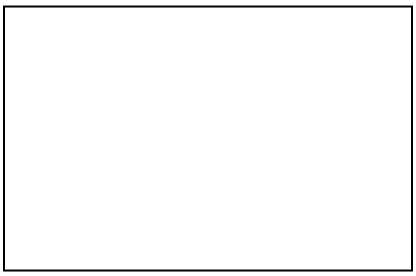
Draw a **QUICK** sketch to describe each type of volcanic explosion.
Extra credit: Name a volcano that is an example of each type of explosion.

Strombolian Explosion



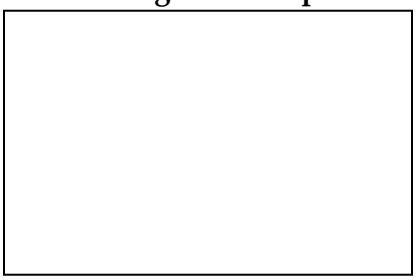
Example: _____

Plinian Explosion



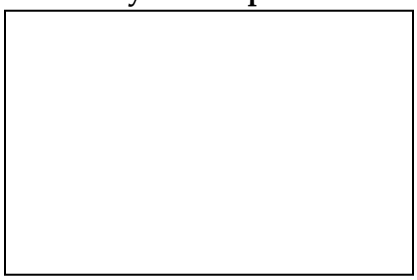
Example: _____

Glowing Cloud Explosion



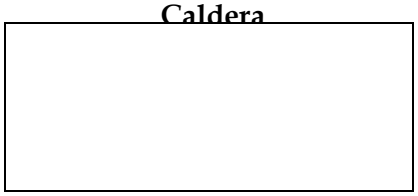
Example: _____

Paroxysmal Explosion



Example: _____

Caldera



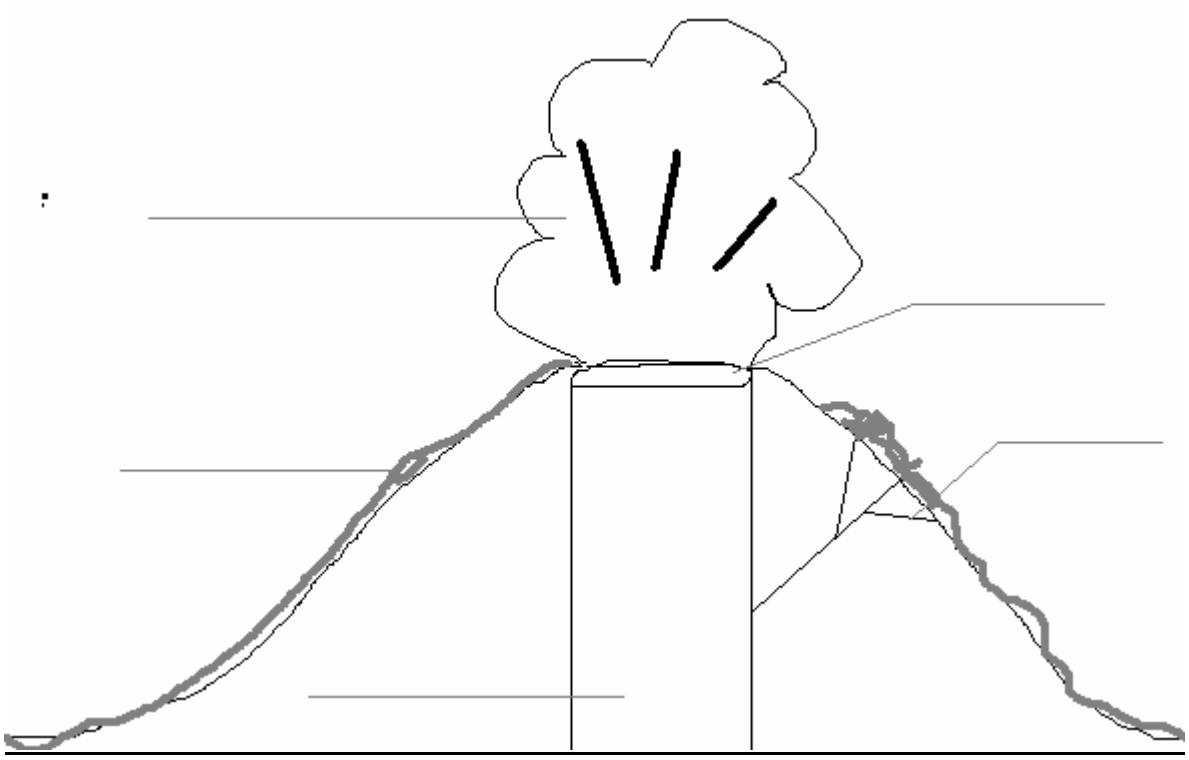
Example: _____

Name: _____

The Volcano

Label the parts of the volcano beneath. Use the word bank for terms to help.

Conduit	Crater	Fissure	Lava	Steam & Ash



BONUS: What is an **extinct** volcano?

_____

_____

"What's Inside a Volcano?"

Written by M. Shay

To the tune of "London Bridge"

What's inside a volcano, volcano, volcano?
What's inside a volcano? Let's find out!

Magma, air and hot ash, hot ash, hot ash,
Magma, air and hot ash, deep inside.

Pressure sends them up, up, up, up, up, up, up, up, up,
Pressure sends them up, up, up,
To the surface!

The conduit goes to the top, to the top, to the top,
The conduit goes to the top,
Making a cone.

Lava pours out on the land, on the land, on the land,
Lava pours out on the land,
Through a fissure.

It becomes igneous rock, igneous rock, igneous rock,
It becomes igneous rock,
Made from lava.

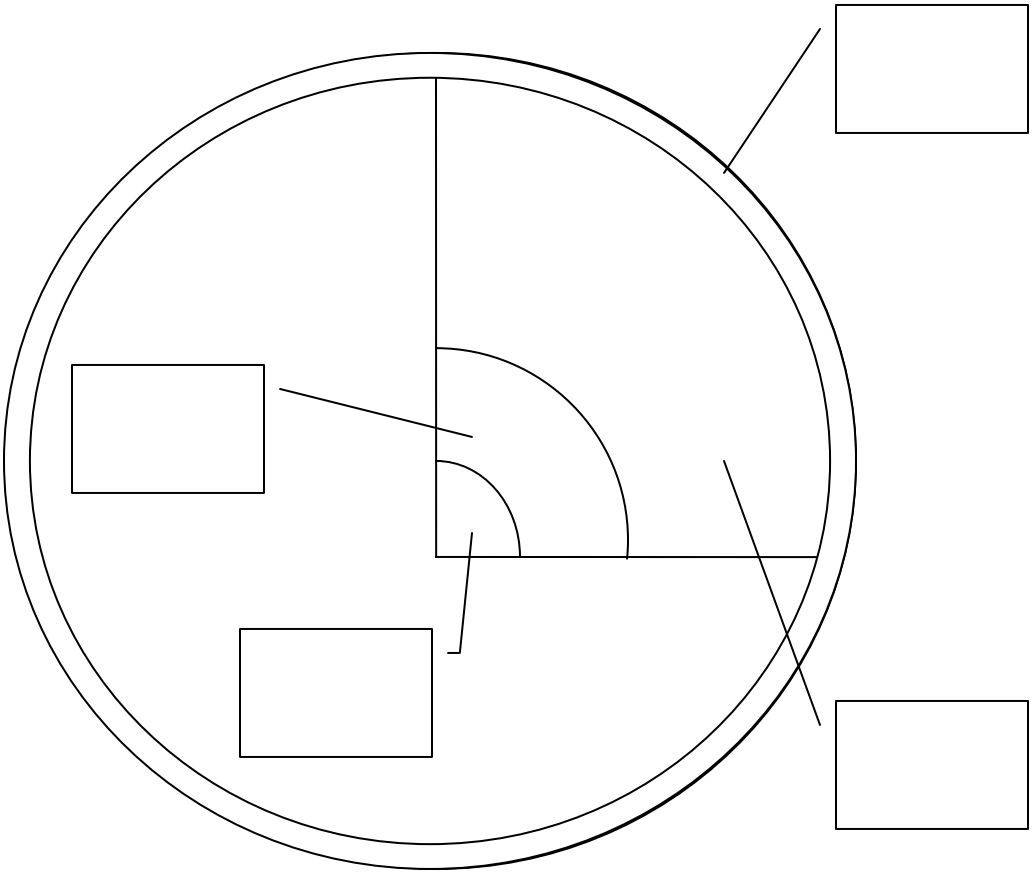
The volcano becomes extinct, becomes extinct, becomes extinct,
The volcano becomes extinct,
No more eruptions!

Name: _____

Date: _____

EARTH'S LAYERS

Label each layer of the Earth in the boxes.
The layers are: crust, mantle, outer core, and inner core.



Name: _____

Date: _____

Volcanoes and Layers of the Earth

Use the word bank below to identify and label the following volcanoes.

Cinder Cone Volcano	**Composite Volcano**	**Shield Volcano**

_____ _____ _____

Read the questions below and choose the best answer.

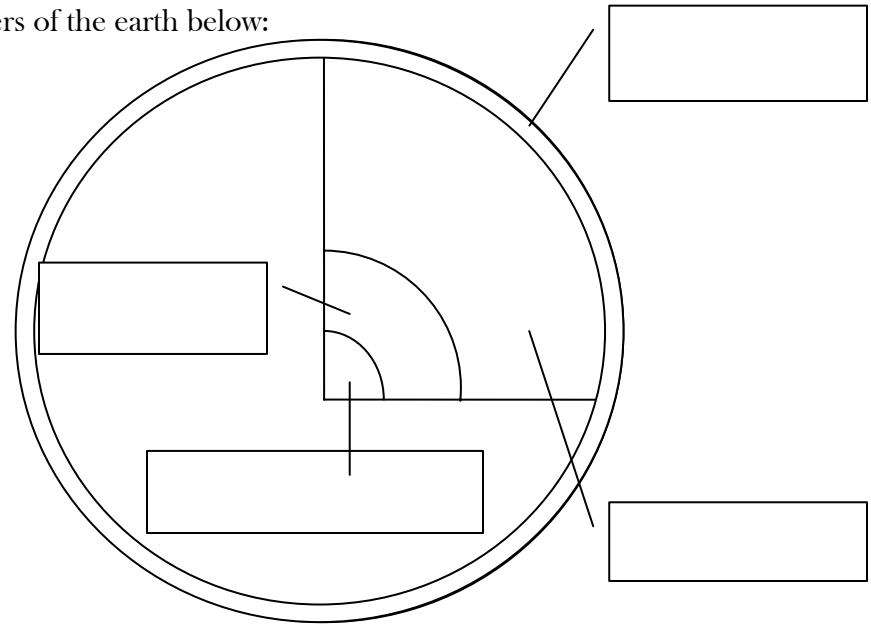
4. Melted rock that is inside the earth's surface is called:
   A. Lava
   B. Ash
   C. Magma
   D. Crystal

5. The thickest layer of the earth is called the:
   A. Inner Core
   B. Outer Core
   C. Crust
   D. Mantle

6. All of these are things that are inside a volcano EXCEPT:
   A. Magma
   B. Steam
   C. Lava
   D. Ash

7. After its first eruption, a volcano will have a cup-shaped top called a:
   A. Fissure
   B. Crater
   C. Magma chamber
   D. Conduit

8. Label the layers of the earth below:



9. Imagine you are trying to teach a friend about the layers of the earth. You are at home and you find three things: a hard-boiled egg, a basketball, and an apple. You make a chart to compare the three items and how they are like the earth's layers and different from the earth's layers. Fill in the chart below.

Item	How it is **LIKE** the Earth	How it is **DIFFERENT** from the Earth
Hard-Boiled Egg		
Basketball		
Apple		

Based on your observations, which ONE of the three things would you choose to show your friend about the earth's layers? **EXPLAIN WHY.**

_____

_____

_____

Name: _____KEY_____

Date: _____

Volcanoes and Layers of the Earth TEACHER'S KEY

Use the word bank below to identify and label the following volcanoes.

Cinder Cone Volcano	**Composite Volcano**	**Shield Volcano**

__Composite_____ _____Shield_____ _____Cinder Cone____

Read the questions below and choose the best answer.

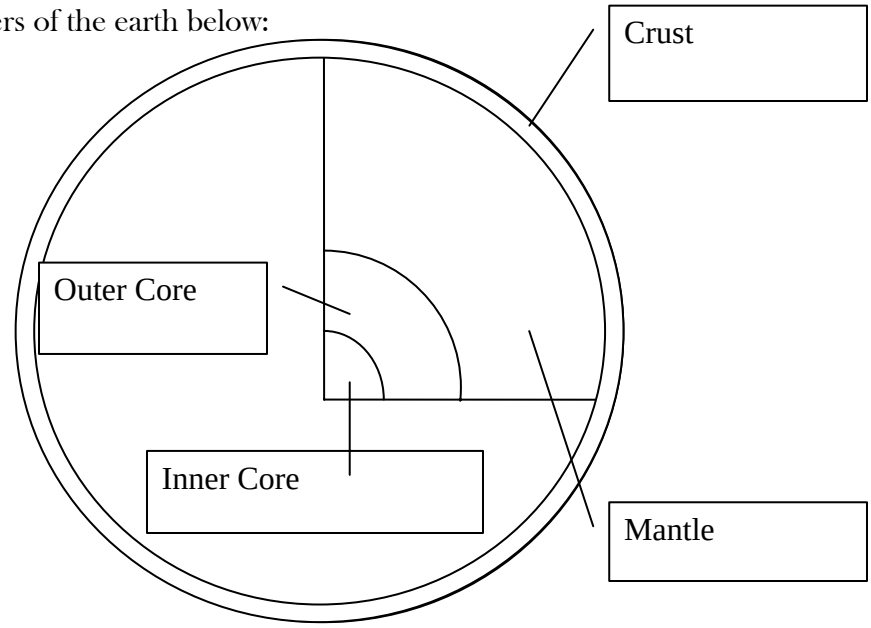
4. Melted rock that is inside the earth's surface is called:
   A. Lava
   B. Ash
   C. Magma
   D. Crystal

5. The thickest layer of the earth is called the:
   A. Inner Core
   B. Outer Core
   C. Crust
   D. Mantle

6. All of these are things that are inside a volcano EXCEPT:
   A. Magma
   B. Steam
   C. Lava
   D. Ash

7. After its first eruption, a volcano will have a cup-shaped top called a:
   A. Fissure
   B. Crater
   C. Magma chamber
   D. Conduit

8. Label the layers of the earth below:



9. Imagine you are trying to teach a friend about the layers of the earth. You are at home and you find three things: a hard-boiled egg, a basketball, and an apple. You make a chart to compare the three items and how they are like the earth's layers and different from the earth's layers. Fill in the chart below.

Item	How it is **LIKE** the Earth	How it is **DIFFERENT** from the Earth
Hard-Boiled Egg	There are three layers (shell, egg white, yolk), like the earth (crust, mantle, core)	An egg is not round. The mantle of an egg (the egg white) is not liquid like the earth.
Basketball	Both are round. They spin.	A basketball is full of air inside. A basketball does not have layers.
Apple	Both have three layers	An apple core is not a solid piece.

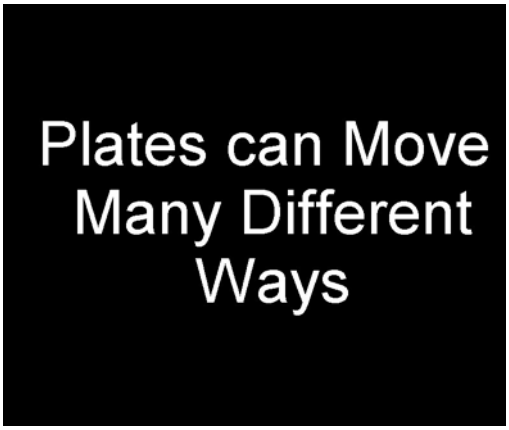
Based on your observations, which ONE of the three things would you choose to show your friend about the earth's layers? **EXPLAIN WHY.**

_____Answers will vary - A hard-boiled egg is the most reasonable answer of the three_____

_____choices, but partial credit should be given to any answers in which students carefully_____

_____explain their answers and give a thoughtful and logical response._____


Plate
Movement
Changin' the Map


Plates can Move
Many Different
Ways

Name _____ Date _____

Plate Movement Chart

Type of Plate Movement	Example(s) of where movement occurs	Effects	Sketch of Plate Movement Direction

Appendix J

A Major Road Block

For fifteen seconds on October 17, 1989, the earth shook in San Francisco. Starting at Loma Prieta Peak in the nearby Santa Cruz Mountains, the shockwaves from the earthquake went for miles, causing damage as far as 70 miles away.

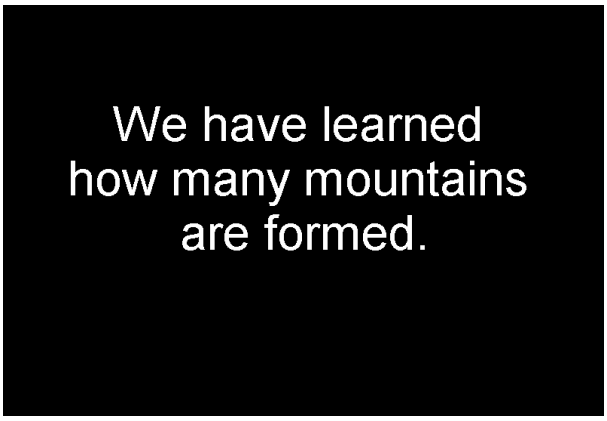
One of the reasons for the damage was the power of the earthquake. It measured 7.1 on the Richter scale, which means it was very strong.

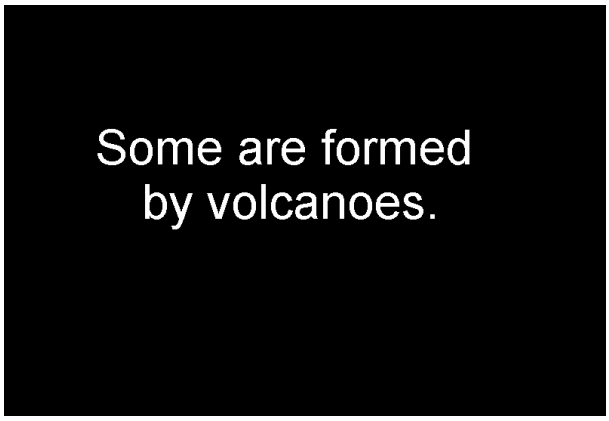
The earthquake caused a lot of damage to homes and buildings that had been built on filled ground - places where construction workers filled in soil over water. Since San Francisco is right next to the Pacific Ocean, many areas in the city that were most damaged had once been part of the bay.

The worst effects of the earthquake were on the highways around the city. Many roads cracked and crumbled, and several highways collapsed. Thankfully, a baseball game in the city had caused many people to leave work early, so even though the earthquake happened at 5:04 PM, the roads were much less crowded than usual.

From the Loma Prieta earthquake, 66 people died and thousands were injured. Tragic events like these raise big questions: How do earthquakes start? How far do they go? How can we predict them and warn people about them? And how can we build cities and highways so that they won't be destroyed by earthquakes?


New and Old Mountains


We have learned how many mountains are formed.


Some are formed by volcanoes.

However, most are formed on plate boundaries.

Mountains that have just been formed look very different than old mountains.

New mountains are usually more jagged and impressive looking.

Old mountains have had time to wear away.

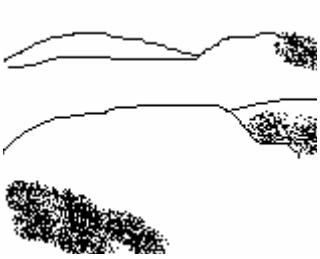
Most of the time, this makes them look more rounded and smooth.

Do you think the following pictures are new or old mountains?

Relief Maps
show elevation and
are a good way to
understand where
mountains are.

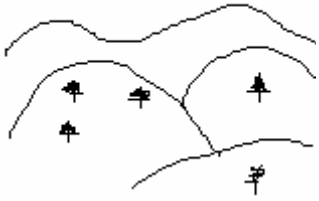
Name: _____ Date:_____

MOUNTAINS



These mountains are _____ because

_____.



These mountains are _____ because

_____.

These mountains are _____ because

_____.

Name: _____ Date: _____

Earthquakes & Plate Movement Quiz

1. Where do most earthquakes and volcanic activity occur?

_____

_____

2. A seismograph is used to measure: (circle one)
   a. length
   b. intensity of earthquake and volcanic activity
   c. the number of earthquakes
   d. how much water is in the ocean

3. The Richter scale uses numbers to express the magnitude of energy released by an earthquake. What may be a possible effect of an earthquake if it measured 7.2 on the Richter scale?

_____

4. There was an earthquake in California last night. Nobody felt it. How do we know it really happened?

_____

5. Explain the difference between old and new mountains.

_____

_____

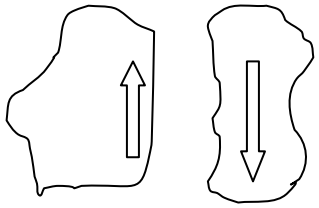
6. Tell me what you know about subduction.

_____

_____

_____

7. What is the name of this plate movement?

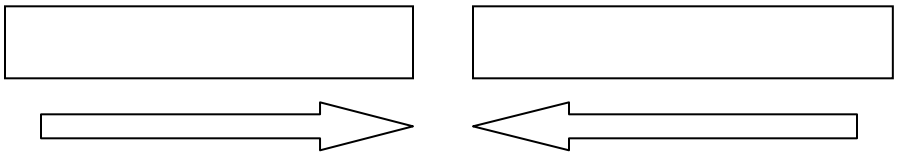


8. What would be the result of this plate movement, possibly?

_____

_____

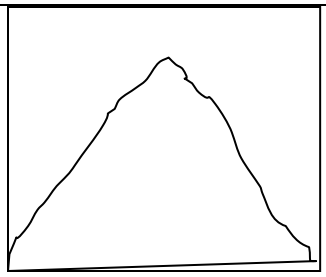
9. What could be an effect of two plates that collide?

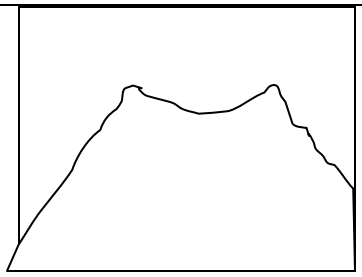


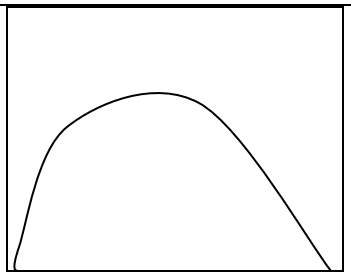
_____

10. Label each picture.

WORD BANK: old mountain new mountain volcano







_____ _____ _____

BONUS QUESTIONS:

1. What is the major fault in California called? _____

2. What is the mountain range created when India collided with Asia?

_____

Name: _____**KEY**_____ Date: _____

Earthquakes & Plate Movement Quiz

1. Where do most earthquakes and volcanic activity occur?

MOST EARTHQUAKES AND ACTIVITY OCCUR ALONG FAULT LINES

2. A seismograph is used to measure: (circle one)
   a. length
   b. intensity of earthquake and volcanic activity
   c. the number of earthquakes
   d. how much water is in the ocean

3. The Richter scale uses numbers to express the magnitude of energy released by an earthquake. What may be a possible effect of an earthquake if it measured 7.2 on the Richter scale?

ANSWERS MAY VARY, EX. DAMAGE TO BUILDINGS AND ROADS

4. There was an earthquake in California last night. Nobody felt it. How do we know it really happened?

A SEISMOGRAPH CAN RECORD THE VIBRATIONS BELOW.

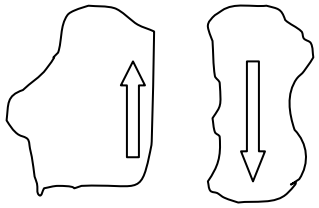
5. Explain the difference between old and new mountains.

OLD MOUNTAINS HAVE ERODED LONG AGO. NEW MOUNTAINS HAVE BEEN "RECENTLY" MADE BY VOLCANIC OR SEISMIC ACTIVITY

6. Tell me what you know about subduction.

SUBDUCTION OCCURS WHEN ONE PLATE COLLIDES WITH ANOTHER AT A CONVERGENT BOUNDARY. IN SUBDUCTION, ONE PLATE GOES UNDERNEATH THE OTHER PLATE.

7. What is the name of this plate movement?



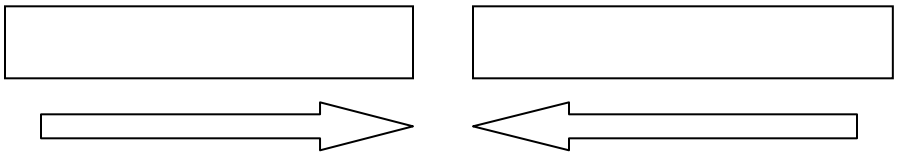
_____TRANSFORM_____

8. What would be the result of this plate movement, possibly?

ANSWERS MAY VARY, FOR EXAMPLE, A FAULT LINE CAN BE SEEN AND CRACKS MAY APPEAR IN ROADS OR SOIL.

_____

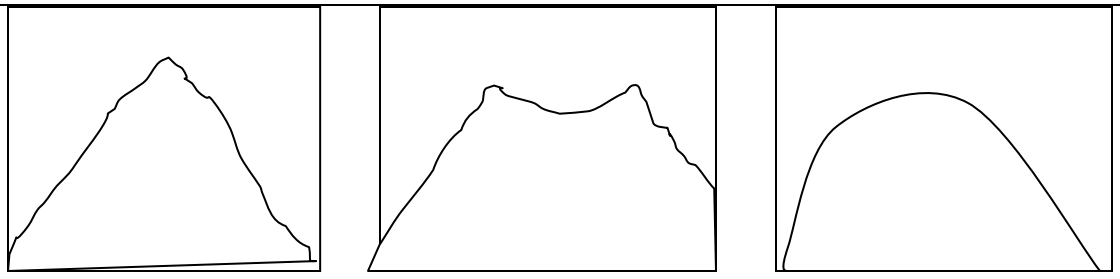
9. What could be an effect of two plates that collide?



_____ANSWERS MAY VARY, EX. MOUNTAINS ARE CREATED.__

10. Label each picture.

WORD BANK: old mountain new mountain volcano



_____ _____ _____

NEW VOLCANO OLD

BONUS QUESTIONS:

1. What is the major fault in California called? **_____SAN ANDREAS__**
2. What is the mountain range created when India collided with Asia? **_____HIMALAYAS_____**

Geologic and Historical Observations of Landform # 1

1832 An explorer's journal entry as he traveled across the landform:

This is one of the most beautiful places I've seen yet. The small, rolling hills and grassy plains are pretty. But the most amazing sight of all is a low, round mountain covered in a green blanket of pine trees. It rises more than 1000 feet above the surrounding plains. The climb to the top is a bit steep, but the climb down into the mountain's center is worth the effort. Standing inside the mountaintop feels like standing at the bottom of a huge arena. If this land were in Greece, the ancient Greeks might have used it as a location for their Olympic games.

1995 Cave paintings discovered near the landform:

Anthropologists dug up slabs of rock with carvings that tell the story of some sort of huge explosion. In the pictures, lots of fire and particles that look like rooster tails appear above a big hill. They also show mammoths and giant bison running away from the hill. Some of the animals have fallen down and are covered in the black ash. Scientists believe these rock paintings were made **60,000 years ago**.

2004 A scientist's journal entry from a field visit to the landform:

Wildflowers bloom in the area each summer. The landform is home to many animals, including mule deer, wild turkey, black bear, and other wildlife. The animals look calm and happy, like they have lived there peacefully for a long time.

A forest of huge, pine trees covers the landform. These trees are very tall and large, and some of them might be hundreds of years old. I doubt the area has changed much in the last 500 years. One of the tree trunks is carved with the date 1585 from a Spanish explorer who traveled across this area! My rock samples of the area are all igneous rock.

The mountain is so perfectly round. It couldn't have formed in the way that most mountains are formed, through folding or colliding land. Standing at the top of the landform is like standing center field at the Houston Astrodome, except this dome is covered with real grass and pine trees. It is a very beautiful spot. I've never seen anything like it on Earth.

Pictures of Landform #1

Aerial View (from the sky)

Side View

Geologic and Historical Observations of Landform # 2

April 1999 A scientist's journal entry on her first visit to the area:

This morning we arrived by boat and made a steep journey from the coast toward the landform. We had to make our way through a tropical rainforest to reach the landform. We carried many bottles of water in our backpacks, because the heat and humidity made us sweat a lot.

The only wildlife we saw were a few small birds in the highest branches of the trees. As we climbed through the rainforest, we came to a huge area that was completely blackened and dead. You could barely recognize the remains of palm trees and tropical vines. The ground felt warm beneath my feet. Suddenly, the climate, or the weather in the area, changed from the humid heat of the tropical rainforest to a bare, cold, and windy area. The ground under me felt warm, even though there was snow on the ground nearby.

500 B.C. The written observation of Hannon, an ancient navigator (ocean explorer):

My crew and I were sailing along the coast early one morning before sunrise. All of a sudden, a sailor on the night watch started shouting, "Wake up! Man the deck!"

We looked out at the coastline. A huge, black cloud was rising into the sky. A red-hot liquid like a sea of fire was rolling down to the coast through the forest, covering the beach and almost reaching the sea. We could hear rumbling and smell the burning of trees. It was a terrible sight.

We quickly changed our course and sailed further into the ocean to stay as far away as we could from the sea of fire.

Year	Highest Richter scale rating
1990	0.5
1991	1
1992	1.2
1993	3.5
1994	2
1995	2.5
1996	2
1997	2.5
1998	2.5
1999	5.2
2000	5
2001	2
2002	1
2003	1.5
2004	2.3

Landform #2
Seismic Activity in the past 15 years

Relief Map of Area

Different views of Landform #2

Geologic and Historical Observations of Landform # 3

1854 An explorer's journal entry as he traveled across the landform:

May 14 - Our caravan arrived at a flat area this morning looking over some rugged land. It is very scenic, and it has many lush plants. Most trees are short and brush-like, but there are also several pines. I believe we are near some mountains. The soil is very dark and rich…one of my partners, upon arriving here, exclaimed, "I would wish to see a farm begin in this rich land!" Large boulders are becoming a common sight, and in the near distance, we see what I believe to be foothills to large mountains.

Many of these hills seem to have eroded long ago. I wonder what this land looked like before man set foot here…there are some strange patterns among the hills. One set of hills continues in a line segment south as far as our group can see…We camped in an area between this line and another. We are staying between two sets of hills, and those to the north begin about 200 yards to the east, continuing north. Vegetation also follows these hills, so that on one side, a row of bushes and small trees lines the bottom of the valley. It begins again on the other side, continuing along the bottom of the valley, about 200 yards removed from the other brush. Quite a strange sight indeed!

1968 Earthquake news report from the area:

An earthquake struck close to Borrego Mountain yesterday. It was measured 6.5 on the Richter scale. Geologist Len Thompson was quick to announce to local officials, "This is the largest quake we've seen here since the Kern County earthquake 16 years ago." Movement was felt as far away as Las Vegas and even Yosemite National Park. Power lines were broken in San Diego County, sidewalks cracked in Los Angeles, and boats by the coast rocked back and forth on a windless day. The earthquake caused some landslides near the epicenter, and large boulders fell onto roads.

Scientists are measuring some movements that local residents observed in the nearby foothills. "It looks like some trees moved," one woman was heard saying. A line of orange trees in one farmer's field was split in half by almost a foot, creating two separate lines.

More news will come soon...

Continued Observations of Landform # 3

2003 A scientist's journal entry from a field visit to the landform:

Today our team visited the old site of the earthquake from 1968. We measured vegetation along the epicenter, and split up to record measurements around the nearby hills. One team went to Borrego Mountain to conduct research on landslides and erosion.

From all observations, the land seems to have moved about 35 centimeters since the earthquake of '68. Another geologist reported to me that her measurements show a movement of 10 millimeters since last year, which is about how much it has moved every year since the big quake.

Our team conducted research on some plants in various areas and found that, in some areas, remains of vegetation and some soil samples seem to be related. Two large groups of hills gave us samples that matched up from about 150 years ago. Some of the members of the team believe that these two groups used to be one hill...they just are not sure when. Some think as early as 150 years, others 300 years, and a few think it was even longer ago. We are looking into what caused this.

View from a hill

View of farmer's orange tree field in 1968

Geologic and Historical Observations for Landform # 4

November 1642 From the climbing journal of explorer Darby Field:

> *My two native guides and I have been hiking northward across a mountain range for two weeks now. We are now approaching an area that is **very** steep and rocky. It began snowing this morning, and by now it is snowing so heavily that I don't think we will be able to continue much longer. The rocks under our feet have become slippery with the snow, and I fear we do not have the proper equipment to climb such a height.*

January 1911 Historical records of landform:

> Record low temperature of –40 F recorded at the top of the mountain. Ten feet of snow cover the ground which is frozen for at least another 10 feet below the snow.

April 12, 1934

> Wind speeds at 231 MPH recorded on the mountain. Ten people hiking near and on the mountain have died in the last year due to terrible winter weather.

June 2003 From a geologist's observation log:

> The path I have taken to climb to the top of the mountain is only 4 miles long. It is a small mountain, rising only 6,233 feet above sea level. But the area is so steep and dangerous that it has taken me two days to reach the top even in summertime. It was well-worth the risk, though, because the view is incredible from up here! I can understand why Darby Field tried over and over again to climb to the top, risking his life to achieve his goal. I can see how many people would want to travel to this place for the scenic views.
>
> No seismic activity has ever been recorded in this area, and no explorers or hikers have ever reported feeling an earthquake. Also, the rock samples I have taken from the area are definitely NOT igneous rock. Most of the rocks in the area probably formed from spreading when the continental plates in the area shifted during the break-up of Pangea 200 million years ago.

Appendix Q, Page Two

Side view of Landform #4

Folded rock, (close-up)

Geologic and Historical Observations of Landform #5

1997 - A college student's travel journal of a trip to Lake Taal

Today we went to Lake Taal, in the Philippines. What makes Lake Taal so neat is that the lake has a little island in the middle of it. The island is a big hill with a smaller lake on the top of the hill! The hill was really rocky, and there were lots of cool black rocks we picked up. We swam in Lake Taal, and it was so nice! The water was cool and we could even drink some of it. There were lots of fish inside the lake. After that, we climbed the hill to swim inside the small lake on the hill. We couldn't stay too long, though, because the water was kind of hot and it burned our eyes. One of our friends started complaining that it was burning his skin. The lake had no plants or fish in it, and I think I know why. I accidentally swallowed some of the water and it was gross! It was really salty and tasted a little bit like eggs. I heard some guy went scuba diving inside the lake and said it was 60 feet deep.

At about 1:30 pm we packed up and hiked back to the mountain on the island. It's called Mt. Tabaro and the walk towards it was hot since there weren't many plants or trees close to the mountain. On the way, we saw some little pools of boiling water!! We knew not to swim in those. After a brief climb we went back to the campsite late in the afternoon.

1999 - Scientific Overview of Taal Lake History

The marine life study of Taal Lake shows that the body of water here may have been, in fact, salt water in pre-historic time. Even today, we can still find traces of an ancient beach littered with seashells on the bottom of the lake (about 30 meters deep).

The whole island is made of igneous rock with a channel opening towards a bay. Fossils show an explosion that might have affected pre-historic life. Ancient village stories talk about Taal Lake being formed hundreds of years ago when the gods moved parts of the island to make a circle.

Taal Lake is home to the only known species of sea snake that inhabits fresh water, Hydrophis semperi. Dr. Dioscoro Rabor even reports that sharks once swam Taal Lake's water. He studied their biology personally before they were killed by fishermen in the 1930's.

Continued Observations of Landform #5

2005 - News Report of Tabaro (Taal)

Taal's lake is acting up, making lots of tourists unhappy. Tourists have been told to stay away from any hiking trails near the lake, and all swimming in the lake has been banned. Yesterday, a fountain of mud came up from the lake for about 4 hours, ruining many vacationers' afternoons.

The ground around the lake has been getting warmer, according to temperature readings of soil. No water temperatures have been taken yet. Seismic readings have also been increasing.

Police are ready to help people on the island leave if any more geologic movement happens.

Map of Lake Taal

Native Painting of Lake Taal legend - "God Moves the Land"

Lake Taal - 2000

Geology Performance Task Teacher Kit

Includes:

- Key page (current page)
- Student Task Sheet
- Teacher-created sample
- Thumbnail images

Key to tasks:

#1 - Extinct volcano, Mt. Capulin in New Mexico
- Includes: 2 photos, Observations page.
- Needs: 1 seismograph strip of flat seismic lines (dated several years apart)

#2 - Active volcano, Cameroon Mountain in Cameroon
- Includes: 1 double photo, Observations page, 1 elevation map, 1 graph
- Needs: 1 seismograph strip of active seismic readings (dated April 1999)

#3 - Fault line (transform boundary), San Jacinto fault in California
- Includes: Observations page, 2 photos

#4 - Mt. Washington (old mountain), White Mountains, New Hampshire
- Includes: Observations, 2 photos (2nd photo is "folded" rock on cliffside)

#5 - Crater Lake, Lake Taal in the Philippines
- Includes: Observations, 2 photos (1 photo, 1 painting), 1 map

Name _____ **Date** _____

Due Date: This project (the research and the pamphlet) must be completed and ready to present on: _____

Geological Research Project

The Situation. You are a geologist working in an area of the world where few people live. Government officials have asked you to investigate the geologic history of the area before they allow further development of the area. This area has an important geologic landmark. That landmark might be a volcano, mountain, or fault line.

You've been given different kinds of information about the area, such as:

- seismograph readings or graphs
- an elevation map or other kind of map
- photos of the area
- written observations from explorers and scientists who have visited the region.

The Task. First: Determine what kind of geologic landmark is located in the area.
Second: Make a prediction about what could happen in the future.
Third: Explain the benefits and dangers of building and living in the area.

Questions you should be able to answer for the government officials:

- What kind of geologic landmark exists in the area?
- If it is a volcano, is it extinct, dormant, or active?
- If it is a mountain, is it new or old?
- Have any earthquakes occurred in the area? How recently?
- Will plants and other wildlife grow well in the area? How do you know?
- How safe is it for people to live in the area?

The Product: Once you have determined what kind of landmark exists in the area, you must present your findings by creating a pamphlet that explains everything you have learned about the geologic landmark. The pamphlet should answer the questions above, and should also include:

- the pictures, map, seismograph readings, and observations as evidence
- a caption or short summary <u>for each piece of information</u> that explains how you used each piece to identify the geologic landmark
- explanations of any geologic activity that has occurred in the past
- predictions for possible future geologic activity in the area.

The Presentation: You will show your pamphlet to a small group of classmates. Be prepared to explain all parts of your landmark and your findings. Be prepared to justify your decisions (explain how you came to your conclusions about the landmark).

*** Challenge Task*:** AFTER including all other requirements in your pamphlet, you may propose a safety plan to the government officials. The plan should tell people how and where to build, live, or travel on the land so that they will be safe from any dangers that the geologic landmark might bring.

Geological Research Project Rubric

Your pamphlet and presentation to the small group will be graded according to the following rubric. Make sure your pamphlet is as **neat and colorful** as possible and that you **use correct spelling, capitalization, and punctuation.**

Student Name: _____

CATEGORY	4	3	2	1
Writing - Organization	There are three sections in the pamphlet: geologic history, benefits, and dangers. Each section is clearly supported with evidence.	There are three sections in the pamphlet. Two sections are clearly supported with evidence.	There are three sections in the pamphlet. The sections are supported with some evidence, but they lack clarity.	The pamphlet is missing one or more sections. The information in the sections is confusing.
Attractiveness & Organization	The pamphlet is colorful, creative, and eye-catching, and it has well-organized text & graphics.	The pamphlet is colorful and neat, and it has well-organized text & graphics.	The pamphlet has well-organized text & graphics.	The pamphlet's formatting and organization of material are confusing to the reader.
Content - Accuracy	All facts in the pamphlet are accurate.	The landform is accurate, but 1 explanation or fact is wrong.	The landform is accurate, but 2-3 explanations or facts are wrong.	The landform is not accurate, and/or several explanations or facts are wrong.
Knowledge Gained	Student can accurately answer all questions related to facts in the pamphlet.	Student can accurately answer most questions related to facts in the pamphlet.	Student can accurately answer several questions related to facts in the pamphlet, but still leaves several questions unanswered.	Student appears to have little knowledge about the facts in the pamphlet.

Name: _____

Geological Research Project Rubric

Category	4	3	2	1
Organization				
Attractiveness				
Accuracy				
Knowledge				
Column Totals				

Total Rubric Score: _____

Numeric Grade: _____

Rubric Scoring Conversion Chart

14-16 = A
11-13 = B
8-10 = C
< 8 = D

Name: _____

Geological Research Project Rubric

Category	4	3	2	1
Organization				
Attractiveness				
Accuracy				
Knowledge				
Column Totals				

Total Rubric Score: _____

Numeric Grade: _____

Rubric Scoring Conversion Chart

14-16 = A
11-13 = B
8-10 = C
< 8 = D

Thumbnail Images for Student Use

More Thumbnail Images for Student Use

Mount Colima... An Awesome But Dangerous Landform

The land around Mt. Colima has lots of rich soil and seems like a good place for farming. Pictures of the area make it look like a beautiful place to live. But beware—my scientific studies show that this landform is an explosive volcano. Its frequent eruptions will surely bring disaster to anyone who tries to live and work near this area.

You can see from the trail of smoke rising out of the mountain top that this is no ordinary mountain. A closer look at the mountain top gives more clues that tell me this is NOT the best place to build a housing development or shopping center.

The white, fluffy stuff you see in the next picture is definitely not a low-lying cloud. The cup-shaped mountain top is a volcanic crater. It is surrounded by black ash kept warm by the steam rising from the crater top.

I know you builders are wondering, "Just how dangerous can a bit of warm steam be?" You might try to turn this landform into a luxury sauna for tourists. Fortunately for those tourists, I have more evidence that proves that Mt. Colima is definitely NOT dormant.

Year	Highest Richter Scale Measurement
1913	8.0
1961	6.1
1980	2.5
1987	7.1
1999	6.1
2000	3.5
2004	2.8

The seismograph readings above were taken over the last century, or one-hundred years. As you can see, most of the seismic activity occurred in the past ten years. My findings show that small earthquakes are happening almost daily. This means hot magma is rising up the volcano's conduit, and the pressure is making the ground shake.

Seismograph readings are not the only clues that help me to predict how violent Mt. Colima might become. I researched the history of the area and found that an explorer observed the 1913 eruption, which formed a huge crater (750 yards wide!). That explorer kept returning to the volcano years after the eruption to make sketches of the crater.
The sketches looked like this:

The volcano's top changed from a crater to a dome because of a build-up of lava. Each time the explorer returned, the crater was filled with more and more lava, or magma that had risen up the conduit and reached the Earth's surface. Once the lava was exposed to the air outside the Earth's crust, it cooled and hardened to form a lava dome.

The volcano might have been dormant while the lava dome kept building. However, this DID NOT cause the volcano to become extinct. I know this is true because earthquakes started happening again in the 1980s and 1990s. Also, the pictures of the volcano that were taken this year show that hot ash and maybe lava have burnt away large sections of trees and other plant life from the mountainside.

I don't think these minor earthquakes and puffs of steam are all the volcanic activity we will see from Mt. Colima in the future. That lava dome has already blown out to form a small crater again, as you can tell from the photograph on the previous page. The current seismic activity tells me that once enough magma, heat, and pressure have built up, Mt. Colima will blow her top off completely. There will be a major eruption with lava flows and huge ash clouds sometime soon.

I know that many business owners want to build in this area, but I strongly advise against allowing those businesses to follow through with their plans. If you build anywhere within 20 miles of Mt. Colima, you will be putting your company, other businesses, and peoples' lives at risk.

You hired me because you know I'm an expert in geology and you respect my professional opinion. My opinion is: Don't allow people to build here. The government should block off the area around this landform to prevent anyone from going near it. Mt. Colima is EXTREMELY dangerous.

Extension activity:

Safety Plan Proposal for Mt. Colima Volcano

A Geological Survey of

Landform #392

for the Government of Mexico

Presented on: September 19, 2005

Landform Inspection by
Rock E. Overtime

_____